2022 Garden Notes

FOR COLORADO MASTER GARDENER AND COLORADO GARDENER CERTIFICATE TRAINING

COLORADO STATE UNIVERSITY
EXTENSION

Colorado Master Gardener$^{\text{sm}}$ Program
Colorado Gardener Certificate Training
Colorado State University Extension
Updated October 2016

CMG GardenNotes

By number

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MASTER GARDENER

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The Colorado Master Gardener Program

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Prepared by **David E Whiting,** Extension Consumer Horticulture Specialist and Colorado Master Gardener Coordinator (retired)

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- Colorado State University, U.S. Department of Agriculture , and Colorado counties cooperating.

Revised October 2017

Class Objectives

At the end of this class, students will:

1. Describe techniques to enhance his/her learning.
2. Describe how mind filters influence communications.
3. Self-evaluate factors that enhance and impede his/her communications.
4. Describe the Cooperative Extension System
5. Describe the CMG Program and the role of volunteers.

Homework

1. To become familiar with the resources, spend a few minutes surfing the CMG website at www.cmg.colostate.edu.

2. From the CMG website, enter VMS and set-up your profile.

3. Reading
   a. ***The Science of Gardening***, chapter 1 (page 3) on the Benefits of Gardening
   b. ***CMG GardenNotes***
      #011, Learning
      #012, CMG Code of Conduct
      #014, The CMG Program
      #015, Communications
      #017, Listening Habits Evaluation
      #018, Using Copyrighted Materials…

4. Review Questions: *CMG GardenNotes* #010

5. Homework: *CMG GardenNotes* #019

Review Questions

Learning

1. In a long class period, like CMG/CGC training, it is easy to miss concepts that expand and update the student's knowledge. What techniques can students use to maximize their learning potential?

2. In the learning process, when you question or reject a concept, how should it be reprocessed?

3. To gain the most out of the CMG/CGC training, take a few moments to self-reflect on your mind filters that may play into your learning potential. What mind filters will help you learn? What mind filters may impede your learning?

CSU Extension

4. Describe the ***Extension*** system. Who are the partners?

Colorado Master Gardener Program

5. When may the title "***Colorado Master Gardener***" be used?

6. What is required to become a CMG volunteer? After the first year, what is required to continue in the program?

7. In counting hours, what counts for volunteer hours versus continuing education hours?

8. List criteria for CMG activities.

9. What are "conflict of interest" and "implied endorsement"? As CMG volunteers employed in the green industry, can you advertise that you are a "*Colorado Master Gardener*"? That you have completed the *Colorado Gardener Certificate Training*?

10. Under the "fair use" doctrine of copyright law, what are the restrictions on making a single copy for a client? For making multiple copies for classroom distribution?

11. While working in official CMG activities, CMG volunteers are covered by University liability; but under what conditions?

12. CMG volunteers are not authorized to give legal or medical advice. Give examples of common questions that could fall under legal or medical advice. Where should clients be referred?

Communications

13. Take a few quiet moments for some self-reflection on your "mind filter". What mind filters are powerful in your communications? What mind filters sometimes impede your communications?

Tools for Success

14. If you were calling CSU Extension for advice on a gardening problem, how would you like to be treated? (A rather simple question, yes; but we do not want to be that "governmental agency" which forgot customer service.) Give it some serious thought.

15. A client wants you to tell her what to do for a garden problem. What is your role in the decision making process?

16. Why do some questions have no answers?

17. What are the two most common complaints about CMG services?

18. Why do we recommend that you read directly from reference materials? Why do we recommend that you cite references?

19. What types of reference materials are not acceptable?

20. May you use your own practical experience? What if it is different from recommendations?

21. What is a CMG role related to pesticide information?

22. What sources are acceptable for pesticide information?

23. Where do you refer clients that need in-depth information about pesticide safety issues?

24. How does visualizing a client's situation help you diagnose a problem?

25. How does repeating back, in your own words, what the client said help you diagnose a problem?

26. As you are talking with the client, you often have a new piece of information come up that does not fit the diagnoses you were thinking about. How can you look smart (and save face) and move on with a new direction of thinking?

27. Why should a diagnosis be framed such as ***"based on the information you provided, the problems could be…"***?

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CMG GardenNotes #011

Learning

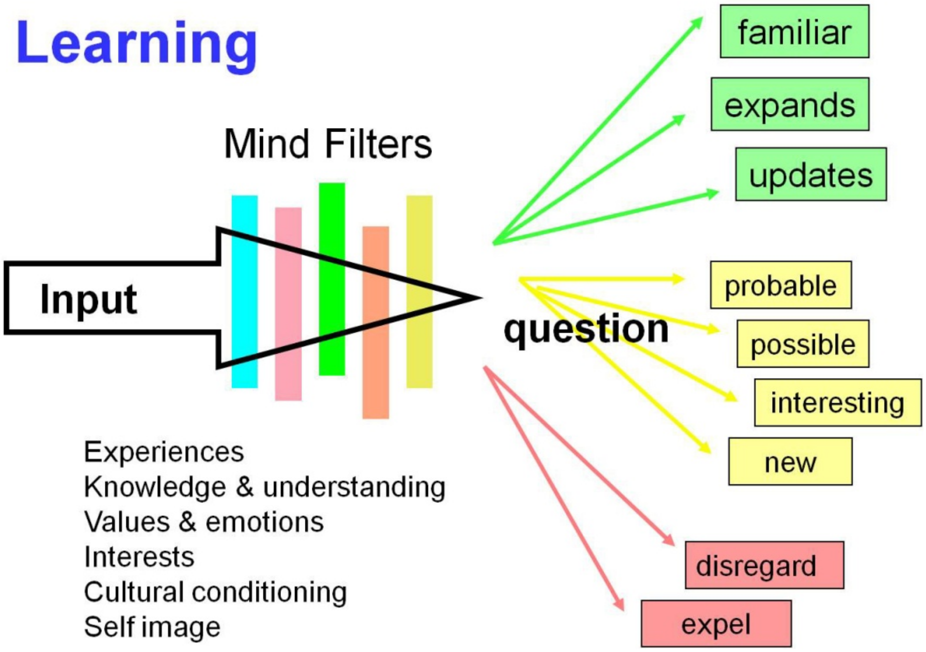
Outline: Mind filters regulate learning, page 1
- Accepted, page 2
- Questioned, page 2
- Rejected, page 4

As the "learner," page 4
As the "teacher," page 5
Characteristics of the adult learner, page 5

Learning is a complex process. It happens **within** us, not **to** us. It involves our minds, emotions, values, interests, and behavior.

Mind Filters Regulate Learning

Like communications, all forms of input into our minds are processed through the mind filters of past experiences, understandings and personal values. Input may be: 1) accepted as familiar to what we already know, value and trust; 2) questioned; or 3) rejected.



Accepted

The input will be accepted when it is in harmony with our mind filter of knowledge, understanding and values.

Knowledge is added word phrase by word phrase and sentence by sentence, rather than by paragraphs and chapters. It must connect to prior knowledge and understanding, thus learning is easier when one has a prior knowledge of the subject matter.

<u>Familiar</u> – The input may be readily accepted because we already know and accept the input as fact (or fiction). The input may reinforce our knowledge, understanding and values.

<u>Expand</u> – We add the input to our mind filters as <u>new</u> knowledge and understanding only when it is in harmony with our current knowledge, understanding and values. In this situation, active learning takes place as we expand our knowledge and understanding of the topic.

<u>Update</u> – Here we may accept the input because it logically fits with our mind filters as we replace and update previous knowledge, understanding and values. In this situation, active learning takes place.

Since updating is changing our vision of the world and life, it is difficult for most people. People often refuse to learn because we are subconsciously unwilling to allow changes to our mind filters. Some students only want the input to validate their prior knowledge, thus blocking the learning process that updates their knowledge and understanding. When the mind filters of values and emotions are involved, updating is difficult for most people.

<u>Maximizing your learning potential</u> – Most students sit in class and passively process that they already know this point and that point. When a point is different from their current understanding, most students automatically disregard the input. With the normal approach, little learning actually takes place. People become bored when the bulk of the content is familiar and quickly feel overwhelmed when the content is unfamiliar to their current knowledge base.

To maximize learning, take an active approach in the classroom. Actively look for that word phrase and sentence that expands or updates your knowledge and understanding. Make notes on what is new and different.

With the active approach, learning skyrockets! Students become energized by input that expands and updates their knowledge and understanding. In classes where much of the content is already familiar, those update tidbits make the class still rewarding.

Questioned

We naturally question any input that is not in harmony with our mind filters of knowledge, understanding and values.

<u>New</u> – It is natural to question any input that is new to our mind filters.

<u>Interesting</u> – Our interest may increase as we begin to question the input as fact (or fiction) based on our mind filters.

Possible – With repeated input, the questionability of the input will become more focused as possibly factual.

Probable – With additional input, our mind filters will render the input as probably factual (or fictional). It may eventually be accepted as factual (or fictional).

Working in the questionable realm may be part of the learning process as we move from interesting to possible to probable to accepted. This is the science of marketing. In the marketing process we may eventually come to accept the input simply because it is familiar rather than because we actively legitimized the information as factual or fictional.

Maximizing the learning – When the mind filters question a concept, make a note and reprocess the input looking at why it was questioned. Understanding why your mind filters questioned it will enhance your learning potential. Common reasons for the mind filters to question a concept include the following:

- **New and different** – The mind naturally questions input that is new or different from current knowledge, understanding and values.

- **Different perspective –** A lot of questioning arises due to differing perspectives. Differing perspectives may be on target, but from differing frames of view.

  For most people, it is hard to understand another's perspective unless the background is explained. For example, an instructor who works primarily with commercial growers may have different perspectives on growing techniques than instructors more focused on home gardening. An instructor with a soils background may have different perspectives on fertilizing flowers than an instructor with a background in flowers. Gardeners specializing in annual flowers may see general flower growing concepts differently than gardeners specializing in flowering perennials. Each could be factual from their respective points of reference.

  Oftentimes the confusion arises from changing needs in the life cycle of a plant. For example, newly planted trees are intolerant of water stress. Established trees in good health are tolerant of short-term drought. Older trees in decline are intolerant of drought. General statements about watering trees during a drought need to be prefaced with information about the life-cycle stage of the trees.
- **Gardening experience --** Your own gardening experience will be different from that of other gardeners. Do not assume that other gardens have the same soils, pests, microclimates, irrigation needs, favorite plants, or landscaping styles. One of the difficult things in working as a CMG volunteer is understanding that the clients' gardening needs, problems, and questions are different from your own.

- **Bridging between general concepts and site-specific needs** – Making the jump from general garden concepts to how they may or may not apply to site-specific situations can be difficult.

  For example, a general concept in soil management and water wise gardening is to improve the soil to 4-5% organic matter (general concept). This enhances plant growth and makes maintenance easy. However, soil improvement may not be possible in many sites due to cost, the physical labor involved, rocky soil, etc. (site-specific need). When soil improvement is not possible, we must adapt our general gardening techniques to compensate for the unimproved soil. Some native plants may prefer a soil that is not improved (site-specific need).

Aphids on shade trees do not generally warrant management efforts for the health of the tree (general concept). However, trees that are water stressed (due to drought, new plantings, or restricted root spread) are rather intolerant of aphids (site-specific need).

Remember that no gardening concepts are universally adaptable to all sites. We have to match the approach with the objectives of the garden and site limitations.

- **Values and emotions** – If the topic tugs on values and emotions, learning may be difficult. People have many values and emotions about gardening that come from the plants we love and dislike and our values towards garden inputs such as pesticides, irrigation, and landscape styles. When emotions are highly charged about a topic, it is normal to block any input that has a different point of view. It takes active work to unblock the input that would update or expand our knowledge and understanding.

Rejected

People naturally reject input that our mind filters evaluate as contradictory to our accepted knowledge, understanding, and values.

Disregard – In most situations, we simply disregard the input. In fact, we may disregard the input so automatically that we do not even process it.

Expel – When the input is in strong opposition to our mind filters of values and emotions, we typically expel the input. We may respond in a variety of manners including getting an upset stomach or headache, feeling nervous or anxious, becoming quiet or vocal, feeling angry, or even becoming violent.

Maximizing the learning – When the mind filters reject a concept, make a note and reprocess the concept looking for why it was rejected. Understanding why your mind filters rejected it will enhance your learning potential.

Common reasons for the mind filters to reject a concept include that it was new and different, that it was a different perspective or experience from your own, and the strong filters of values and emotion.

As the “Learner”

Education is about change as we expand and update our mind filters of knowledge, understanding, and values.

When involved in a learning experience, pay attention to your mind filters that may enhance or detract from your learning potential. Being aware, up front, of the impact of mind filters allows us to focus energy where needed to enhance the learning process. For example:

- If you have high interest in a topic, learning may be easy.

- If you have low interest in a topic, it will require more energy on your part to enhance the learning process.

- If you feel well versed on a topic, your knowledge base may interfere with your learning potential. Your mind filters may be closed to input that expands and updates your knowledge and understanding. You may automatically disregard "new" and "relearned" input without even processing the data.

- If you have values or emotions attached to a topic, your mind filters will be very powerful. This could enhance your learning if the input is in harmony with your mind filters. However, it may block learning as mind filters cause you to automatically disregard or expel any contrary input without evaluation.

In the Classroom Setting

To maximize the learning potential in a classroom setting, education experts teach students to take time to review the class content within 24 hours of the class period. This enhances the movement of expanded and updated input into long-term memory.

In the review process, give special attention to concepts that expand and update knowledge and understanding. Particularly in long class periods (like CMG training), so much material is covered so fast that students readily fail to make these new connections without actively reprocessing the input as new and different. Study questions with CMG units are designed to help with review of learning objectives.

As the "Teacher"

When CMG volunteers are in the teaching role, remember that your mind filters are trying to communicate with the client's mind filters. Communication and learning are two-way processes. Most of the time our clients are thrilled with whatever help we can provide.

However, in limited situations we cannot educate when the client is not open to learning. Sometimes they just call to verify their current knowledge and understanding and will "auto reject" any new or different information. Sometimes they have an auto-rejection mode turned on due to values, emotions and interests related to pests, pesticides, organic gardening, and xeriscaping. Sometime they are unwilling to accept any responsibility for the problem they called about, blocking learning. As a CMG volunteer, do not take it personally when clients are not open to learning.

Characteristics of the Adult Learner

The framework for CMG volunteer work is education of the gardening public. Sometimes the CMG service is in organized outreach activities. Other times the CMG volunteer may be structuring the learning situation. People have their own motivations for coming to us for information. It is important to respect their reasons.

Motivations for Learning

Application oriented – They need to take action, solve a problem, or accomplish something.

Knowledge oriented – They want to satisfy their curiosity and learn for the sake of acquiring new knowledge and understanding. They want to use their intellectual abilities and sometimes like to be challenged. Unlike children, they come from a base of experience.

Socially oriented – They will attend a class or make a contact for social interaction and enjoyment.

Principles of the Adult Learning Environment

Experience – Adult learners have large and growing storehouses of experiences that represent rich resources for their own learning and that of others. Many want to share that knowledge and experience.

Continuing process – Adults see learning as a continuing process of gaining knowledge and skills that can be applied right away.

Relationship –The information must be related to the adult learners' needs or interests.

Logical – The information must make sense to the adult learner.

Independent – Adult learners are independent, taking initiative without having to be told what and how to do it. They engage in learning activities because they want to—often with a clear idea of what they want to learn and how they want to learn. They seek step-by-step solutions.

Self-diagnosis – Adults learners like to see a model of competence—what good looks like—against which learners can compare themselves and figure out what they need to learn.

Shared evaluation – Instead of teachers deciding whether participants have learned, adult learners prefer to assess their own learning.

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- Colorado Master Gardener *GardenNotes* are available on-line at www.cmg.colostate.edu.
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CMG GardenNotes #013

VMS

Instructions for Using the CMG Online *Volunteer Management System*

Outline:

The online ***Volunteer Management System, VMS***, is user friendly, intuitive, and has many helpful features. It was developed specifically for Master Gardener programs by the University of California Cooperative Extension and is used in Colorado under a license agreement with the University of California.

VMS Login

1. Go to the CMG website at www.cmg.colostate.edu. On the left hand navigation bar, click on the link to the VMS. The direct URL to VMS is https://colorado.volunteersystem.org/.

2. Enter your email address (the email address that you have provided to your Extension office) and password. Click on **Login**. (Note: for your initial password, contact your county Extension office.)

3. Depending on your county, you may either go directly into the **County Home Page** or see a screen called **Select Program**. If Select Program comes up, click on your **[county]** link from the list.

Note on email addresses: Many volunteers have multiple emails. To login, use the one that you have provided to Extension. If in question, contact the CMG staff in your County Extension Office. For instructions on how to change your email address, refer to **Change Your Email Address** on page 3.

If you have problems with the login, contact the CMG Staff in your County Extension Office.

Change Your Password

1. Log in to VMS.
2. In the left-side **Your Information** pod, click on the **Edit Your Profile** link. This will open your profile page.
3. On the **Edit Member Profile** page, scroll down to the **Change Password** box. Enter the new password. It must have at least seven characters in length with no spaces and may contain numbers or special characters.
4. To save the change, scroll down to the bottom of the page and click on the **Save Information** button.

Forgotten Password

A new password can be issued through two methods.

- **Call the Extension Office** – Call the CMG Staff in your County Extension Office. They CANNOT look up your password, but they can reset it.

- **Temporary Password Sent to Your Email Address**

    1. Go to https://colorado.volunteersystem.org/.
    2. Click on **Password Problems? Click here for Help** at the bottom of the page. This opens the **Forgot Password** page.
    3. Enter your email address (the email address that your Extension office has in the system for you).
    4. Click on the **Receive email to access portal** button. An email will be sent to the email address with an access link.
    5. Go to your email account to open the email. It will be from Mary.Small@colostate.edu with the subject of **ANR Master Gardener Login – Access Information**. The message gives you a temporary password and a direct link into the system.
    5. Click on the **Access Colorado Master Gardener Volunteer Management System** link. This will take you directly into the system. Note this direct link only works once. YOU MUST CHANGE YOUR PASSWORD TO GET BACK INTO THE SYSTEM AGAIN.
    6. To change your password, refer to instructions **To Change Password** above.

Change Your Email Address

1. Log in to VMS.
2. In the left-side **Your Information** pod, click on the **Edit Your Profile** link. This will open your profile page.
3. On the **Edit Member Profile** page, scroll down to the **E-Mail Address** box. Enter the new email address.
4. To save the change, scroll down to the bottom of the page and click on the **Save Information** button.

VMS Home Page

In VMS, the Home Page has a three-column format. The left column is a series of navigation pods used within VMS. The center column is county and state news. This is updated frequently. The right column has the **Your Hours/Miles** pod, which summarizes your hours to date, and the **Your Calendar** pod listing the events that you are signed up for. To review an event on the list, click the link for that event.

The **State Links** pod lists useful links related to CMG activities. It changes with the seasons. The most useful link here takes you to the ***Online Yard and Garden Publications Index*** on the CMG website. This is the master index to *CMG GardenNotes*, Extension Fact Sheets, and PlantTalk Colorado Scripts.

VMS Setup for the Volunteer

To make VMS functional, you need to do a couple of things:

1. **Update your Profile and Interests**.
2. **Select Projects of primary interest.** These can be changed by you at any time. Selecting Projects puts you on the email list for that project information. It does not sign you up for any specific events (date and times).

Update Your Profile and Select Interests

1. Click on the **Edit Your Profile** link in the left-side **Your Information** pod. This opens the **Edit Member Profile** page.

2. As you work down the **Edit Member Profile** page, update and add information, as needed.

    - **Private** – CSU Extension respects the privacy of your contact information. If you prefer that your address and phone numbers are not visible to other CMGs using the Roster, click the **Hide this information from other Master Gardener** box.

    - **Upload Photo** – We request that you upload a head-shot photo of yourself so that others can connect names with faces. Click on the **Browse** button to open your computer files to select the picture.

- **Edit Interests –** In this section, place a check in the topics where you have expertise that you would like to share in CMG outreach efforts. The list includes gardening topics and volunteering skills. Program coordinators and other volunteers will use the list to connect volunteers. You can change this list at any time by removing checks from topics.

- **Other Interests** – You may add other interests here that are not in listed above.

3. To save your information, click the **Save Information** button.

Projects

VMS works with two levels of activities, ***Projects*** and ***Calendar Events***. ***Projects*** are the basis for system operations and hours are reported for volunteer activities related to projects. Projects are groups of similar outreach activities. Examples of projects include answering phones at the Extension office, staffing an informational booth at a garden center and working in a school youth garden.

The next level is ***Calendar Events***. Events, located on Calendars, are tied to specific days and times. For example, answering phones at the Extension office on July 6th from 9 to 12 noon is an *event* on the Office Phones Calendar. When volunteers sign up for an event, they are committed to serve at a specific day and time.

Sign-Up for Projects

As part of the VMS setup, each volunteer needs to sign up for ***Projects*** of their interest. Signing up for a project puts volunteers on the email list for information about that project and notifies the project coordinators about their interests. It does not commit them to any specific event (day and time).

To Volunteer for Projects

1. In the **General Information** pod (lower left-hand corner), click on the **Project** link. This will open the **List of Projects** page showing the list of projects offered by the county/area program.
2. Click on the title to open the specific project page of interest.
3. Scan down the page to the **Volunteer For Project** section. Click on the **Volunteer for Project** button.

Note: Once you have selected at least one project, the **List of Projects** page changes to a list of your **Active Projects** and a list of **Projects You Can Volunteer For**.

To Unvolunteer for a Project

1. In the **General Information** pod (lower left-hand corner), click on the **Project** link. This will open the **List of Projects** page showing the list of projects offered by the county/area program.
2. Click on the title of the project that you want to remove your name from.
3. Scan down the page to the **Volunteer For Project** section. Click on the **Unvolunteer** button.

Event Calendars
Sign-Up/Unsign-Up for Volunteer Outreach and Continuing Education Activities

In VMS, ***Events*** refers to specific volunteer outreach activities and continuing education classes on a set day and time. ***Events*** are located on ***calendars*** related to the type of event or ***project*** or on the General Calendar.

Volunteer (Sign Up) for an Event

1. Click on the appropriate calendar for the event. The calendar for that project/type of event opens.

2. Events can be viewed in a **Monthly View** (calendar) style or in a **List View** style. Find the event in the **Monthly View** or **List View** style.

    - In the **Monthly View** (calendar style), move to the month of the event you want to see.
    - In the **List View** style, events are listed in order by date. To limit the list to a specific time frame, enter **Start Date** and **End Date** in the boxes and click on the **Submit** button to refresh the list to the time period entered.

3. Click on the event that you desire to look at. This opens the **County Event** page with details about the event.

4. **To volunteer (sign up) for the event,** scroll down the page to the **Volunteer for Event** section.

    - **IF space is available for this event**, the **Volunteer** line says **You are not signed up for this event**.

        ✓ To volunteer/sign up, click on the **Volunteer for Event** button. The line will change to **You are currently signed up for this event!**

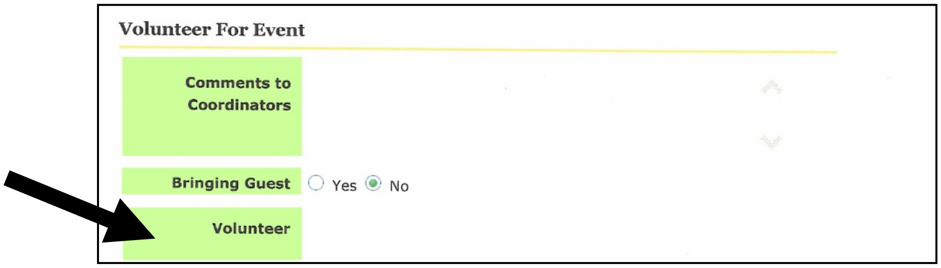
Volunteer For Event

Comments to Coordinators

Bringing Guest ○ Yes ● No

Volunteer You are not signed up for this event.

- **IF space is NOT available for this event because the volunteer slots are all filled**, the **Volunteer** line is blank. There is no **Volunteer for Event** button.



Bringing Guest: ○ Yes ● No

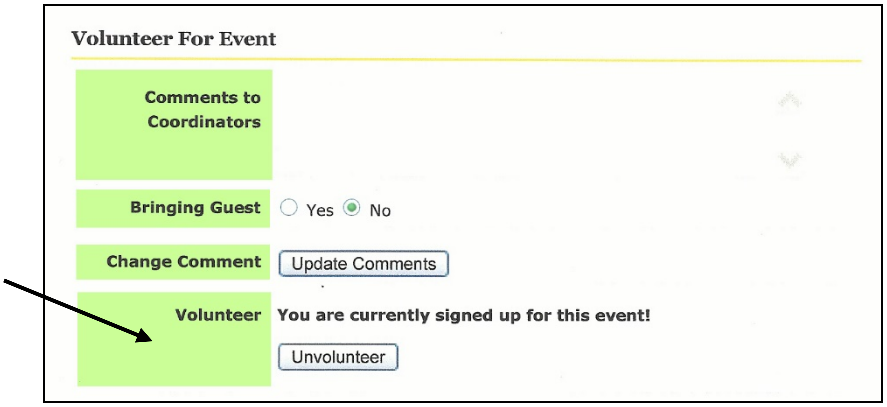
- **Block Events** – The VMS system allows events to be blocked from volunteering/unvolunteering within 0-14 days of an event. When it is blocked, the **Volunteer** line will say **Volunteering and Unvolunteering is closed for this event.** You will need to contact the County CMG Staff about this event.

5. In the **Comments to Coordinators** box, you may add comments to the event coordinator, if desired. Save comments by clicking on the **Update Comments** button.

6. **Event Reminder** – If you want VMS to send you an email reminder of the event, move up to the **Event Reminder** Section. At **Remind Me**, select from the drop-down menu the number of days before the event that you want the reminder sent. Then, click on the **Save Reminder** button.

Unvolunteer (Unsign-up) for an Event

1. In the **Your Calendar** pod (right side), click on the event that you want to change. This will open the event page.
2. Scroll to the **Volunteer for Event** section near the bottom of the page. The **Volunteer** line says **You are currently signed-up for this event!**
3. To unvolunteer/unsign-up, click on the **Unvolunteer** button. The line will change to **You are not signed up for this event.**



Bringing Guest: ○ Yes ● No

Volunteer: You are currently signed up for this event!

- **Note on Volunteer Commitment**
  - CMG Outreach events: The CMG program expects volunteers to fulfill their commitments for CMG outreach events. When conflicts arise, CMGs are expected to find replacements. **Failure to honor volunteer commitments, and leaving assignments unfulfilled are automatic grounds for dismissal from the CMG Program.**

  - CMG Continuing Education Events: When conflicts arise, so that you can no longer attend a Continuing Education Event, please unregister (unvolunteer) for the event, allowing others to fill in the space.

- **Block Events** – The VMS system allows events to be blocked from volunteering/unvolunteering within 0-14 days of an event. When it is blocked, the Volunteer line will say, **Volunteering and Unvolunteering is closed for this event.** You will need to contact the County CMG Staff about this event.

Hours and Contacts Reports

Reporting Hours and Contacts

To report volunteer hours, continuing education hours and contacts:

1. Click on the **Add New Hours** link in the **Your Information** pod.

2. Work through the items on the **Add Volunteer Hours** page, filling in details as needed:

    - **Event Description** – Give a few words to identify the event, such as *Office phone*, *Maple Hills Garden Center Clinic,* or *Plant Select Demonstration Garden*.
    - **Event Date** – Enter the date of the event using the drop-down calendar.
    - **Apply to Project** – Select the Project Area for this event.
    - **Miles Driven** – Here you have the option of keeping track of miles driven for your income-tax purposes.
    - **Volunteer Hours** – Enter the hours of volunteer work rounded to the nearest half hour, such as 1.5.
    - **Continuing Education** – Record hours for continuing education, rounded to the nearest half hour.
    - **Population Served** – Enter your contacts for the outreach event.

3. Click on the **Save Hours** button.

Viewing Your Hours

1. To view your hours click on the **View Your Hours** link in the left-hand **Your Information** pod. This opens your **Volunteer Hour History** page. It will show all recorded events to date (since you started using VMS).

2. **To limit the list to a specific time frame** (such as the current CMG reporting year of November 1st to October 31st), add the **Start Date** and **End Date** in the boxes and click on the **Submit** button. The program will refresh the list using the entered time frame.

Editing Your Hours Report

VMS allows volunteers to edit reports for any given event.

1. To edit the report for any given event, click on the **View Your Hours** link in the **Your Information** pod. This opens your **Volunteer Hour History** page.
2. From the list, click on the event that you need to edit. This opens the **Edit Volunteer Hours** page.
3. Edit the information in the report as needed.
4. Click on the **Save Hours** button to save the change. If you want to delete the entire report, click on the **Delete Hours** button.

Member Roster

The **Member Roster** (**General Information** pod in the lower left-hand corner) allows you to contact other CMG volunteers. The roster lists volunteers and staff in the program with their emails and preferred phone numbers.

- **Click on the person's name** for his or her photo (if he or she has uploaded one), address, and preferred phone number.
- **Click on the person's email** to send the person an email.

The Roster is for internal communications within the CMG Program and must not be used for commercial purposes.

Email an Individual

- To send email to an individual, **click on the person's email**. This opens your email program.

Email a Group

1. In the **General Information** pod, click on the **Member Roster** link. This opens the **Member Roster** page.
2. Click on the **Email Member** link. This opens the **Email Volunteer** page.

    - To email everyone on the list, check the **Email all volunteers** box.
    - To filter the email by Interests, Project or CMG Status, place checks in the boxes desired.

3. Click on the **Email by Interest or Group** button.
4. The Email Volunteers page opens. Write the email.

    - A list of volunteers will be shown. You may unselect individuals by unchecking their names.
    - Add a title in the **Subject** box.
    - Add the message in the **Message** box.
    - **Attach files** (if desired).
    - If you want a copy of the email, check the box in the **Copy Me** line.

5. Click on the **Send Email** button.

View Member Interests

1. In the **General Information** pod, click on the **Member Roster** link. This opens the **Member Roster** page.
2. Click on the **View Member Interests** link. Members will be listed, showing their interests.
3. To go back to the Member Roster, click on the **Hide Interests** button.

Newsletter and Documents

VMS has a feature for newsletters and documents. Click on the **Newsletters/Documents** link in the lower left-hand **General Information** pod. Click on the links to open items.

Needing Additional Help with VMS

When you need additional help with VMS, please contact the CMG staff in your county Extension Office.

Prepared by **David Whiting**, Extension Consumer Horticulture Specialist (retired),
Colorado State University.

Revised December 2017

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

COLORADO MASTER GARDENER℠

Volunteer Handbook

2020 Edition

GardenNotes #14

Colorado State University

WELCOME!

Welcome to Colorado State University Extension! We are thrilled you are joining the Colorado Master Gardener program. In your volunteer role, you serve as a Colorado State University authorized volunteer and your efforts contribute to an impressive and important statewide mission with 45 years of history in Colorado.

As a Colorado Master Gardener, your primary role is as a community educator – sharing knowledge and resources about horticulture and best practices for gardening in our state today within your local county or region. Your efforts are part of a much larger network of Extension Master Gardener volunteers – an incredible group of over 100,000 people serving across the nation and internationally.

Take the time to learn about this program through our online CMG Introduction course and this Volunteer Handbook. These resources will help you understand Extension and the Master Gardener program history and your role in educating and empowering Coloradans to improve our communities through horticulture. Consider this a guide to return to as you have questions and need a starting point. Your local county staff can answer additional questions or provide clarification.

Thank you for your service, time and talent. Your role as a Colorado Master Gardener volunteer is important and valuable. Enjoy the adventures ahead… w*e are so glad you're with us!*

In gratitude,

Katie Dunker

Katie Dunker
Statewide Coordinator
Colorado Master Gardener Program
Colorado State University Extension

TABLE OF CONTENTS

CHAPTER 1:

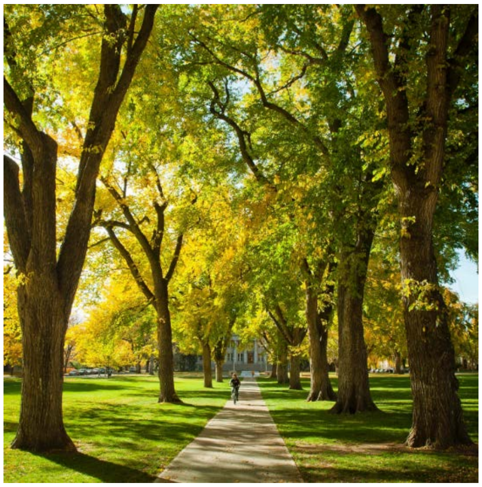
ABOUT THE COLORADO MASTER GARDENER PROGRAM & COLORADO STATE UNIVERSITY

Colorado State University's Mission & Values

Inspired by its land-grant heritage, Colorado State University is committed to excellence, setting the standard for public research universities in teaching, research, service and extension for the benefit of the citizens of Colorado, the United States and the world.

Colorado State University's Values

- Be accountable
- Promote civic responsibility
- Employ a customer focus
- Promote freedom of expression
- Demonstrate inclusiveness and diversity
- Encourage and reward innovation
- Act with integrity and mutual respect
- Provide opportunity and access
- Support excellence in teaching and research



Colorado State University Extension's Mission

Empower Coloradans to address important and emerging community issues using dynamic, science-based educational resources.

CSU Extension's Vision

CSU Extension is highly valued for inclusive, impactful community engagement in support of our land grant university mission.

What is Colorado State University Extension?

Colorado State University Extension is a joint agency between the **United States Department of Agriculture** (USDA) (federal partner), **Colorado State University** (state partner), and **Colorado counties** (local partner). It is a nationwide system delivering research-based education at the county level with resources from the federal and county partners and the state's land-grant university.

When referring to the organization, use the full name: ***Colorado State University Extension***. After the initial use of the term, repeated referrals may be shortened to ***Extension***.

The Land Grant University System

Land grant universities have three primary missions: teaching, research and outreach. Extension's start can be traced as far back as the early 1800s. When President Abraham Lincoln signed the **Morrill Act of 1862**, establishing the land-grant college system. Two additional acts fueled the creation of the modern extension system; the **Hatch Act of 1887** and the **Smith-Lever Act of 1914**. The former led to the establishment of agricultural research stations. The Smith-Lever Act of 1914 formalized the extension system across the nation. Agents (or county-based faculty and staff) were placed in nearly all of Colorado's counties and were supported by specialists on the main campus, often professors who provided research and tools to the community-based staff. This exchange of information between campus and community was a novel innovation and became an integral piece of the land-grant system's outreach efforts.

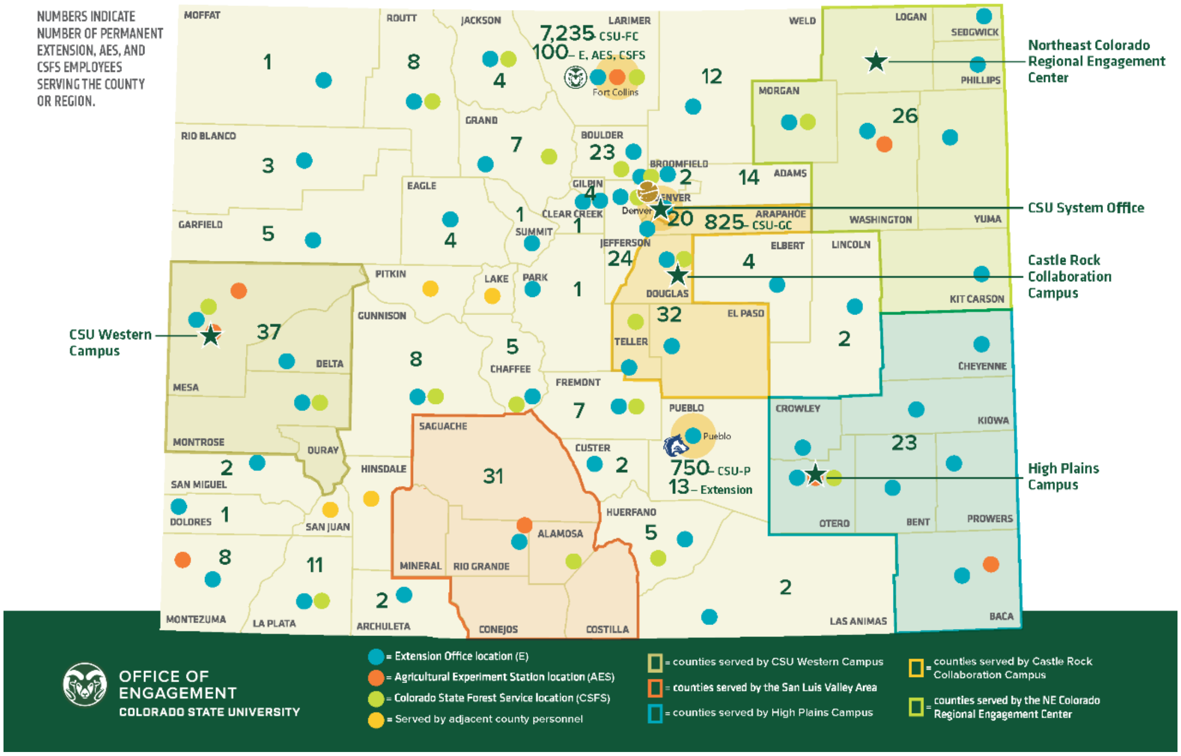
CSU Extension Funding

Current Colorado State University Extension funding sources include:

- 14% Federal funds (USDA budget)
- 33% State funds (Colorado State University budget)
- 41% County funds
- 12% other sources (sales, fees and program grants)

CSU Extension's Regional Model

Colorado State University Extension is organized into three regions: Western Region, Peaks & Plains and the Front Range. Each county is part of a regional and statewide network of Extension & Engagement.



>> YOU CAN LEARN MORE ABOUT THE CSU EXTENSION'S REGIONS, FACULTY & STAFF ONLINE AT HTTP://EXTENSION.COLOSTATE.EDU <<

Staffing

County-based faculty or agents and staff - The county is the basic program delivery unit for CSU Extension and is staffed around locally identified needs. County level staff includes Extension Agents (or county-based faculty), a County Extension Director, (an Extension agent/faculty leading the local team), program coordinators and assistants and support staff. In Colorado, county-based educators may work across county lines in regional efforts or teams.

University-based faculty and specialists also support the local Extension program behind the scenes by providing leadership and research and by assisting with program delivery. Depending on assignment, Colorado State University campus-based, departmental faculty may split time between research, teaching, and Extension activities. Campus-based faculty with Extension appointments are known as ***Extension Specialists***. Extension programs also work closely with Agricultural Experiment Stations, located around the state.

The **County Extension Advisory Committee** provides input on current and emerging issues that need attention. Local citizens serving on the committee play a key role in helping staff identify and prioritize program needs at the local level.

The **Colorado Master Gardener Statewide Coordinator** is housed on the Main Campus in Fort Collins and is dedicated to serving the statewide needs to provide leadership, organization and support for both local county programs as well as statewide initiatives specific to Extension and the Colorado Master Gardener program.

History of the Master Gardener program

The Master Gardener program began in 1973, when it was founded in the state of Washington. With its success, it quickly spread to other states. In Colorado, the program began in 1975 in Denver, Boulder, Jefferson and El Paso counties. Today, there are programs in all 50 states, the District of Columbia, nine Canadian provinces and South Korea.

Volunteers in the Colorado program support gardeners from the plains to the highest elevations of the state. They support Colorado State University Extension staff through their participation in educational activities that expand the reach of local horticultural experts. Their journey begins with a rigorous 10 weeks of training on topics including everything from soils to plant diseases and insects. Volunteers then give back to communities through various activities.

Volunteers might teach public classes, respond to public phone calls and emails, staff booths at farmers' markets and other events, teach youth and community gardening, maintain public research and demonstration gardens, write blogs and develop videos. In 2018, 1364 volunteers across 35 counties donated 54,111 hours, worth about 1.5 million dollars in community contributions.

Colorado Master Gardener Program℠ Mission Statement

The Colorado State University, Colorado Master Gardener Program volunteer network strives to enhance Coloradans' quality of life by:

- Extending knowledge-based education throughout Colorado communities to foster successful gardeners;
- Helping individuals make informed decisions about plants to protect neighborhood environments.

We are committed to using horticulture to empower gardeners, develop partnerships and build stronger communities.

Colorado Master Gardener Program Vision Statement

The Colorado State University, Colorado Master Gardener Program strives to lead educational efforts to nurture Colorado's natural environment and communities by:

- Collaborating with the green industry, public agencies and nonprofits to provide current research-based information to the public;
- Developing educational programs for local needs such as water issues, alternative pest management and ecosystem characteristics, to encourage environmentally sound horticultural practices;
- Reaching out to new audiences through a variety of technologies;
- Providing lifelong learning opportunities and a variety of meaningful volunteer options for Colorado Master Gardeners, resulting in a committed, active network of horticultural educators who serve communities across the state;
- Cultivating long-term support and securing abundant resources from diverse constituencies for the Colorado Master Gardener Program by showing the differences that this program makes in Coloradans' quality of life.

GROWING PLANTS. GROWING PEOPLE.

> We are committed to using horticulture to empower gardeners, develop partnerships and build stronger communities.
>
> *CMG Mission*

Colorado Master Gardener Program Funding

At the state level, the Colorado Master Gardener program is completely self-funded.

Funding Source	What it supports
Colorado Master Gardener training fees and CMG Annual volunteer dues	One full-time state coordinator salary and benefits including professional development and travel. Operational expenses for program such as travel for instructors, office supplies, IT support and educational materials production.
Colorado Garden Foundation ***Annual Grant***	Supplies and materials for training Annual VMS lease fee
CSU Online's Certified Gardener online badging program	Course development, updates, marketing Staff for short term projects Additional program costs not covered by annual dues & training fees
Foundation Accounts ***Barbara Boardman CMG Endowed Fund*** ***Colorado Master Gardener Endowed Fund***	Professional development for staff Special projects

Colorado Master Gardener Service Mark

Colorado Master Gardener is a registered service mark of Colorado State University Extension and is used to identify volunteers as representatives of CSU Extension. **It may be used ONLY in connection with official CSU Extension activities.**

In print materials, the first use of the title ***Colorado Master Gardener***^{sm} should be followed with a small "sm" after Gardener.

When CMG volunteers are not officially representing Colorado State University Extension, the general term "master gardener" without any verbal connection to the CSU Extension System can be used.

Colorado State University Branding & Logo Information

The CSU logo and brand is an important identity marker for the University and university programs, such as the Colorado Master Gardener program. As a volunteer, you can work with your local county staff to gain access to the current logos and brand guidelines for CSU Extension and the CMG program specific to your county.

The university brand site will show you all of the general university brand guidelines: https://creativeservices.colostate.edu/brand-style-guide/

These are examples of current, official CSU Extension and Colorado Master Gardener logos:

COLORADO STATE UNIVERSITY
EXTENSION

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CHAPTER 2:

VOLUNTEER OPPORTUNITIES & CONTINUING EDUCATION

Colorado Master Gardener Products & Audience

Colorado Master Gardeners assist Colorado State University Extension staff in delivering research-based gardening information to foster successful gardening in Colorado communities**. Activities must focus on education**. CMGs do not provide garden labor or consultant services without an educational purpose. The Colorado Master Gardener program is neutral and unbiased toward specific commercial products, services and other groups.

Audience

The CMG Volunteer's audience is exclusively non-commercial, home gardeners. Green Industry or commercial growers are referred to Extension faculty or agents.

Educational Products

Transfer of technical knowledge and development of decision-making skills: Our role is to provide Coloradans with research-based information and relevant options, empowering them to make informed decisions customized to their situations and needs. These decisions can have economic, environmental and health related impacts. The product delivered by CMG volunteers is **education** through the transfer of knowledge and skills. *Most CMG outreach falls into this type of activity.*

Restorative gardening: This is the purposeful production, maintenance and harvest of plants for individual and community resilience. Our educational product is **life skills**. The intended impacts are increased health and stability for individuals, families and communities relative to their emotional, psychological and physical well-being.

Definition of a CMG Volunteer Activity

1. Activities must be ***supportive*** of CSU Extension issues.
2. Activities must be ***educational*** in nature. What knowledge and skills does the client develop?
3. Activities must have ***advanced approval* of *designated*** county staff. The local CMG agent/coordinator makes the final decision about what is acceptable.

4. Volunteers must be ***identified*** as *Colorado State University Extension, Colorado Master Gardeners.*

How Do I Know if an Activity is Educational?

Sometimes there is confusion about what makes an activity an educational one – or not. In an educational activity, participants gain knowledge or skills or both. Three components that further help identify an educational activity are:

- The activity has been **marketed.**
- The activity has a **defined audience.**
- The activity has an **intentional message.**

Difference Between Educational and Service Activities

This is a very important distinction to understand so here's an example: Let's say you are involved in a youth garden with the assignment of coaching youth to transplant cabbages; this is an educational activity. You are teaching them how, perhaps even demonstrating how, they are learning the steps to transplant the cabbage and gaining the skill to perform transplanting. You do not transplant for them.

Another example may be demonstrating how to prune a tree as educational outreach to a local gardening club. Going to a gardening club member's home and pruning all their trees is NOT educational. Pruning trees for citizens is an example of a service activity where education or learning a new skill are not provided to the consumer.

Educational outreach	Service-oriented outreach
Share information about right plant, right place and factsheets on landscape plants for Colorado's climate, soils, sun, etc.	Develop a landscape design.
Share information about plant species adapted to local growing conditions.	Call around to find nurseries that carry a product or certain plants for an individual.
Mentor a community group, working with them.	Maintain a garden for a group/organization.
Implement an educational demonstration/teaching garden that empowers viewer to adapt concepts demonstrated.	Maintain a garden to beautify an area.

What about Landscape Design?

It can be tempting to assist the public with landscape design. However, **this is not educational in nature and is outside the scope of CMGs**. Landscape design is a *profession* that requires site visits, time and resources to do well.

In your role as a CMG Volunteer, you can recommend resources to support in this work such as design ideas/templates from Plant Select, Colorado Native Plant Society, & Garden in a Box; Soil testing information; Colorado-hardy plant lists; climate considerations (zones); and many factsheets related to the topic including, *Selecting Trees, Selecting Shrubs, Selecting Plants, How to Plant a Tree*, etc.

Projects Examples & Considerations

Mentoring

CMG volunteers can serve as mentors to other groups, like 4-H clubs and school or church youth groups, who are planting and/or maintaining parks, community gardens and other green spaces. Here the CMG serves in an educational role demonstrating a technique, coaching or instructing clients.

Demonstration Gardens

To be acceptable for CMG hours, the demonstration garden must truly empower the viewer to make knowledgeable decisions. This requires signage and print materials about the garden's educational objectives. For example, an attractive xeric garden does not give viewers the knowledge to adapt xeric principles in their home gardens. Signs need to identify xeric plants the viewer may want to purchase. Onsite printed materials, online links and/or QR codes should give additional information about techniques for reducing water usage. CMG programs should also consider sponsoring public educational activities in the garden. It could also be used as a backdrop or tool for blogs, newspaper articles and you-tube video production.

When a demonstration garden produces food that is donated to a food bank or similar entity:

1. The demonstration garden must meet the above description of an educational demonstration garden;
2. **AND** must meet the definition of a CMG volunteer activity to be counted as a CMG activity.

Food raised in a church, school or community garden may not be counted as CMG volunteer time unless there is an approved CMG educational activity affiliated with it.

University Research Efforts

Interested CMG volunteers can become actively involved in University research efforts, working with state and county staff. In these projects, research staff work WITH Master Gardeners to create a two-way flow of information and a learning environment for all.

Free Labor Crew

As Colorado Master Gardeners, **volunteers may NOT work as a free labor crew** to plant and/or maintain city and county parks, plant trees for community groups or otherwise maintain private or public properties. These activities are not educational in nature.

Initiating Local Projects

Local community projects may be initiated by CMG volunteers. However, they must be educational in nature, follow CMG guidelines and use Colorado State University recommendations. Projects should provide educational value to participants such as sharing information, consulting and/or demonstrating techniques.

Projects discouraged include those where Colorado Master Gardeners provide only labor or involve commercial businesses where there appears to be a conflict of interest.

CMG volunteers desiring to initiate projects should contact the agent/coordinator in charge of the local program and discuss it with him/her. Roles of volunteers, partners, funding, responsibilities and operations should be identified in written form before approval is given. When a county has ample, existing projects for the volunteer program, a project may be denied.

Cross-County Projects

Volunteer service may include special cross-county volunteer projects. There should be a memorandum of agreement that includes the following items:

- ✓ Statement clarifying the nature of a cross-county CMG outreach project, including:
    - Nature and scope of the work in the home county
    - Communication plan, related to the special project, between the volunteer and staff
    - A statement clarifying any specific division of volunteer efforts and other program support concerns between counties, as appropriate
    - A statement clarifying that volunteer engagement support will be provided through the host county and that the non-county resident/volunteer will be a regular, active member of the host county CMG Program including all communication and reporting.
- ✓ The memorandum of agreement is signed as part of the application process by the county CMG Program staff and county directors. It may be modified with agreement of all parties.

>> VOLUNTEER SERVICE: 50 HOURS IN APPRENTICE YEAR;
24 HOURS PER YEAR THEREAFTER <<

Continuing Education Requirement – 12 hours per year

The continuing education requirement serves three purposes:

- Provides opportunity for continued learning.
- Defines a minimum participation level within the program.
- Reduces liability to Extension and agents by expecting non-paid staff to be continually updated on research- based information.

A minimum of six hours must be from educational events specifically sponsored by Extension for CMG volunteers. All 12 hours may be from these events. Examples include:

- *CMG OnLine* classes. Counties are not to restrict the hours that volunteers may view these resources.
- A county may require that up to six hours of the continuing education be from other specific venues.
- County, regional, and state CMG updates by specialists, agents, experienced CMG volunteers, Green Industry members, etc.
- State CMG conferences
- Specialized training courses, like "Diagnostic Clinics"
- Re-attendance at basic training sessions
- Volunteer development training
- Writer's workshops

Other educational activities ***may*** count as they relate to horticulture as a CMG *AND* with ***prior approval*** of designated agent or coordinator.

Examples include:

- Public garden classes
- Academic classes
- Garden club speakers
- Gardening videos
- Distance learning opportunities
- Job-related in-service
- Special research projects
- Independent projects

Time *may* include preparation time for CMG outreach activities and *reasonable* travel time to and from CMG events unless prohibited by county drive-time policy. It **does not include** personal study time.

IF IN DOUBT…

Volunteer hours are counted when the CMG provides educational programs to clients. **Continuing education hours** are counted when the CMG is in the student role, receiving the training.

Volunteer Commitment

The term "volunteer" is used to help the public understand that Colorado Master Gardener Volunteers are donating their time to assist them and are not paid staff of CSU Extension or the county. This is important in setting the public's level of expectations. Coloradans are very appreciative of CMG efforts donated to assist them. This is important because some can become rather demanding of *paid staff*.

However, being a "volunteer" NEVER implies a lack of responsibility in fulfilling commitments. When a CMG volunteer fails to honor a commitment by not showing up, it may create serious problems for the program. A CMG volunteer who makes a habit of not showing up will be released from the program.

Colorado Master Gardener Program Titles & Status'

Apprentice Master Gardener

- Applicants, 18 years of age or older, that have been accepted into the program and are working towards completing their apprentice requirements. These requirements include: completed core training, 50 hours of volunteer service (60 for 2-year apprentices), final coursework exam (70% or better) and paperwork.
- Receive the Colorado Master Gardener training at a reduced fee in partial exchange for their volunteer service. The volunteer service is considered part of the training received by *Colorado Master Gardeners*.
- Receive the Colorado Master Gardener certificate upon completion of the required training, service and reporting.
- May also receive the Colorado Gardener Certificate upon completion of the CMG certificate requirements. This certificate may be used to market their expertise.

Colorado Gardener Certificate

- Adults, 18 years of age and older, who desire the Colorado Master Gardener training only, without a volunteer commitment.
- Pay program's full training tuition in lieu of the return volunteer service.
- Receive the ***Colorado Gardener Certificate*** upon completion of the coursework and passing the final exam with a score of 70% or better.
- **Not** Colorado Master Gardeners but may apply to become a CMG within three (3) years of their completed training without having to re-take the core training program.
- Certificate may be used to establish training credentials and market expertise.

Colorado Master Gardener

- Successfully completed apprentice requirements.
- Completes annual reappointment paperwork and pays annual dues each year.
- Completes 12 hours of continuing education each year.
- Volunteers a minimum of 24 hours each year.
- Completes reporting in VMS each year.
- In good standing with local county program.

Limited Activity/Inactive CMG

- This status is determined by the local coordinator following request and consultation.
- Status can be in place for up to 12 months *and may be longer depending on circumstances.*
- Continue to receive emails and may choose to participate in meetings and volunteer projects as able.
- Must continue to complete annual reappointment paperwork, pay CMG annual dues and report any volunteer and continuing education hours completed.
- May reactivate as CMG after consulting with local coordinator/staff.
- This status cannot be used at the end of the CMG year due to incompletion of commitments; rather it should be discussed with the local coordinator when a need arises and/or is anticipated.
- Note: **Years in inactive status do not count toward years of CMG service**

Affiliate Colorado Master Gardener

- CMG volunteers whose role has evolved from traditional CMG activities but continue to serve valuable roles in the program as community contact or collaborator.
- Have completed CMG requirements.
- May be a CMG who speaks for the CMG program interests on an advisory board.
- May be a CMG in a green industry role who supports the program as a consultant, collaborator or instructor.
- May be a CMG whose primary role serves as program contact for another organization in collaboration with the CMG program.
- Assigned this status by the local coordinator ONLY following consultation.
- Continue to receive emails and may choose to participate in meetings and volunteer projects as able and appropriate.
- Must continue to complete annual reappointment forms, pay CMG annual dues and report any volunteer and continuing education hours completed.

Colorado Master Gardener Emeritus

- Have made a substantial contribution to the CMG program; designated by county coordinator and CMG coordinator following consultation and review of requirements.
- Must be in good standing with the program at the time of the designation.
- Desire to continue, but circumstances limit participation beyond their control such as personal or family health needs.
- Continue to receive emails and may choose to participate in meetings and volunteer projects as able and appropriate.
- Must continue to complete annual reappointment forms, pay CMG annual dues and report any volunteer and continuing education hours completed.

Released

- Volunteer no longer active or affiliated with the Colorado State University Extension CMG program.
- May not identify themselves as affiliated with Colorado State University Extension or identify as a "Colorado Master Gardener."
- Will be removed from the county VMS roster.
- May re-apply for admission within 3 years without repeating the core training if they left in good standing at their own request.

Volunteer Release

Non-renewal, release or dismissal of a CMG

Under a ruling of the U.S. Supreme Court, volunteering for any organization is a privilege, not a right. Organizations have the right to select individuals they desire to work as volunteers in their organization. Organizations may release volunteers at the discretion of the organization.

According to CSU Extension policy, volunteers serve at the request of CSU Extension as non-paid staff. That request can be withdrawn for any reason or no reason at any time.

Examples of situations when CMG volunteers may be released/dismissed:

- Repeated failure to give knowledge-based information.
- Repeated failure to show-up for volunteer commitments.
- Repeated failure to turn in reports in a timely manner.
- When a volunteer oversteps his/her authority.
- When safety of clients/staff/other volunteers is in danger ie., abusive, bullying, disrespectful, hostile or threatening behavior.
- Showing up for CMG activities under the influence of drugs, including marijuana or alcohol.
- Other situations where the actions as a Colorado Master Gardener does not reflect well on the University.
- At the discretion of the agent or request of the volunteer.
- To accommodate the training of additional people as community gardening resources.
- At the discretion of the agent or request of the volunteer.

CHAPTER 3:
COLORADO MASTER GARDENER PROGRAM POLICIES

Apprentice Application Process

Newly accepted volunteers begin as *Apprentices*. This means you're in-training to become a Master Gardener The application and acceptance process occurs at the local county level. Like all programs, we have a few considerations for interested applicants:

- You must be at least 18 years old to apply.
- Criminal background checks are required for all volunteers. These are initiated by the local county but facilitated through the University Human Resources department. Detailed results are not shown – only a pass or no pass.
- If you're accepted into a program, there are training fees your first year and dues ($25-35 in most counties) required every subsequent year.
- We do offer financial need-based scholarships reducing your fee to $85. Details are in the application.
- Initial horticulture training requires 80% minimum class attendance, **completion of all on-line classes** and completion of homework assignments and weekly reading.
- You will need reliable access to the internet and email to be successful in our program. Accommodations can be made in local offices as needed.
- Following training, apprentices are encouraged to engage in local projects which vary widely. Your apprentice year requires 50 hours minimum volunteer time in your county/area CMG program by the end of the program year, October 31st.
- Our program does allow for a 2-year apprenticeship option, requiring 60 hours of volunteer service over a 2-year period and successful completion of all other requirements.

Applicants interested in joining a program outside of their home county, due to personal reasons or because their local county does not offer a program, should see **"***Memberships, Transfers & Cross-County Enrollment"* in this handbook.

Failure to Complete the Apprentice Volunteer Requirements

As outlined and agreed to in the Apprentice Volunteer Application, training fees are reduced for future volunteer requirements in the first one to two years. These hours are considered "payback" hours. Those who fail to complete the minimum "payback hours" by October 31st of the training year will be billed for the class tuition.

The billing rate is $15.00 per uncompleted hour, up to $500 maximum.

Individuals with special situations may be given an extension for up to 12 months at the discretion of the local staff based on extenuating circumstances and hardships.

Becoming a Colorado Master Gardener & Recertification

Once you've completed your Apprentice requirements (CMG Training program, including passing the exam, completing volunteer hour requirements and reporting all hours in VMS), you will graduate and become a Colorado Master Gardener [see *Colorado Master Gardener Titles & Status'* in this handbook for more details]. Upon graduation, you'll receive a certificate and name badge from the university.

Continued certification requires 12 continuing education credit hours per year and a minimum of 24 hours of volunteer service on authorized projects. [See *Volunteer Opportunities & Continuing* in this handbook] Annual dues are also required and collected by your local county when reappointment paperwork is done.

Use of Colorado Master Gardener Name

Our program is known as the **Colorado Master Gardener** program. The term "master gardener" without any reference to the Colorado State University Extension System at the state or county level is considered generic and is used by many organizations and businesses. It may be used in situations not affiliated with the Colorado State University Extension System. However, use of this term is discouraged. When volunteers refer to themselves as members of our program, they should use the term "Colorado Master Gardener" or "Colorado State University Master Gardener." "Extension Master Gardener Volunteer" is another term used nationally and in other states to identify trained and active Master Gardeners.

Since Colorado Master Gardeners represent the university as "authorized volunteers," you may not use this title outside of CSU sponsored/affiliated projects. Extension volunteers, such as Colorado Master Gardeners, provide a public service offering unbiased, research-based information. Representing yourself as a Master Gardener outside of your volunteer service in connection with commercial activity or personal financial gain is NOT allowed. However, Individuals are encouraged to list Colorado Master Gardener on their personal resume as volunteer experience.

The Colorado Master Gardener Code of Conduct

The agreements, policies and code of conduct below clarifies the scope and expectations of our program. CSU and local counties invest a lot in volunteers and volunteers in turn giveback and invest in CSU Extension and their local communities. It's important for future and current volunteers to understand what our program is about and determine if it's a good fit. CSU Extension values the service of CMG volunteers and commits to do our best to make the volunteer experience a productive and rewarding one. The information below is agreed to in the Apprentice application AND annually during reappointment.

In applying to become a *Colorado Master Gardener Volunteer*:

- ✓ I understand that the decision to accept me or not accept me as a volunteer is the right of Colorado State University Extension. I understand, that in many counties, more individuals apply than the program can accommodate.
- ✓ I understand my acceptance into the Colorado Master Gardener Program commits me to 1) the Colorado Master Gardener Training, and 2) 50 hours minimum volunteer work in the CMG program during the CMG activity year (ending October 31st) OR 3) 60 volunteer hours over a 2 year commitment ending October 31 two years from start date.

- ✓ If I do not complete the 50 hours minimum volunteer work by October 31st, I agree to reimburse Colorado State University Extension for the course work at the rate of $15 per each uncompleted hour, to a maximum of $500.
- ✓ I understand that Colorado State University conducts background checks on all volunteers. A criminal record will not necessarily bar me as a volunteer, but will be considered as it relates to the specifics of the volunteer work. I understand that if I do not respond to the inquiry regarding background checks, my application will not be processed.
- ✓ I understand that volunteering for an organization is a privilege, not a right. If selected as a volunteer, I understand that I serve at the request of Colorado State University Extension and that the request can be withdrawn at any time.

In the capacity of a ***Colorado Master Gardener Volunteer***:

- ✓ I agree to be civil and courteous towards Extension staff, other volunteers and the public. Others may think and do things differently than what I personally prefer, but I will be respectful of their values and perspectives.
- ✓ I understand that as a CSU volunteer I am part of the larger CSU community and agree to uphold the **Principles of Community**. Read these at https://diversity.colostate.edu/ principles-of-community/
- ✓ I agree to cooperate with and support the local Extension Office staff and volunteers to jointly further the missions and objectives of the CMG Program. In addition, I agree to comply with training, reporting, certification, annual renewal requirements and other program directives as stated in CMG GardenNotes #14 https://cmg.extension.colostate.edu/Gardennotes/014.pdf
- ✓ I understand that the title "*Colorado Master Gardener*" may be used only in connection with official Colorado State University Extension activities. The title may not be used to associate the Colorado Master Gardener name with commercial products or give implied endorsements of any product or place of business. The title may not be used to advance my personal political, religious or environmental beliefs.
- ✓ I agree to disseminate information without regard to race, age, color, religion, national origin or ancestry, sex, gender, disability, veteran status, genetic information, sexual orientation, or gender identity or expression.
- ✓ I agree to follow federal, state, county, Colorado State University and Extension Office policies and regulations appropriate to my role as a volunteer.
- ✓ I agree to provide research-based horticultural information from Colorado State University or other research-based institutions.
- ✓ I understand CMG volunteer clientele are non-commercial home gardeners. I understand that as a CMG volunteer it is not my role to advise commercial growers or green industry professionals and will refer these clients to the appropriate Extension staff.
- ✓ I understand that as a CMG volunteer, I may not give advice that could be considered by the client as legal or medical in nature. I will not discuss the following issues: hazard trees, poisonous plants and mushrooms, medical use of herbs including growing and use of marijuana, pesticide toxicity and the misuse of pesticides. I will refer these issues to the appropriate Extension staff.
- ✓ I will follow pest management recommendations based on integrated pest management (IPM) strategies, allowing the client to select methods in harmony with their values. Any reference to the use of pesticides must come directly from Extension resources. All inquiries beyond this scope will

be referred to appropriate Extension staff.

- ✓ I understand that I will not discuss or make comments about the toxicity of organic or synthetic pesticides. Inquiries about pesticide toxicity will be referred to the *National Pesticide Information Center*, found here: http://npic.orst.edu/
- ✓ I will avoid being disruptive and distracted in training classes and volunteer events. I understand that the CMG email communication system (VMS) and membership lists are for internal Extension business use only. I will not use it for commercial business, share the information in it outside of Extension business or send spam type communications.
- ✓ I will adhere to CSU's Social Media policy (http://policylibrary.colostate.edu/policy.aspx?id=497) and will avoid answering questions using the Colorado Master Gardener title or responding on behalf of CSU on my personal social media accounts.
- ✓ I agree to refrain from using or possessing alcohol or illegal substances while participating in volunteer activities. Being under the influence of alcohol, marijuana or illegal substances during CMG service will result in disciplinary action.
- ✓ In support of the program operations, I agree to pay annual CMG Fees and other expenses in regards to the program (i.e. books, transportation, course fees, clothing), as assessed by the state and my local county program.
- ✓ As non-paid staff, I understand that I am not covered by CSU worker's compensation or other medical insurance.

CSU's Minors' Policy

All Colorado Master Gardeners, regardless of status in the program, must read and agree to uphold this University policy designed to protect vulnerable populations: http://policylibrary.colostate.edu/policyprint.aspx?id=734

Colorado State University Extension to the extent possible will:

- Provide opportunities for my continual learning through volunteer activities, classes and workshops and online learning opportunities.
- Provide training, supervision, equipment, and direction to volunteers through the local Extension office.
- Communicate expectations and responsibilities of the program to volunteers.
- Uphold and cultivate a respectful relationship between staff and volunteers.
- Uphold CSU's Principles of Community.
- Provide access to CSU Extension reference materials and professionals.
- Provide a safe working environment within the Extension office and at CMG events.
- While serving in an official CMG capacity preapproved by the local agent/CMG Program Leader, the University covers CMG volunteers with University liability insurance provided that the volunteer uses research-based information and applies good judgment.
- Match volunteer skills and interests with volunteer opportunities within the local program.

Colorado Driver’s License and Automotive Liability Insurance

Volunteers who drive as part of their volunteer service must be in compliance with State of Colorado laws, including, but not limited to:

1. Having a valid Driver’s License with a relatively clean driving record.
2. Having at least the minimum auto insurance required by state law.
3. Complying with seat belt use and other traffic laws.

Furthermore, it is expected that any vehicle used to transport CMG volunteers is maintained so that it is “safe and reliable” for the conditions, weather, and distance in which it is to be driven. Most counties do not allow volunteers to include driving time as part of their volunteer hours. Check with your county for local guidelines.

Conflict of interest

Any situation that has the potential to infer that Colorado State University promotes or endorses a private business or product could be a conflict of interest. Most conflict-of-interest problems arise from implied endorsement, i.e. implying that the service is provided by or in collaboration with Colorado State University or implying that Colorado State University is recommending a business or product.

CMG volunteers are identified as Colorado Master Gardeners or otherwise affiliated with Colorado State University, ONLY while serving in authorized CMG activities.

Volunteers with green industry connections may NOT use CMG activities as a source of business contacts. CMG volunteers may not wear CMG name badges or CMG clothing items while working as employees or owners of a nursery, garden center or other business. **The title “Colorado Master Gardener” or other indicators suggesting affiliation with Colorado State University, may NOT be used on any marketing materials for private business.** The Colorado Gardener Certificate implies participation in training only. Since it does not imply that the holder is representing the Colorado State University Extension system as a volunteer, it may be used for marketing purposes.

Copyright Law

CMG volunteers must not violate copyright laws in performance of volunteer service.

CSU Extension gives permission to CMG volunteers to make copies of our fact sheets and CMG GardenNotes as part of their CMG work. However, they are generally available free from the website. Copies must be of acceptable quality, of the current version, and made without changes. Permission to copy Colorado State University materials does not extend to publications available for sale or other print materials.

Copyright law prohibits making multiple copies of any material for group distribution without permission of the copyright holder. For additional information on copyright, refer to CMG GardenNotes #018, Using Copyrighted Materials: Are You Legal?

What CMGs cannot provide: Legal & Medical Advice

While working as volunteers, Colorado Master Gardeners are not authorized to give legal or medical advice. Violation of this protocol by CMG volunteers is ground for automatic dismissal from the CMG Program.

1. **Hazard Trees** – CMG volunteers do NOT address hazard tree issues (concerns about the potential for a tree to fall on a house or other structure resulting in injury or property damage.) Rather, they should refer the client to a certified arborist. [legal issue]
2. **Poisonous Plants and Mushrooms** – CMG volunteers do NOT address poisonous plant or mushroom questions. [medical issue]
3. **Medical Issues including Human Health Entomology and Medical Marijuana** – CMG volunteers do NOT advise on medically related issues, including the influence of insects on human health and the medicinal use of herbs. [medical issue]
4. **Pesticide Misuse** - CMG volunteers do not advise on the misuse of pesticides by others. In these situations, customers should contact the Colorado Department of Agriculture. [legal issue]
5. **Pesticide health and environmental safety issues** - As a CMG, volunteers are not authorized to discuss pesticide health and environmental safety issues. The role of CMG volunteers also does NOT include any discussion about merits or limitations of any type of pesticide. [legal issue]

Pesticide Information

Provide Pesticide options - The role of Extension in pest management is to help clients understand non- chemical and chemical options, not to spread personal values or opinions about the use of pesticides.

Direct to Appropriate Pesticides The role of CMG volunteers is limited to directing clients to appropriate pesticides, using Extension Fact Sheets and other Extension print materials. It is a good practice to supply a print copy of the fact sheets when possible. Use of other reference materials is not acceptable for pesticide information.

Pesticide toxicity information – Although CMGs may not discuss pesticide health and safety issues, a client may be directly referred to the ***National Pesticide Information Network*** *(see box below for information)* . This program is sponsored by the Environmental Protection Agency (EPA) in cooperation with Oregon State University.

Pesticide Use in Demonstration/Research Gardens - CMGs may use general use pesticides in these settings. All pesticides must be used in accordance with all applicable state and federal laws and regulations and the label directions. Volunteers must read and follow the label directions. No "home remedies" may be used as a pesticide unless Colorado State University has a published recommendation for the product.

NATIONAL PESTICIDE INFORMATION NETWORK

Phone: 1-800-858-7378
E-mail: npic@ace.orst.edu
Web: http://npic.orst.edu
Hours: 7 days a week, excluding holidays, 6:30 am to 4:30 pm [PST]

CSU Extension Protocol for Marijuana

The General Counsel's staff at Colorado State University has informed CSU Extension of the following in regards to Marijuana. These restrictions apply to all Colorado State University Extension staff members and volunteers, including Colorado Master Gardener volunteers.

While the use of Marijuana is legal in the state of Colorado, Marijuana remains a Schedule 1 illegal drug under federal law and as such, Colorado State University Extension cannot be involved with this item.

Assistance with Medical Marijuana plant health questions will not be provided. Individuals requesting such information will not be provided referral information. CMG volunteers will not address the issue with the media.

Our offices are considered drug-free workplaces, as CSU is a federal contractor. Marijuana plants and/or plant parts are not permitted in CSU Extension offices. Marijuana plants or plant parts delivered to or left at CSU Extension offices will be turned over to legal authorities for destruction.

If CSU Extension employees or volunteers, including Colorado Master Gardeners, assist marijuana growers, they will be acting outside the scope of their employee/volunteer role and assume personal liability for any legal action that may be taken against them.

Liability

While working in an official CMG volunteer capacity as a non-paid University staff, CMG volunteers may covered by University liability insurance for mis-information, provided they are using research/knowledge-based information and applying good judgment. This means that the University may assist with a defense if it is in the best interests of the University. CMG volunteers will not be covered if they go out on a limb with personal information or information from special interest groups.

A CMG would not be covered for information shared outside of official, approved CMG activities.

Assumption of Risk & Liability Waiver

As an authorized volunteer of Colorado State University, you are required to complete and sign a waiver annually acknowledging the inherent risks involved in volunteering. Contact your local county staff to obtain this waiver if you have not completed one for your current service year.

Worker’s Comp and Medical Insurance

As non-paid staff, CMG volunteers are NOT covered by worker’s compensation or other medical insurance

Equal Opportunity

CSU Extension programs are available to all without discrimination. Colorado State University has zero tolerance for discrimination based on race, gender, age, disability, color, veteran status, religion, genetic information, national origin or ancestry, sexual orientation, sex, gender identity or expression.

Memberships, Transfers & Cross-County Enrollment

Cross-county enrollment procedures were developed to address varying needs of CMG volunteers and ensure that each volunteer is engaged in an active local CMG Program.

Resident Applying to a neighboring County's CMG Program

Being accountable to local taxpayers and county budget support, applicants should apply to their home county program. **Counties will give priority to local residents**.

Some potential applicants may better connect to a neighboring county, due to work, social, and family settings, rather than their county of residency. Residents may apply or transfer as a volunteer to another county under a written memorandum of agreement. The agreement includes the following:

- ✓ A statement clarifying the situation why the applicant prefers membership in a program outside their county of residence.
- ✓ A statement clarifying that the volunteer work will be done in and behalf of the host county. The volunteer understands and accepts the travel commitment between the between counties. Travel time incurred for volunteer outreach from the home to volunteer activities does NOT count towards volunteer hours in most cases.
- ✓ A statement clarifying that the volunteer is not at will to float between CMG Program in their county of residence and the host county.
- ✓ A statement clarifying that volunteer engagement support will be provided through the host county that the non-county resident volunteer will be active member of the host county CMG Program including all communication, continuing education and reporting.

A memorandum of agreement is signed as part of the application process by the CMG applicant, the hosting county CMG Program agent/coordinator and the county of residence agent/coordinator. After the initial year, active membership continues with the host county program.

Serving as a Master Gardener volunteer in two counties:

CMGs must be committed to one county program. Volunteer service should be done in the home county program. Exceptions to this do occur but are managed by county staff based on program fit and extenuating circumstances. [see Resident Applying to a Neighboring County's CMG Program] On a related note, cross-county projects do occur and can count for hours in your home county. [see Cross-County Projects]

Residents of an Extension County without CMG Programs applying to neighboring CMG Program

Non-county residents may apply or transfer to a neighboring county under a written memorandum of understanding as follows:

Volunteering for the host county – work will be done for and on behalf of the host county. The memorandum of agreement includes the following items:

- ✓ A statement clarifying that the volunteer work will be done in and on behalf of the host county. The volunteer understands and accepts the travel commitment between the between counties. Travel time incurred for volunteer outreach from the home to volunteer activities does NOT count towards volunteer hours in most cases.
- ✓ A statement clarifying that volunteer engagement support will be provided through the host county that the non-county resident volunteer will be a regular, active member of the host county CMG Program including all communication, continuing education and reporting.
- ✓ The memorandum of agreement is signed as part of the application process by the CMG applicant, the hosting county CMG Program agent/coordinator and the county of residence agent/coordinator. After the initial year, active membership continues with the host county program.

Residents from a Non-Extension County

Counties where the County Commission elects not to fund the Extension Partnership

Residents may not apply to or transfer to a neighboring county as CMG volunteers. If a county terminates funding of the Extension partnership, current CMG volunteers will be "released" from volunteer service. All CMG program outreach and training ends within the county.

Transfer to Another County within Colorado

Colorado Master Gardeners may <u>request</u> a transfer to another county's program. Consideration will be based on recommendations of previous county staff and need for additional volunteers in the local program. Transfers are not approved for CMG volunteers who have not fully honored their volunteer commitment. In most situations, a transfer may be feasible only at the beginning of the calendar year when volunteer opportunities are readily open.

Transfers will be denied for volunteers who have failed to complete volunteer commitments of 50 hours volunteer service in the apprentice year and 24 hours each additional year, plus continuing education requirements.

Under a ruling of the US Supreme Court, volunteering is a privilege, not a right. A transfer is not guaranteed.

If a transfer is approved, the CMG volunteer should participate in some type of local orientation with staff. Volunteers need to understand that county programs may be vastly different in outreach focus and operational procedures. Procedures will be different than in the previous county and the volunteer will need to shift his/her mind-set to the new county's procedures.

Transfer From Another State to Colorado

Nationally, MG training is not coordinated between states. States do not automatically accept training offered in other states. Each state varies greatly in the amount of training and subject matter covered.

In Colorado, important skills for CMG work include being familiar with local soils, insects and diseases. **Our training content is Colorado-based.** Content even varies to some degree within different areas of the state in order to focus on local needs.

In order to have years of service in the Master Gardener program transfer, a recommendation and verification of years serviced in good standing are required from a previous state/county coordinator.

There are two options for out-of-state Master Gardeners looking to join our program:

1. **Apply to the Colorado program as a transfer:**
   - ✓ If active within the past three years, the individual may APPLY to become a CMG volunteer. Acceptance is based on:
     - Recommendation from state/county coordinator in previous state;
       - Recommendation must include: confirmation MG was active and in good-standing, starting/training year, total years in program and any relevant information concerning leadership positions, contributions, certifications, etc.
     - Interest and availability for volunteer work; and
     - Background check.
   - ✓ CMG volunteers should understand that they may request a transfer, but that there is nothing automatic or guaranteed in the process. Volunteering is a privilege, not a right.
   - ✓ Based on the area of the nation the volunteer is moving from, the county staff will require that the CMG volunteer participate in basic training sessions where content would be different in Colorado. **Attending CMG Training does require paying training fees.**
2. **Apply as an *Apprentice CMG*,** going through the application and acceptance process, basic training and volunteer service.

Serving as a Master Gardener volunteer in two states:

If you live in two states and wish to be a Master Gardener Volunteer in two states you are expected to meet all program requirements in both states. Volunteer hours done in another state do not count towards your Colorado Master Gardener volunteer service.

CHAPTER 4:
Volunteer Resources

VMS - Online Volunteer Management System

The online Volunteer Management System, VMS, is user friendly, intuitive, and has many great features allowing CMG volunteers to:

- ✓ Sign-up for CMG Project
- ✓ Volunteer for CMG Events
- ✓ Sign-up for CMG Continuing Education
- ✓ View program calendars
- ✓ Report/View/Edit hours and contacts
- ✓ Email other CMGs
- ✓ Update directory information
- ✓ Change your login password

All Colorado Master Gardeners are required to report their hours and contacts and the information must be recorded in the VMS system.

Login at: **https://colorado.volunteersystem.org/** You'll use your email address and a temporary password sent by your local county coordinator. Contact your coordinator if you need to get set-up.

This program was developed specifically for Master Gardener programs by the University of California Cooperative Extension, and is used in Colorado under licensed agreement with the University of California.

>> VMS It is not to be used for commercial business or sending spam types of communications. It is for internal CSU Extension business use only. <<

Answering Horticulture Questions

Helpdesk, plant diagnostic clinics and "Ask a Master Gardener" outreach is a core project and "product" offered by most county CMG programs. As you continue in your training, you'll receive ample information about helpdesk policies, processes and support. [see Master Gardener Tools & Resources in this handbook for a 'cheat sheet' of researching options and tools at your fingertips]

On-the-spot plant Q&A can be daunting and overwhelming - even experienced CMGs and agents do not know everything and pouring through resources to find answers can be difficult. Here are a few important tips to seeking research-based information and providing solutions and resources to clients:

- Ask lots of questions to get a better understanding of the problem. Suggestions include: Do you know the plant name? Tell me about where it's planted... Tell me about how you water... etc. Many counties have protocols in place to ensure you get as much useful information as possible.
- Ask the client for pictures and samples if possible.
- Never be afraid to delay a response so you can research appropriate solutions/possibilities. "Thanks for this information. I'll need to research this situation and get back to you."
- Extension Master Gardeners are not expected to know everything! You should utilize the resources available to you and lean on your training, fellow CMGs and county staff.
- Once you've researched possible researched-based solutions, follow-up with the client to provide answers, links and other resources based on the information provided to you.

Learn More About ‘Why Plants Matter’

Hidden Value of Landscapes

Explore the environmental, community and health benefits of landscapes particularly as it relates to water use and drought. This document was created by Colorado State University Horticulture faculty.

https://extension.colostate.edu/docs/pubs/garden/landscapes.pdf

Plant Blindness

Learn more about what 'plant blindness' is and why it matters.

https://www.bbc.com/future/article/20190425-plant-blindness-what-we-lose-with-nature-deficit-disorder

Plants Do That

Read about what wonderful things plants do in "Plants Do That" press releases from the National Initiative of Consumer Horticulture.

https://consumerhort.org/plantsdothat

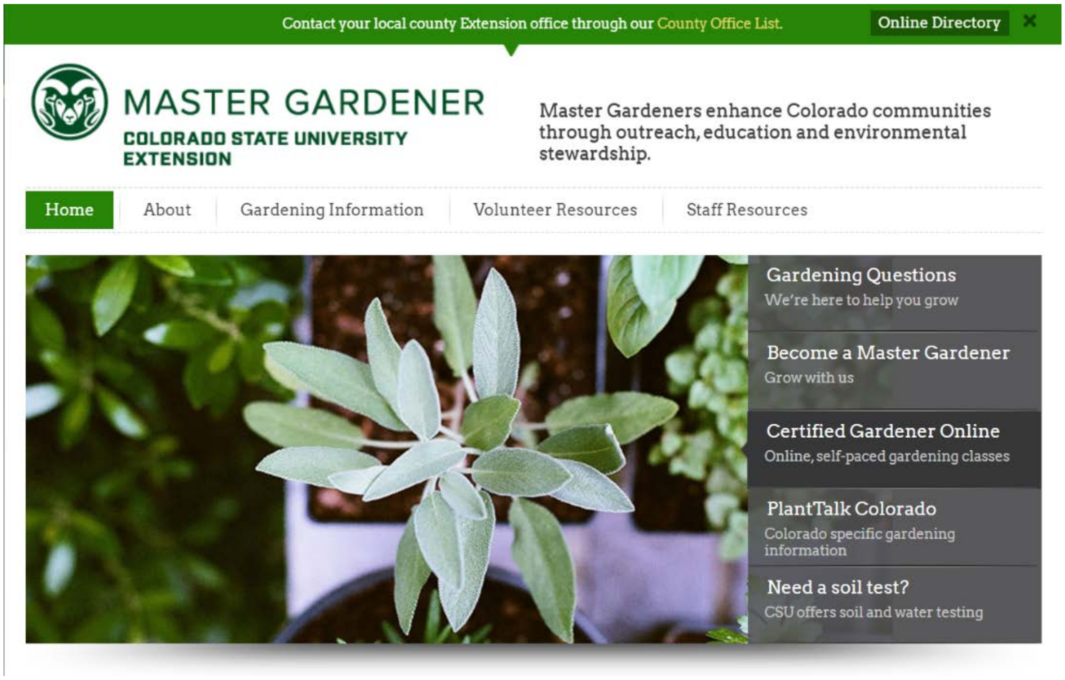
Placemaking

Learn about the art and science of improving communities through strategic greening and community gardening.

https://doitgreen.org/topics/community/placemaking-designing-garden-community

Colorado Master Gardener Statewide Website

Our statewide website is your best tool for connecting with other resources you’ll need as a CMG.



Contact your local county Extension office through our County Office List.

Master Gardeners enhance Colorado communities through outreach, education and environmental stewardship.

http://ColoradoMasterGardener.org

Master Gardener Tools & Links

The following sites/links are resources you'll use often as a CMG. Check them out so you're familiar with them before you start at a Helpdesk or Outreach booth. These are all useful tools as a Colorado Master Gardener.

PlantTalk Colorado http://planttalk.org

PlantTalk is a Colorado-specific horticultural resource site that features simplified information for home gardeners. Be sure to check out the video resources – these are especially useful. More in-depth resources are linked to most topics, including University factsheets. **This is an excellent resource for CMGs to share with clients – very useful for answering helpdesk questions – and provides an excellent first step when researching and providing links to clients.**

CSU's Soil Testing Lab www.soiltestinglab.colostate.edu

CSU offers soil testing for home gardeners and professional growers. Detailed instructions for how to collect and send in samples can be found on their website. These tests have associated costs and do not test for everything. Learn more before recommending to clients.

CMG's GardenNotes https://cmg.extension.colostate.edu/volunteer-information/cmg-gardennotes-class-handouts

GardenNotes is your online text for the CMG training program. It's also an excellent resource for answering client questions in your volunteer role. These are OK to reproduce, link to and copy so feel free to share these valuable resources.

Yard & Garden Factsheets https://extension.colostate.edu/topic-areas/yard-garden

Become familiar with Factsheets – you will use them often as a CMG. Factsheets are University bulletins that cover a specific topic and provide useful solutions, advice, information and resources for common questions.

Online Garden Publications https://cmg.extension.colostate.edu/gardening-resources/online-garden-publications/

This landing page provides a simplified directory of factsheets by topic.

Ask An Expert https://ask.extension.org/groups/1955/ask

Hosted by our national extension partner, eXtension.org (pronounced "e-extension"), this site links anyone with a Colorado question in your county to your local helpdesk and staff. Local county staff will provide training regarding how to respond to these questions. The link above is how the general public will ask questions. *Try it out if you have questions yourself!*

Plant Diagnostic Clinic https://plantclinic.agsci.colostate.edu/

The CSU Plant Diagnostic Clinic offers more in-depth plant pathology assessment. This service does have costs associated with it. Most gardeners will not require this level of testing, but it is available.

Plant Select http://plantselect.org

Plant Select is the country's leading source of plants design to thrive in high plains and intermountain regions; more beauty, less work. This is a collaborative program between Colorado State University and Denver Botanic Gardens and Green Industry growers.

Social Media & Other Communication Tools

Follow horticulture and University social media channels – it's fun and informative.

Instagram:

- Follow @ColoradoMasterGardeners https://www.instagram.com/coloradomastergardeners/
- Follow @JeffCoGardener https://www.instagram.com/jeffcogardener/

Facebook: Like/Follow https://www.facebook.com/extensioncolorado/

Blogs: *Trendy, timely information posted regularly from statewide faculty & staff*

- CSU Horticulture Blog: http://csuhort.blogspot.com/
- CSU Mountain Gardening Blog: http://coloradomountaingardener.blogspot.com/

Important University Resources & Links

Principles of Community - https://diversity.colostate.edu/%20principles-of-community/
Each member of the CSU community has a responsibility to uphold these principles when engaging with one another and acting on behalf of the University.

CSU's Social Media Policy - http://policylibrary.colostate.edu/policy.aspx?id=497
We encourage CMGs to post about our program on their personal social sites, but please don't post AS a CMG unless it's pre-approved by your county program.

CSU's Minors' Policy - http://policylibrary.colostate.edu/policyprint.aspx?id=734
Become familiar with this policy to ensure the protection and considerations necessary when working with vulnerable populations.

Concerned about someone? Tell Someone – http://tellsomeone.colostate.edu
If you are concerned about safety or mental health – your own or someone else's, please tell someone locally in your CSU Extension office or through this site.

CSU's Bias Reporting - https://supportandsafety.colostate.edu/incidents-of-bias
If you experience a bias-related incident at work or witness bias firsthand, please use the CSU Bias Reporting System.

CSU's Office of Equal Opportunity - https://oeo.colostate.edu
Matters of discrimination and harassment based on protected groups must be addressed by the Office of Equal Opportunity. If your concern is about unlawful discrimination or harassment, contact the Office of Equal Opportunity at oeo@colostate.edu or 970-491-5836.

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #015

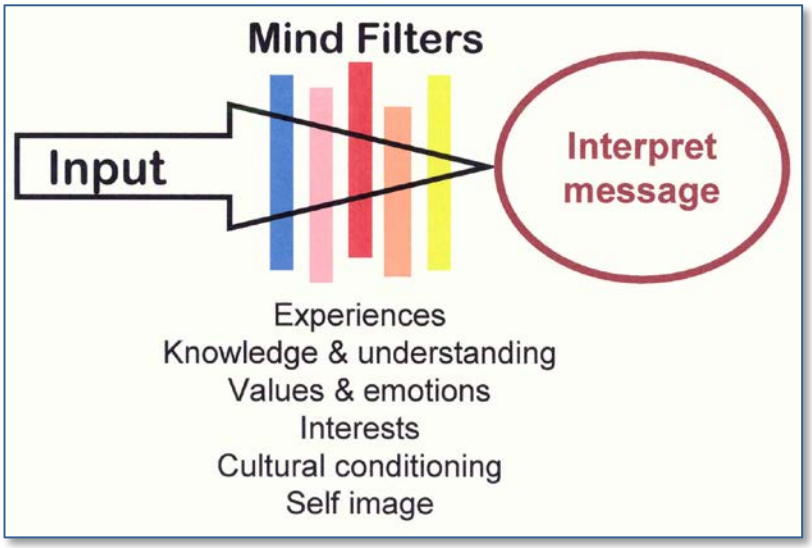
Communications

Outline: Mind filters interpret the message, page 1
Communicating as gardeners, page 2

Mind Filters Interpret the Message

Ninety-three percent of interpersonal communication is nonverbal. In verbal communication, non-word aspects (tone, speed, inflection, emotions) account for the majority of the message.

We hear a message (verbal and nonverbal), but do we understand the intended meaning in the communication? As messages come into our minds, our mind filters of experiences, knowledge and understanding, values and emotions, interests, cultural conditioning, and self-image filter or interpret the messages. Our interpretation may be similar to or totally off-base from the sender's intended meaning.



"Words do not convey meanings; they call them forth. I speak out of the context of my experience and you listen out of the context of yours; and that is why communications is difficult."

David O. McKay, Educator and Prophet

Communication becomes more difficult when it involves messages linked to strong emotions or values. Common examples include discussions on money, religion, politics, love, sex, drugs, and violence. Recognizing when emotions and values (from either party) play into the message helps defuse sensitive issues.

Repeating back, in your own words, what you hear is an effective tool in helping to clarify meaning.

Communicating as Gardeners

In the gardening arena, communication barriers may include emotions and values related to pesticides, organic gardening, xeriscaping, expectations of what a garden should look like, and expectations about the time someone invests in gardening activities.

In diagnosing plant disorders, communication is key. The client will describe the situation based on his/her observations and gardening experiences. The CMG volunteer will interpret based on his/her gardening experiences. Inevitably, there will be some miscommunication!

In CMG volunteer work, we are often called upon to diagnose plant disorders solely through verbal descriptions by the client. As most clients don't know what to look for in the diagnostic process, the description will typically be lacking in detail. Diagnosis may be impossible.

<u>As professionals, we need to recognize that we have very limited potential to diagnose plant disorders over the phone or in a clinical setting</u>. It is natural to add details about the plant's problem based on our experiences, but details added by our mind filters may be totally off base for the specific situation.

In talking with clients about gardening problems, ask lots of questions and do lots of listening. Ask questions to verify every detail raised by your mind filters. Repeating back in your own words what you are hearing often helps to clarify where mind filters are interfering with communication.

Author: David Whiting, Extension Consumer Horticulture Specialist and State CMG Coordinator (retired), Dept. of Horticulture & LA, Colorado State University. Artwork by David Whiting; used by permission.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

Revised October 2017

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #016

Fielding Questions: Tips

Outline:

As a Colorado Master Gardener volunteer, you will have opportunities to answer gardening questions in a wide variety of situation. The following hints will help you be prepared.

Colorado State University Extension

Remember that you are representing Colorado State University Extension in your county or area.

a. Identify yourself as a Colorado State University Extension Master Gardener volunteer, as a Colorado Master Gardener, or in a similar form that your county coordinator/agent directs.
b. We empower Coloradoans to make decisions using research- based information.
c. We give clients research-based information only.
d. Treat clients in the manner you would like to be treated – courteously and professionally.
e. The role of CSU Extension and the Colorado Master Gardener program is education, not regulation.

About Questions

a. There are no dumb questions; treat each question seriously.
b. Questions are not context free. There is always a situation behind the question. Ask for specifics so you can answer the question well.
c. The first question asked may not reflect the real concern. You may have to “dig deeper.”
d. We empower clients to make choices, not make the choice for them.
e. Many questions don’t have an answer because:
    - We don’t have enough information
    - Some topics don’t have a research base for information
    - They may relate to personal values or expectations

What Callers Want

- To get information.
- To verify their own understanding or diagnosis.
- You to agree with them. Stand firm on research-based information and recommendations.
- To justify emotional decisions with facts.
- To vent.
- To have you listen to them.
- Services beyond the scope of the program. Review with them what the program is for – education – and refer to businesses or agencies that may provide the services requested. When in doubt, check with your coordinator/agent

Your Information Sources

Look up information in Extension materials such as CMG GardenNotes, PlantTalk scripts and CSU Extension fact sheets and publications. When using the internet, always look for educational resources (use site:.edu in your search engine).

Read directly from the research-based information and cite references used.

Questions About Pesticides

Our role is to help clients understand non-chemical and chemical options related to pest management issues. All information related to the use of any pesticide must come from Extension resources. Any pest management questions beyond the scope of the fact sheet should be referred to your county coordinator or agent.

For information about pesticide *toxicity*, refer the client directly to the **National Pesticide Information Network**, http://npic.orst.edu which is sponsored by the EPA and Oregon State University. Colorado Master Gardeners do not discuss pesticide toxicity with clients.

Diagnosing Problems

See GardenNotes #102 for more details on Diagnosing Plant Problems

a. Ask questions to help you visualize the situation or problem. For example:

- "I'm trying to picture your situation in my mind. Let me see if I understand what you're saying" (repeat back in your own words)

b. As you diagnose a problem, be flexible about receiving additional information. As details unfold, you may find you are headed in the wrong direction. In this situation you could say:

- "With that piece of information, the situation just changed. Let's back up and look at this again…."

c. Usually there is inadequate information to confirm a diagnosis. The best we can do is to suggest some possibilities.

- “Based on the information you provided, the problem could be…”

d. When possible, work as a team. Multiple minds, with different points of view, often are the best way to work through complex problems.

Taking Phone Calls

Don’t worry if you don’t know the answer to a question. You’re not alone! In the Colorado Master Gardener program, we don’t expect you to know everything; we expect you to be able to *find* the answers.

- When you don’t know the answer to the question or can’t find it quickly, tell the client “I don’t have that information right now” or “I’m not finding the answer quickly. May I have your name and phone number or email so I can get back to you?”

- If you can’t find the information promised to a client by the appointed time, contact the client anyway to let them know you are working on it and haven’t forgotten about them. This is just good customer service.

- Be an active listener and an active questioner.

- Smile when you talk as you will sound friendlier. You can “hear” a smile over the phone!

- Ask for help from your coordinator, agent or another Colorado Master Gardener.

- Avoid shaming statements that put people down or place blame like “you can’t do that!”

Your confidence will grow with experience and time.

Author: David Whiting, Extension Consumer Horticulture Specialist and State CMG Coordinator (retired), Dept. of Horticulture & LA, Colorado State University. Revised by Mary Small, State CMG Coordinator.

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CMG GardenNotes #017

Listening Habits Evaluation

Read each question. Do not try to second-guess the intent. Answer with a yes or a no, according to your usual behavior. Your answers may help you discover where you have good listening habits.

1. Science says that you think four times faster than a person usually talks to you. Do you use this time to turn your thoughts elsewhere while you're keeping general track of a conversation?

   Yes   No

2. If you feel it would take too much time and effort to understand something, do you go out of your way to avoid hearing about it?

   Yes   No

3. If you want to remember what someone is saying, do you think it is a good idea to write it down?

   Yes   No

4. Do your thoughts turn to other subjects when you believe a speaker will have nothing interesting to say?

   Yes   No

5. Can you tell by people's appearance and delivery that they are not worth listening to?

   Yes   No

someone says, do you try to get the question straightened out immediately, either in your own mind or by interrupting the speaker?

Yes   No

7. Do certain words, phrases or ideas so prejudice you against the speaker that you cannot listen objectively to what is being said?

   Yes   No

8. Do you start formulating your response before you hear all of the facts or ideas?

   Yes   No

9. When people are talking to you, do you try to make them think you are paying attention when you are not?

   Yes   No

10. When you are listening, are you easily distracted by sights and sounds?

    Yes   No

Evaluation

Each “no” answer indicates good listening habits. Each “yes” reflects an area where some attention may improve your communication skills.

1. Skip and jump listening

Most people talk at the rate of 125 words per minute. Most of us think at least four times faster than this. With concentration and practice, we can listen and understand as many as 400 words per minute. Since we think so much faster than people speak, our mind tends to wander to other things.

A good listener avoids mental wandering and concentrates on the speaker. Paying attention to voice changes, facial expressions and gestures will also help increase your ability to concentrate on what is being said. You can develop better thought patterns by asking yourself questions such as, "What is the person trying to say?" or "What point is the person trying to make?" Weigh facts and evidence given by a speaker by raising such mental questions as, “Are the facts accurate, prejudicial and complete?” or “Is the source reliable?”

2. Skip–the-difficult listening

To quit listening if a subject is difficult to understand can become a habit. You could cheat yourself by "tuning out" things you might really want to know.

Make a point to concentrate on topics that require effort to follow. It will help if you ask the person a question that will help clarify a point or help you understand a main idea. If you can't interrupt, make a note to ask the questions later.

3. Pencil-and-paper listening

When we concentrate on taking notes we can only hear half of what is being said. Write down just enough to let you recall those ideas.

Develop the habit of listening for ideas. Keep in mind that the more senses – sight, hearing, taste, smell, touch – are involved, the more effective communication becomes.

4. Premature dismissal

Be cautious about developing the habit of deciding in advance that a subject is not important. We can close our minds to whatever the speaker has to offer. An open approach will help correct this habit. Listen for ideas.

5. Deceived by appearance or personal habits

Just because a person may not look like your image of an authority does not mean they aren't. Some of our greatest scientists, artists, and musicians have not been impressive in either appearance or manner. If you must be mentally critical, wait for the person to speak. You will find that by concentrating on what is being said you will no longer be aware of the person's appearance. Listen for ideas... then be critical.

6. Supersensitive or argumentative listening

If you have firm convictions or prejudices, a person presenting a different opinion may unwittingly step on your mental toes. When this happens, you unconsciously stop listening and start developing arguments to defend your position. In the meantime, you may have completely missed the main points of the other person's comments.

A good practice is to learn to control your emotional reaction. Hear the person out. Evaluate objectively the facts and opinions presented. Try to figure out why the person is saying what he/she says.

7. Emotional deaf spots

Certain words can push our buttons, making us see red. They trigger emotional reactions, and we pull down a mental filter tuning the speaker out. We start thinking of unpleasant memories brought up by the use of one of these words or phrases. While recovering from this emotional reaction, you may miss important data the other person is trying to give.

List those words and phrases that cause you trouble. Analyze them to find out why they bother you. Recognizing your response, listing the words, becoming aware of your sensitivity, and learning to be objective will help you control your emotional reactions.

8. "I get the facts" listening

A speaker is presenting a series of facts. While you are trying to concentrate on fact one and memorize it, the speaker may already be discussing fact two or three. After several facts you wind up with a few memorized, others garbled and some missed completely.

Instead, listen for ideas. Weigh one fact against another. Look for relationships between facts as a person is speaking, and you will find that she may be using several facts to develop one or two main ideas. You will be listening at the "thinking level."

9. Pretending attention habit

Many of us learned at an early age how to pretend to be listening. We frequently do this when the subject is difficult to comprehend, or the speaker is a person we do not recognize as an authority. Or we may have something else on our mind.

10. Yielding to distractions habit

It takes conscious effort to screen out distractions whether they are audible, visual or physical. Eliminate as many distractions as possible. If you cannot eliminate a distraction, fight it by concentrating on ideas presented by the person talking to you.

Source: ***How Do You Listen***, Ohio Extension Service

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

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CMG GardenNotes #018

Using Copyrighted Materials
Are You Legal?

Self-Test
Quickly answer the following questions on legal copying of materials.

1. If there is no copyright statement on the material, is it OK to make copies as needed?

   Yes No

2. A garden book has a list of shade-tolerant flowers that would be useful as a handout for general distribution. May you legally make copies as handouts for general distribution?

   Yes No

3. Who owns the copyright on materials you produce as part of your Colorado Master Gardener service?

   You CSU

4. A client wants a copy of the page in a book you used for reference.

   A. May you legally make a copy of this page for a client?

   Qualified Yes No

   B. May you legally make copies of this page as a handout for general distribution?

   Qualified Yes No

5. In this month's magazine, you find an article that would make a great handout in class next week.

   A. May you legally make copies for all class participants?

   Qualified Yes No

   B. May you legally make copies next year when you teach the class again?

   Qualified Yes No

6. You find a great article on the Web for your program.

   A. May you legally print a copy for your own scholarly reference?

   Qualified Yes No

   B. May you legally make multiple copies for class handouts?

   Qualified Yes No

   C. May you legally download a copy onto your Web site?

   Qualified Yes No

Background and Answers to Test

The following information is not intended as legal counsel. It is provided only to create awareness of copyright issues commonly encountered in Extension programs.

Copyright

Copyright is legal protection giving authors and other artistic creators exclusive rights to reproduce copies, make derivative works, use materials in other works, transfer format (such as from tape to CD), enlarge or reduce size, distribute, perform publicly, and display publicly.

Examples of copyrighted materials

- Print materials
- WWW materials
- Computer programs
- Pictorial works
- Graphic works
- Musical works
- Dramatic works
- Sculptural works
- Motion picture and video works
- Sound recordings
- Architectural works

What is not covered by copyright protection?

- Titles (covered under trademark or service mark registration)
- Ideas (but rather “tangible expression” of the idea)
- Common knowledge (but rather the “tangible expression” of the knowledge)
- Lists and bibliographies (but rather the “tangible expression” of the knowledge)
- Blank forms (but rather the “tangible expression” of the form)
- List of ingredients (But rather what you do with the ingredients)
- Some federal government documents

Duration of copyright

- After 1978
    - Life of author + 50 years
    - “Works for hire” – shorter of 75 years from first publication or 100 years from first creation
- Before 1978 – 28 years, renewable for 47 years

Digital Millennium Copyright Act (DMCA) of 1998, from the U.S. Copyright Office, is legislation that implements two 1996 World Intellectual Property Organization (WIPO) treaties: the WIPO Copyright Treaty and the WIPO Performances and Phonograms Treaty. The DMCA also addresses a number of other significant copyright-related issues

Question 1.

If there is no copyright statement on the material, is it OK to make copies as needed? **NO**

- Copyright registration is no longer mandatory for works published after May 1, 1989.
- Registration (filling out a copyright application and paying a fee) only enhances the copyright holder's ability to collect damages.
- **Basically anything in a fixed, tangible form is automatically protected by copyright.**

Question 2.

A garden book has a list of shade-tolerant flowers that would be useful for a handout. May you legally make copies for a handout for general distribution? **NO**

- While the "list" is not covered by copyright, the "tangible expression of the knowledge" is covered.

Copyright Ownership

- The employer owns the copyright for any work done by employees as part the work assignment and responsibilities, unless other arrangements are made in writing in advance.
- Specially ordered or commissioned works depend on contractual agreement.
- Unpublished materials – The writer, not the owner of the materials, owns the copyright.
- Computer software – The purchaser "buys" a license to use software only as outlined in the agreement.
- Pictures – The person who takes the picture , not the person who owns the picture, owns the copyright.
- Videotaping –
    - The presenter holds rights on the presentation.
    - The video taper holds rights on the taped version.
- Music – Writers (words and music) and performers (vocal and instrumental) all have copyrights on what they contributed.

Question 3.

Who owns the copyright on materials you produce as part of your Colorado Master Gardener work? **Colorado State University**

- Unless other arrangements were made in writing, in advance, Colorado State University Extension owns the copyright of materials you produce as part of your Colorado Master Gardener service.

Fair Use Doctrine

"Fair use" doctrine defines the privileges of others to use materials in a reasonable manner without consent for "purposes such as criticism, comment, news reporting, teaching, scholarship or research.

- Criteria for "fair use" include:

1. Use must be nonprofit, educational in nature.
2. Nature of work – "Fair use" extends further in factual works, and is very limited in fictional works or artistic creations.
3. Amount vs. total work – The laws get into word counts and percentages. Basically, the use must not convey the nuts and bolts of the work.
4. Potential on market – The bottom line is how the use impacts potential sales of the product. Use must not circumvent sales in any way.

Criteria for single copy – Under "fair use" doctrine, for "scholarly review," a single copy may be made of

- a chapter from a book
- an article from a periodical
- a short story, essay or poem
- a chart, graphic form from a book, periodical or newspaper

Criteria for multiple copies, classroom distribution – Under "fair use" doctrine, the making of multiple copies is extremely limited, and must meet all five5 tests:

1. "Spontaneity" –
    - Used within 60 days, thus the instructor doesn't have reasonable time to seek copyright permission.
    - Used with "instance and inspiration of the teacher."
    - Note: In Cooperative Extension work, it is uncommon that copies will pass this "spontaneity" test, since we typically use and reuse materials that have been in print for more than 60 days.
2. "Cumulative effect" – supportive to the educational process, but not the focus of the class.
3. Brevity – Keep it short, never more than 10% of the work.
4. Profit – Distributed without profit (may recover printing costs).
5. Copyright notice must be included on all copies.

Student use

- Students have "fair use" for classroom projects.
- But if the project goes beyond the learning classroom, copyright permission is needed. The scope of "fair use" is broader for factual works than fictional and creative works.

Misconceptions – Contrary to popular opinion, the following situations do NOT make copying "OK":

- Educational
- Nonprofit
- Volunteers
- Church
- Out of print
- As a means of bypassing fees or purchase price

Common violations of “fair use” include:

- Copying consumable works (unless the copyright statement gives permission)
- Copying without including the copyright notice
- Copying more than one work from a single author per class and/or per project
- Copying the same item each time a class is taught (spontaneity test)
- Creating course packets
- Copying as a substitute for purchase
- Copying on direction of the “boss”

Question 4.
A client wants a copy of the page in a book you used for reference.

A. May you legally make a copy of this page for a client? **Qualified YES**

- “Fair use” criteria permits a single copy for scholarly review of the page. Remember that it must also include the copyright statement from the book (see single copy criteria above).

B. May you legally make multiple copies of this page for a handout for general distribution? **NO**

- Making multiple copies for distribution does not meet criteria for “fair use.” You must seek permission of the copyright holder.

Question 5.

- In this month’s magazine, you find an article that would make a great handout in class next week.

A. May you legally make copies for all class participants? **Qualified YES**,

- This would meet “spontaneity” criteria for multiple copies.

B. May you legally make copies next year when you teach the class again? **NO**

- You must seek the copyright holder’s permission. Next year (actually after 60 days) it doesn’t meet “spontaneity” criteria.

Question 6.

You find a great article on the Internet for your program.

A. May you legally print a copy for your own scholarly reference? **Qualified YES**

- Meets single copy criteria for “fair use.”

B. May you legally make multiple copies as a class handout? **NO**

- Doesn’t meet “fair use” criteria for multiple copy distribution

C. May you legally download a copy onto your Web site? **NO**

- Downloading it onto your website will be clear violation of copyright law unless you have permission of the copyright holder. However, you may link from your website to their website.
- Contrary to popular belief, Internet materials are NOT free for the taking. All information found on the Internet is protected, just as any other print material. It's just easier to violate copyright in the electronic media.

Resources:

- The Digital Millennium Copyright Act of 1998
  - www.copyright.gov/legislation/dmca.pdf
  - www.gpo.gov/fdsys/pkg/PLAW-105publ304/pdf/PLAW-105publ304.pdf
- Using the Name or Likeness of Another
  - www.dmlp.org/legal-guide/using-name-or-likeness-another
- A document designed to collect resources and ideas for participants in the workshop "Opening Doors for Multimodal Composers: Intellectual Property and Fair Use in the Classroom" at CCCC 2014 in Indianapolis.
  - http://tinyurl.com/ipworkshop2014
    - http://web.law.duke.edu/cspd/comics
    - http://creativecommons.org/licenses/by-nc-sa/2.5/

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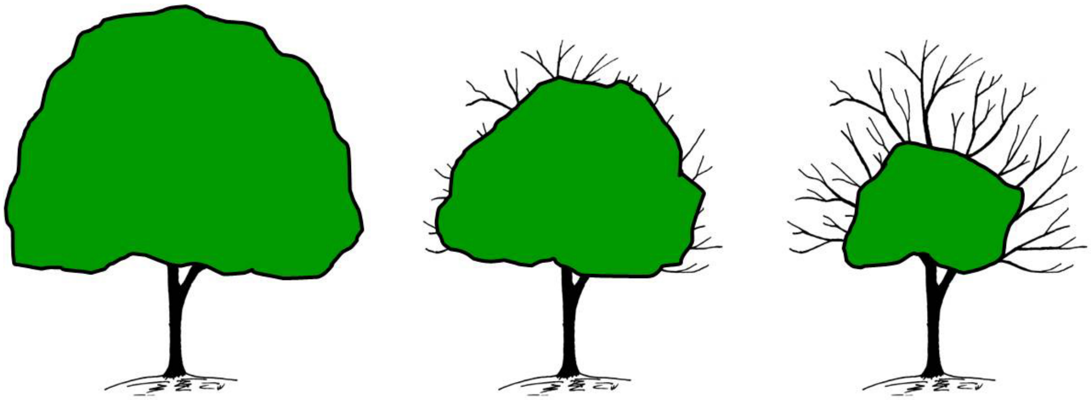

Integrated Pest Management and The Diagnostic Process

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PHC and Diagnosing Plant Disorders curriculum developed by David Whiting (CSU Extension, retired) and Carol O'Meara (Colorado State University Extension). Revised by Mary Small, CSU Extension

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- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

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Class Objectives

CMG volunteers approach diagnostic situations as a process. At the end of class, the student will be able to:

- Describe concepts of *Plant Health Care, PHC*, (IPM as it applies to landscape management)
- Outline the life cycle of trees and describe how tree needs changes with stages in the life cycle
- List steps in the diagnostic process
- Using the diagnostic process, diagnose routine insect and disease problems of trees

Review Questions

Plant Health Care and the Diagnostic Process

1. Define IPM and PHC.

2. Describe concepts central to PHC.

3. Give examples of common PHC tools used in home gardening.

4. What is the PIC cycle? What does it explain about tree care and pest problems?

5. In diagnosing *contributing* disorders, why is it important to also identify the *predisposing* and *inciting* factors to the extent possible?

6. List the four steps, with substeps in the diagnostic process.

7. Give examples of living factors that cause plant problems. Give examples of non-living (abiotic) factors that cause plant problems.

8. Why is it important to correctly identify the plant?

9. Define *symptom* and *sign*. Give examples of each.

10. Define the following terms:

    a. Chlorosis
    b. Blight
    c. Dieback
    d. Decline
    f. Leaf spot
    g. Leaf scorch
    h. Canker
    i. Gall
    j. Fruiting bodies
    k. Mycelium
    l. Slime flux

11. Explain why it is important to define what is normal versus abnormal about a plant problem.

12. List the five growth phases, giving growth objectives for each. What indicates that trees have changed their phase?

13. Why is it important to talk about tree care issues as they relate to growth phases?

14. If the average length of annual growth of twigs changes from 8 inches (4 years ago), 1 inch (3 years), 2 inches (2 years) and 1 inch (1 year), what does it suggest about the tree's vigor? What if the growth changes from 6 inches (4 years) 1 inch (3 years), 2 inches (2 years) and 3 inches (1 year)?

Diagnosing Tree Disorders class

1. Describe essential skills used in the diagnostic process.

2. Explain how knowing the context of the situation helps in diagnosing the disorder.

3. Explain how painting a mental picture of a plant problem helps in diagnosing a disorder.

4. Explain how repeating back the details in your own words helps in diagnosing a disorder.

5. Explain how to tactfully change directions when the evidence leads down another road.

6. Why is it important to discuss management options only after the problems have been diagnosed?

7. List the four steps, with substeps in the diagnostic process.

8. List steps for systematically evaluating a tree.

9. In the landscape setting, what is the universal limiting factor for root growth?

10. What percentage of landscape plant problems relate to root/soil/water (underground) issues?

11. Describe the typical rooting system of a tree. Describe location and function of the following root types:

    - Root plate or zone of rapid taper
    - Transport roots
    - Feeder roots
    - Sinker roots
    - Tap root

12. What two factors play into the rooting depth and spread?

13. What is the typical depth and spread of tree roots? How does this change for compacted/clayey soils?

14. Explain how to calculate the *Critical Rooting Radius* and *Tree Protection Zone (Protected Root Zone).*

15. Describe how potential rooting spread impacts tree growth and vigor. What happens when a tree's root system cannot spread as needed?

16. Describe techniques to evaluate soil/root disorders and soil compaction.

17. Describe worthwhile techniques to reduce soil compaction around trees. Explain why questionable techniques to reduce soil compaction are out of favor.

18. What single factor accounts for the most deaths of landscape trees? What causes trunk-girding roots? How long after planting can trunk-girdling root develop? What can be done for a tree with trunk girdling roots?

19. Describe how a tree balances root growth with canopy growth.

20. In pest management, what are *bionaturals*? What is *preservation* and *importation* of bionataurals? Why don't we import more bionaturals?

21. List the PHC questions for using pesticides.

22. Based on actual records from landscape management, what percentage of pest problems warrant the use of a pesticide?

CMG GardenNotes #101

IPM and Plant Health Care

Gardening and the Environment

Yard care and gardening practices may have positive or negative influences on health and the neighborhood environment. For example, turf enhances the environment by:

- Converting carbon dioxide to oxygen.
- Increasing water infiltration into the soil.
- Reducing surface runoff and erosion.
- Reducing dust.
- Providing a micro-ecosystem that effectively breaks down pollutants.
- Moderating summer temperatures.
- Creating a pleasant “people” space.

On the other hand, lawn care practices negatively affect the environment when grass clippings are mowed or blown onto the street (water quality problem), when fertilizers are over-spread onto hard surfaces, and when the unwarranted use of pesticides occurs.

Several terms (such as *Integrated Pest Management*, *Plant Health Care*, *Sustainable Farming/Gardening*, *Best Management Practices* and *Organic Gardening*) are used to describe farming/garden management systems designed to help farmers/gardeners maximize positive effects and minimize negative effects. In this class, we will focus on *Integrated Pest Management* with *Plant Health Care* mixed in.

Integrated Pest Management, IPM

Integrated Pest Management, IPM, is a multi-prong approach to pest management. IPM incorporates a variety of management strategies including cultural, mechanical, biological and chemical methods. Objectives include minimizing pest damage and health and environmental hazards while maintaining profitability and/or aesthetics.

Because insect and disease problems vary significantly from crop to crop, application of IPM principles is also often crop specific. IPM techniques used in an alfalfa field (perennial crop), a wheat field (annual crop), an apple orchard (perennial crop with minimal tolerance for pest damage) and the landscape (site with multiple plant species and higher tolerance to pests) will be vastly different.

IPM Strategies

Plant Health Care, PHC

The term ***Plant Health Care, PHC***, was coined by the *International Society of Arboriculture* to define IPM techniques as they apply to tree care and landscape maintenance. You will often find the two terms (IPM and PHC) used interchangeably.

PHC, like IPM, is a holistic approach, but specifically to tree and landscape management. The primary objective is to grow healthy plants and minimize the effects of pests in so doing. Concepts of PHC include the following:

- **Healthy plants have fewer pests.** – Many insect and disease problems only attack stressed plants. Minimizing stress prevents many common pests. For example, Cytospora canker fungus and most borers only attack stressed trees (from factors such as soil compaction, drought, root damage and drought).

- **Healthy plants are more tolerant of pests.** – For example, aphids on shade trees generally do not warrant management efforts. An important exception is that trees that are water stressed (dry soils, non-established root systems, limited root spread, etc.) are intolerant of aphid feeding.

- **Life cycle: Plant needs change with stages in their life cycle.** – A plant’s needs for irrigation, fertilizer, pruning, tolerance to pests, etc. continually change through the growth cycles of the plant.

- **PIC cycle: Problems arise from a combination of stress factors.** – For example, over-maturity of forests coupled with drought leads to bark beetles in Western pine forests. Soil compaction, drought and restricted rooting can lead to Cytospora canker disease.

The PIC Cycle

A basic principle of PHC is recognition that plant problems generally arise from a combination of stress factors. This concept is called the ***PIC cycle.***

Predisposing factors reduce a plant's tolerance to stress. These factors should be considered in plant selection. Examples of predisposing factors include:

- Planting trees in a site where root spread will be restricted due to soil compaction or hardscape features.
- Planting trees intolerant of wet soils (like crabapples) in heavily irrigated lawns (leads to root rots).
- Planting trees susceptible to iron chlorosis in soils with *free lime*.
- Failure to structurally train young trees (predisposing trees to storm damage).

Inciting factors include primary insect, disease, and abiotic disorders that attack healthy plants, causing acute stress. Examples include:

- Soil compaction, the most common stress factor leading to many insect and disease problems.
- Planting trees too deep (leads to trunk girdling roots).
- Drought.
- Leaf chewing insects, such as caterpillars and sawfly larva.
- Leaf sucking insects, such as aphids and leafhoppers.
- Bark damage from lawn mowers.
- Bark cankers and frost cracks from rapid winter temperature changes coupled with winter drought.

Contributing factors include secondary insect, disease, and abiotic disorders that attack plants already stressed. They often lead to the plant's death and frequently cannot be controlled. Examples include:

- Bark beetles and borers (secondary to soil compaction, drought, and wind damage).
- Cytospora fungus (secondary to soil compaction, drought, and restricted rooting system).
- Trunk girdling roots caused by planting too deep.

Management of contributing factors typically needs to be directed at the predisposing and inciting factors that stress the plant.

IPM Techniques

Examples of techniques used include the following:

- **Plant selection: *right plant, right place* –** Select plants to minimize future stress issues for the site.

- **Soils management –** Many landscape plant problems relate to soil conditions.

    - Manage soil compaction (low soil oxygen and poor drainage)
    - Manage soil drainage
    - Improve soil tilth with routine applications of organic matter
    - Nutrient (fertilizer) management

- **Water and irrigation management**

    - Water plants appropriately - the water requirement for plants to survive compared to the water needed for plant growth may be vastly different.
    - Use plant tolerance to wet or dry conditions in water management
    - Chronic, springtime overwatering often causes or contributes to the development of iron chlorosis symptoms.

- **Cultural care**

    - Plant at appropriate time
    - Use varieties with resistance to common pests
    - Use a diversity of plants
    - Plant appropriately for good spacing and air flow
    - Consider plant's potential exposure to sun and wind
    - Use mulch
    - Prune appropriately

- **Weather influence on plant growth and pest potential**

    - Consider both high and low temperatures
    - Consider wind and rain effects
    - Consider timing of insect activity

- **Mechanical methods to manage pests**

    - Covers and barriers
    - Traps

- **Bionaturals for managing pests –** Use of predators, parasites, disease organisms, and beneficial nematodes

    - ***Preservation*** is taking steps to encourage naturally occurring predators and parasites.
    - ***Importation*** is the purchase and release of predators and parasites

- **Pesticides –** if selected, use the appropriate pesticide to manage the problem at the correct rate and at the correct time of year.

Pest Management Questions

As part of IPM/PHC, ask the following questions to guide pest management:

1. **What is the plant?** Correctly identifying the plant will shorten the list of potential insects, diseases, and abiotic disorders.

2. **What is the disorder/pest?** Correctly identifying the disorder/pest will guide effective management options. Gardeners often fail to control pests because they have misidentified the problems and are applying ineffective management techniques.

3. **What type of damage/stress does it cause?** In the landscape setting, most insect and disease problems are only cosmetic and may not warrant management efforts. To protect plant health, management may be needed on some pests. Fruits and vegetables typically have low tolerance to insects and diseases.

4. **Under what situations will management efforts be warranted?**

   In production agriculture, ***economic thresholds*** determine how much damage can be tolerated before it becomes economically feasible to treat. For example, this may be determined by counting the number of insects per leaf, the number of insects in a square foot of soil, or the percent of leaves infected.

   In landscape horticulture, ***aesthetic thresholds*** characterize a relative level of cosmetic damage that can be tolerated before treatment is warranted. This threshold will vary considerably from individual to individual and from location to location.

   Spider mites are an example of a common pest generally kept in bounds by nature. However management efforts may be warranted in situations where mite populations flare up due to hot weather, drought, dust on plants (interferes with activity of beneficials) or the use of some insecticides including imidacloprid (Merit) and carbaryl (Sevin).

5. **What management options are effective on the disorder/pest and when are they applied?**

   - Weather – While we cannot control the weather, it directly influences the occurrence of many insects and diseases
   - Cultural – Such as watering more or less

- Mechanical – Such as washing down the plant with a forceful stream of water to wash off pests
- Bionaturals – Use of beneficial predators and parasites
- Pesticides – Many types

Life Cycle of a Plant

A key concept in PHC includes recognizing that plant care changes with various stages of growth. Failure to relate cultural practices to the life cycle often leads to reduced growth and confusion about appropriate cultural practices. Tables 1 and 2 give an overview of the life cycle of trees.

Life cycle of a tree	Life cycle of a vegetable (annuals)
1. Nursery production	1. Seed germination and emergence
2. Establishment phase	2. Seedling growth
3. Growth phase	3. Growth phase
4. Maturity	4. Flowering and fruiting phase
5. Decline phase	

Table 1 – Life Cycle of a Tree

Growth Phase	**Growth Objectives**	**Change to Next Growth Phase**
Nursery production	Top growth = selling price	Planting
Establishment phase	Root establishment	When roots become established, length of annual twig growth significantly increases.
Growth phase	Period of canopy growth – Balance canopy growth with root growth limitations.	Growth slows as tree approaches mature size (for site limitations).
Maturity	Canopy growth slows as tree matures – Balance canopy growth with root growth limitations.	Minimizing stress on aging trees prolongs tree life.
Decline phase	Minimize stress levels.	Death

Table 2 – Influence of Life Cycle on Cultural Practices for Trees

Growth Phase	Irrigation Water Need	Fertilization	Pruning	Pest Tolerance
Nursery production	Water = Growth	Fertilizer pushes desirable top growth.	*Structural training* desirable.	LOW Could influence sales.
Establishment	CRITICAL Trees are under water stress due to the reduced rooting system.	None to very little as high nitrogen forces canopy growth at the expense of root growth.	Heavy pruning slows root establishment.	LOW due to drought imposed by reduced root system.
Growth	Water = Growth Good tolerance to short-term drought. However, short-term drought will slow growth.	IF other growth factors are not limiting, fertilization supports growth.	*Structural training* sets the tree's structural integrity for life.	HIGH, except in stress situations.
Maturity	Good tolerance to short-term drought. Severe drought leads to decline.	Need for fertilizer reduces. Over fertilization could force canopy growth that the roots cannot support in summer heat and wind.	Maturing trees that were structurally trained while young have minimal needs for pruning.	HIGH, except in stress situations.
Decline	Intolerant of drought	Evaluate stress factors as fertilization can accelerate stress in some situations.	Pruning limited to c*leaning* (removal of dead wood). Do not remove healthy wood on stressed trees.	LOW, pests could accelerate decline.

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- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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CMG GardenNotes #102

Diagnosing Plant Disorders

Skills Essential to the Diagnostic Process

Judiciously examine the plant – Many gardeners have a difficult time describing their plants and plant problems. For example, the description “leaves are yellow” is so general that nothing can be diagnosed without more details. A typical home gardener may say they have “black bugs”. What do they mean by “bug”? Are they saying they have a black insect? More details are needed to diagnose the problem.

Read – Part of the diagnostic process is to read, comparing the symptoms and signs of the problems with details in references. Do not simply work from memory.

Referring to multiple books or other refernces on the same topic gives a better understanding of a pests’ description and management situation. In diagnostic work, read for the details.

Ask questions – Diagnosis requires extensive two-way conversations. Often the person trying to diagnose the problem has not been on site and has to totally rely on the descriptions of someone else. In this situation, diagnosis is difficult to impossible. Even with good samples or when visiting the site, questions about the care of the plant, history of the site and progression of symptoms are needed in the diagnostic process.

Practice – Diagnostics is far more than applying knowledge that can be read in a book. The diagnostic process requires the integration of years of gardening wisdom, knowledge and practice.

Patience – Diagnosing plant disorders is a process, not a simple answer to a question. It takes time and patience to work the process. Never jump at an answer just because it seems easy. Don't guess. Take the time to work the process, asking lots of questions.

In pest management, first diagnose the problem and then discuss management options. Because management options are very pest specific, correct diagnosis of the problems must be completed before management can be discussed.

Asking Questions and Gathering Information

Ask questions that create dialogue. For example, *"Tell me how you watered the plant."* Avoid accusatory type questions, (e.g., *"Did you over water the plant?"*)

Some disorders cannot be diagnosed. – We can only complete a diagnosis when detailed information is available. Descriptions, like "yellow leaves" or "poor growth" are inadequate descriptions for a diagnosis.

Diagnosis must be done in the context of the plant's environment. – For example, is a tree in a routinely irrigated lawn or in a site with limited irrigation? Does the site have an open area for root spread or is the root system limited by poor soils or hardscape features?

For example, a client calls with concerns that her tree looks wilted. Should she water more? After asking questions, it is discovered that the tree is located in a construction site and had most of the root system cut. Understanding the context of the root damage is essential to addressing the watering issue.

Questions asked may not reflect the real issues. **-** In the diagnostic process, Colorado Master Gardener volunteers must often help frame questions as well as provide answers. For example, in the previous situation with the tree in the construction site, an important question is the stability of the tree with respect to wind as most of the roots have been cut.

A useful tool in diagnosing trees is visualizing the plant, that is creating a mental picture of it and its surroundings. As you create the picture, ask questions about details. Verify the details. Explain to the client that you are trying to create a mental picture of their plant problem will encourage them to more patiently provide the needed information.

When working with clients, repeat back their description in your own words. This helps clear up miscommunications about symptoms.

When working with clients, verbally explain how you rule out possible causes. This helps the client move on with you and may clarify miscommunication about symptoms.

Diagnosis is not possible when general symptoms are all we have to work with. Keep in mind that multiple problems can have similar symptoms.

Management should only be addressed AFTER the diagnosis is complete. Because disorders generally arise from a combination of factors, management must look at predisposing factors and inciting factors in the discussion. For details on predisposing, inciting and contributing factors (the *PIC Cycle*) refer to CMG GardenNotes #101, ***IPM: Plant Health Care***).

Steps in the Diagnostic Process

Part A: Diagnosis

1. Identify the plant.

2. Identify the problem(s).
    a. LOOK – look at the big picture – the site the affected plant is growing in.
    b. LOOK at the plant itself including leaves, flowers, fruit, twigs, branches and trunk.
    c. LOOK for symptoms and signs.

    d. DEFINE the problem by describing the symptoms and signs.

    d. OBSERVE the turf or soil the plant is growing in. Is it difficult to push a screwdriver into the turf or soil?
    e. ASK questions

    f. READ – Refer to reference materials describing similar signs and symptoms.
    g. COMPARE – Determine probable cause(s) through comparison and elimination.

Part B: Management

3. EVALUATE if management efforts are warranted.
    a. What type of damage/stress does this disorder/pest cause?
    b. Under what situations would management be warranted?
    c. Is management warranted in ***this*** situation?
4. Evaluate management options effective for this disorder/pest and when they are applied.

Step 1 – Identify the Plant

There are hundreds of insects and diseases that attack plants in any geographic region. Once the plant has been correctly identified, the list of potential insects and diseases that attack the specific plant drops to just a few. Additionally, insects and diseases account for only a small percent of landscape plant problems. When working with abiotic disorders, plant identification will be helpful but will not shorten the list of potential possibilities as significantly.

Many gardeners are not familiar with plant materials and need help to correctly identify them. Identification is not practical over the phone. A branch sample with leaves attached should be brought to the Extension office or good photographs should be sent to the diagnostician.(It's really best to see a sample.)

Step 2 – Identify the Problem(s)

Step 2a – LOOK – Define the Problem by Describing the *Signs* and *Symptoms*.

Take a close look at the plant and surroundings. A detailed description of the problem is essential for diagnosis. In situations where the description is limited or symptoms are too general, diagnosis will be impossible. When diagnosing abiotic disorders, systematically evaluating a plant will help organize questions.

> ***Symptoms*** are changes in the plant's growth or appearance in response to causal factors.
> ***Signs*** are the presence of the actual organism or direct evidence of the casual factors.

Time development – Knowing the time frame for the development of signs and symptoms is a helpful tool. Did it occur suddenly or over a period of time? Keep in mind that the gardener may not actually know as he or she may not have observed the early development. Symptoms that occur suddenly and do not progress are typical of abiotic disorders. Symptoms that progressively develop are typical of living factors (insects and diseases).

Keep in mind that **multiple problems have similar symptoms**. Let the symptoms lead you to the diagnosis rather than trying to make a diagnosis fit a group of symptoms.

Terminology used to describe common <u>symptoms</u> includes:

- **Blight** – A rapid discoloration and death of twigs, foliage or flowers.
- **Canker** – Dead area on bark or stem, often sunken and discolored.
- **Chlorosis** – Yellowing.
- **Decline** – Progressive decrease in plant vigor.
- **Dieback** – Progressive death of shoot, branch or root starting at the tip.
- **Gall** or **gall-like** – Abnormal localized swelling or enlargement of plant part. It could be caused by insects, mites, diseases or abiotic disorders.
- **Gummosis** – Exudation of gum or sap.
- **Leaf distortion** – The leaf could be twisted, cupped, rolled or otherwise deformed.
- **Leaf scorch** – Browning along the leaf margin and into the leaf from the margin.
- **Leaf spot** – A spot or lesion on the leaf.
- **Necrosis** – Dead tissue – additional details are needed.
- **Wilt** – General wilting of the plant or plant part.
- **Witches broom** – Abnormal broom-like growth of many weak shoots.

Terminology used to describe <u>signs</u> includes:

- **Fruiting bodies** – Reproductive structures of fungi; could be in the form of mushrooms, puffballs, pycnidia, rusts or conks.
- **Insects** and **mites**

- **Mycelium** – A mass of fungal threads (hyphae) on the plant surface.
- **Rhizomorphs** – Shoestring-like fungal threads found under the bark of stressed and dying trees caused by the *Armillaria* fungi. They may glow!
- **Slime flux** or **ooze** – A bacterial discharge that oozes out of the plant tissues, may be gooey or a dried mass.

Examples of abiotic (non-living) signs includes the following:

- Girdling roots (caused by planting too deep), leads to root starvation.
- Lack of a root flare (sign that the tree was planted too deep with a high potential to develop girdling roots).
- Bark damage on a trunk from lawn mowers and weed eaters.
- Standing water over rooting zone.
- Plugged drip irrigation system emitters.
- Record of spring time freezing temperatures or severe winter temperatures.
- Hardscape over tree rooting area.
- Soil tests indicating high soil salts.

Define What Is Normal Versus Abnormal

It is common for the home gardener to suddenly observe normal characteristics of a tree and mistakenly attribute it to an insect or disease. For example, on evergreens:

- Needle problems and dieback of the new needles at the branch tip are abnormal.
- Yellowing and dropping of older needles from the inside of the tree are normal in the fall. The number of years that needles are retained is a factor of plant genetics and stress. Under stressful conditions, needles may drop sooner.

Other examples of "normal" occurrences often confused as problems include:

- Fuzz on underside of leaves.
- Male pollen cones on pine or spruce mistaken for insects or disease.
- Less conspicuous fruit, such as juniper berries.
- Mushrooms.
- Bluegrass going to seed.
- Spores on the underside of fern fronds.
- Flowers and fruit on potatoes (potato fruit look like cherry tomatoes).
- Tomatoes dropping blossoms after a cool night.
- Male squash blossoms not producing fruit.
- June drop of apples and other fruit.
- Aerial roots on tomatoes and corn
- Seed stalk on rhubarb and onions.

Step 2b – READ – Refer to Reference Materials Describing Similar Signs and Symptoms.

The reading will often send you back to the plant to look for more details.

A key in the back of the CSU Extension publication ***Insects and Diseases of Woody Plants*** makes this step easier for diagnosing insects and diseases of landscape trees and shrubs. Many common abiotic problems are also included.

Step 2c – COMPARE – Determine Probable Cause(s) Through Comparison and Elimination.

When the description of the disorder matches the details in the reference materials, diagnosis is complete. It requires careful reading of fine details. When things do not match up, back up. Is the plant correctly identified? Work through the process again paying attention to details missed.

Let the process guide you through the diagnosis rather than trying to match symptoms to fit a diagnosis.

Abiotic disorders are generally difficult to diagnose. A systematic evaluation of a plant will be helpful in diagnosing abiotic disorders. Abiotic disorders occur in about 80% of the samples diagnosed by CSU Extension and often predispose the plant to insects and diseases.

Step 3 – Evaluate If Management Efforts Are Warranted

Step 3a – What Type of Damage/Stress Does This Disorder/Pest Cause?

The primary question here is to determine if the disorder/pest is only cosmetic, if it adds stress to a plant or if it is potentially life threatening. This may depend, in part, on the overall health of the plant before the disorder/pest started.

Step 3b – Under What Situations Would Management Efforts be Warranted?

Many insect and disease problems are only cosmetic on healthy, stress- free plants. However, stressed plants are much less tolerant.

For example, aphids feeding on shade trees are generally only cosmetic and normally do not warrant management efforts unless they become a nuisance (like dripping honeydew on a car or patio table). However, under water stress, aphid feeding increases the water needs of the tree creating a potentially serious stress issue. In this situation, mechanical (hosing off the tree with water), bionaturals (adding beneficials to feed on the aphids) or insecticidal management efforts would be warranted to protect the tree.

As a rule-of-thumb for leaf chewing insects, healthy trees can tolerate the loss of 1/3 of the total leaving surface before stress becomes a management issue. Tolerance is much less for trees with growth limiting factors.

Evergreens are much less tolerant because the needles last for multiple years. For example, a sawfly larva outbreak that removes all the new needles would have an influence over multiple years; this would bring a healthy tree to a threshold where management would be warranted.

Step 3c – Are Management Efforts Warranted For This Situation?

The bottom line in Step 3 is to determine if management efforts are ***warranted for this situation***. The answer needs to be focused on the ***specifics of this situation.***

Step 4 – Evaluate Effective Management Options for This Disorder/Pest.

Management options may take many forms or directions. For example, hosing off a plant with a strong force of water may be an effective mechanical option for some insect pests. In other situations an insecticide may be needed.

Management efforts may take the approach of dealing with soil issues, such as lawn aeration to reduce soil compaction around a tree.

Other management efforts may go in the direction of irrigating a dry site during hot dry weather or reducing over-watering with better irrigation system design and management.

Management options include far more than just spraying an insecticide. Only four percent of the insect problems on landscape trees warrant insecticides.

Timing of management efforts is another important consideration. Often the effective spray window is past before the pest is observed.

Pesticide Use Questions

When pesticides are a management option, answer these important questions to guide pesticide application.

1. What pesticides are effective on this pest? (Refer to Extension fact sheets.)
2. Which have minimal health risks? (Refer to the pesticide label.)
3. Which have minimal environmental risks for the site? (Refer to the pesticide label.)
4. When are they applied to be effective? (Refer to Extension fact sheets.)
5. How are they applied to minimize health and environmental hazards? (Refer to the pesticide label.)
6. What is the re-entry period and the application-to-harvest interval following application? (Refer to the pesticide label.)

Answers to these questions may indicate that a pesticide may or may not be warranted at the point in time.

Authors: David Whiting (CSU Extension, retired) and Carol O'Meara (CSU Extension). Artwork by David Whiting; used by permission. Revised by Mary Small, CSU Extension.

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CMG GardenNotes #112

Systematic Plant Evaluation

Outline: Steps to Systematically Evaluate a Plant with Focus on Trees, page 1

Steps to Systematically Evaluate a Plant with Focus on Trees

It is important to systematically evaluate the entire plant as part of the diagnostic process (Step 2a).

1. **Macro-look –** Look for things that stand out. These may be clues for other steps. For example, decline from the top down is typical of root problems and/or drought. Give extra attention to the soil and roots in step 3.

2. **Macro-look at surroundings** – Insects and diseases are often host specific. If symptoms are found on a variety of plants, it suggests abiotic disorders. Abiotic problems (like soil compaction) may also affect surrounding plants. For example, how is the lawn under a struggling tree performing? It shares the same soil problems.

3. **Soil and rooting area** – Soil issues contribute to a large part of the problems in the landscape. While we cannot see a root system, other clues will help evaluate it. For additional details on diagnosing soil/rooting problems of **trees,** refer to CMG GardenNotes #113, *Diagnosing Root and Soil Disorders of Landscape Trees*. Look for the following:

    How is the lawn performing? It may share the same soil growth-limiting factors.
    - Push a screwdriver into the soil. How easy or hard it is to push into a moist soil provides an estimation of soil compaction.
    - With a soil probe, take some cores from the rooting area of trees or shrubs. It may indicate issues with soil texture changes and rooting.
    - Surface roots of trees or shrubs indicate soil compaction and/or wet soils, as the roots develop closer to the surface where oxygen is available.
    - The lack of a root flare on a tree suggests that it was planted too deeply or that soil was added over the rooting area (smothering the fine feeder roots). Planting too deep causes trunk girdling roots.
    - Trunk girdling (circling) roots are the most common cause of death in landscape trees. Trees often show a gradual decline from trunk girdling roots 12-20 years after planting. The girdling root may be

below the soil surface.
- Decline of a tree or shrub from the top down or a uniform decline of the entire tree suggests root/soil problems.

4. **Trunk (if a tree or shrub)** – Look for the following:

   - Cankers
   - "Lawn mower decline" (bark damage at ground level from lawn mowers and weed trimmers) is common in many landscapes. If the bark is removed down to the wood on more than 50% of the tree's circumference, the tree is considered to have no value.
   - Look for evidence of decay in large size pruning cuts. A drum-like hollow sound when the trunk is tapped with a wood mallet is a symptom of extensive internal decay.
   - Ridges and valleys along the trunk are symptoms of internal problems and decay.
   - Borer exit holes (which may indicate stress issues).

5. **Major branches** (scaffold branches or secondary trunks) – Look for the following:

   - Cankers
   - Large pruning cuts and evidence of storm damage (suggests the possibility of internal decay)
   - Borer exit holes can indicate stress issues.

6. **Minor branches and limbs** –

An important part of the evaluation is to get an assessment of the plants' growth and vigor by comparing the annual growth increments of the twigs (figure1). Starting at the branch tip, follow the twig back to the first ***annual growth ring*** (*terminal bud scar*). This is where the growth ended the previous year. The annual growth ring looks like a small ring or crown going completely around the twig. On some trees, a slight change in bark color helps identify where the annual growth rings are located. [Figure 1]

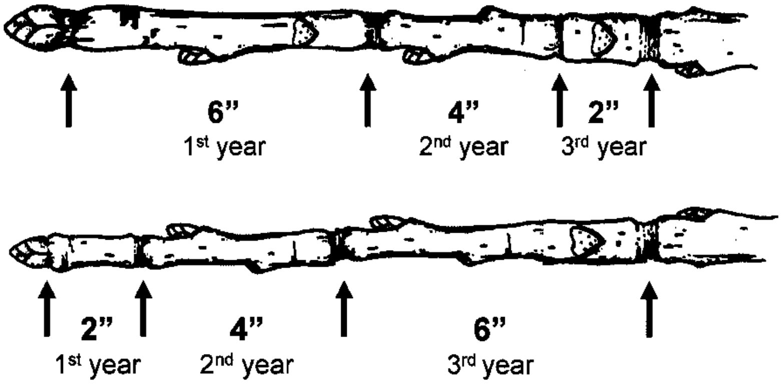

Figure 1 – Comparison of Annual Growth
- Twig on top shows a decrease in stress levels as growth increases from 2 inches to 4 inches to 6 inches in current year.
- Twig on bottom shows an increase in stress levels as growth decreases from 6 inches to 4 inches to 2 inches in current year.

During your evaluation, look at several branches around the tree. Going back three to five years, determine what is typical for each year, not what is longest or shortest. Is the annual growth what would be expected for that species of tree? For example, a young honeylocust tree in an open lawn could readily put on 18 to over 24 inches per year. The same tree located where buildings and hardscape features limit root spread may put on only 6 to 12 inches per year. This reduced growth is in response to the restrictions in rooting.

Another important comparison is the change from year to year. For example, if the length of annual growth is shortening each year, it indicates that the stress levels are increasing. On newly planted trees, twig growth will be minimal until the root system establishes. A significant increase in annual twig growth indicates that the root system has established.

On mature trees, growth will naturally be reduced and must be evaluated by looking at the growth near the top rather than the bottom of the tree.

Evaluating annual growth helps interpret the effects of other problems (like soil/root issues) observed in previous steps.

Other things to look for include scale and other twig insects, borer exit holes (which may indicate stress issues), cankers, and galls.

7. **Foliage** – Look for the following:

- Leaf color and size.
- Leaf spots and other foliage diseases – Typically more serious on the lower inner foliage of any plant where humidity is higher.
- Leaf chewing insects, sucking insects, mites and galls.
- Leaf scorch and dieback from the top down are general symptoms of root problems and/or drought.
- Leaf scorch on a specific side (suggests abiotic disorders originating on that side).
- Early fall color (a general symptom of stress).

Authors: David Whiting (CSU Extension, retired) and Carol O'Meara (CSU Extension). Artwork by David Whiting; used by permission. Revised by Mary Small, CSU Extension.

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CMG GardenNotes #113

Diagnosing Root and Soil Disorders

On Landscape Trees

Symptoms of root and soil disorders on landscape trees are often non-specific, making diagnosis difficult. This CMG GardenNotes expands on ***Step 3, Evaluate Roots and Soil***, in the ***Systematic Evaluation of Trees***, (CMG GardenNotes #112).

Root Function and Symptoms of Root/Soil Disorders

Roots account for approximately 1/3 of the total biomass of a tree. The functions of tree roots include the following:

- Water and nutrient uptake
- Anchoring the plant
- Production of gibberellins, a hormone that promotes canopy growth
- Storage of photosynthates (along with the woody tissues)

Symptoms of root/soil disorders are non-specific in nature, including the following:

- Reduction in photosynthesis
- Reduction in root growth
- Reduction in canopy growth
- Reduction in winter survival
- Reduced tolerance to other stress factors (insects, diseases, drought, etc.)
- Poor anchoring of the plant resulting in tree failure

Root, soil and water issues contribute to a large portion of landscape plant problems, for example:

- Soil compaction and/or drought are the *inciting* factor for many *contributing* insects (borers) and diseases (Cytospora and other cankers).
- Soil compaction and/or hardscape features often limit root spread, which is expressed as reduced growth and leaf scorch.
- Soil compaction reduces a trees' tolerance to common stress factors, including drought, heat and wind, aphids, mites, and other insects.
- Overwatering and drainage problems (soil compaction) are often expressed as iron chlorosis, root rots, leaf scorch and limited growth.
- Trunk girdling roots, caused by planting too deep, is the most common cause of tree decline and death in the landscape.

Diagnosing Root and Soil Disorders

Uniform stress through canopy or stress from the top down suggests root, soil, and water related problems. Diagnosis cannot be from these symptoms alone, but requires a more complete evaluation of the tree, its rooting system and growth. The following is a systematic approach to diagnosing root and soil disorders, based on common problems.

1. Define the Root System

Types of Roots

Root Plate – Zone of Rapid Taper

The *root plate* or *zone of rapid taper* is the primary structural roots extending outward from the trunk. Roots branch readily, tapering in diameter. It is a continuation of the pipeline carrying water and nutrients from the absorbing and transport roots into the tree trunk. [Figure 1]

The root plate is the tree's primary support in winds up to 40 mph. Avoid disturbing the soil and roots in the root plate area. Construction and hardscape features should not encroach into the root plate! When the tree fails by tipping over, often exposing the root plate, it is failure at the edge of the root plate.

As a rule of thumb, the radius of the root plate is three to six times the trunk DBH (diameter at breast height, 4.5 feet).

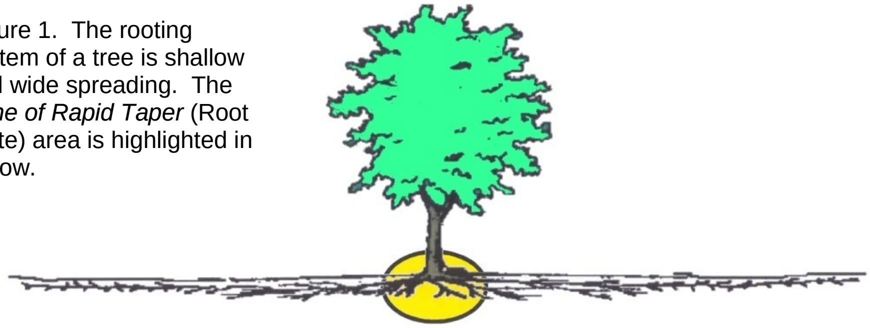


Figure 1. The rooting system of a tree is shallow and wide spreading. The *Zone of Rapid Taper* (Root Plate) area is highlighted in yellow.

Transport Roots

Transport roots serve as a continuation of the pipeline carrying water and nutrients from the absorbing (feeder) roots to the root plate root and trunk. These are the major spreading roots of the tree and follow soil oxygen gradients across the rooting area. In compacted areas (with lower soil oxygen), they will come to the surface. In soils with good structure (higher oxygen), they will be deeper. They also provide additional support to the tree in winds above 40 mph. [Figure 2]

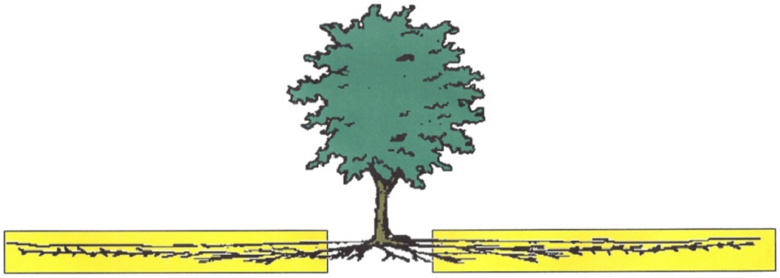


Figure 2. Transport and absorbing roots are found through the entire rooting area beyond the *Zone of Rapid Taper*

Transport roots are typically thumb-size in diameter, long, meandering, and with limited branching. Transport roots do not uniformly spread around the tree. Some areas may be void of roots, other heavily concentrated. In a hole dug in the rooting area, transport roots are readily observed sticking out the side [Figure 3].

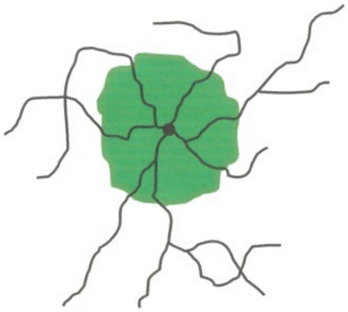


Figure 3. Transport root are long and meandering. They are NOT uniformly distributed around the trunk.

Absorbing Roots

Absorbing (feeder) roots serve the function of water and nutrient uptake. These tiny roots are found near the soil surface throughout the entire transport rooting area. As a rule of thumb, they are found in the top 12 inches on soils with good tilth, and in the top four inches or less in compacted, clayey soils. [Figure 2]

Absorbing roots have a short life, being replaced in four to five flushes of growth through Colorado’s growing season. A short-term drought stress (defined as 10 days) can shut down growth for 1-5 weeks. Long-term drought stress (defined as 22 days), can shut down growth for 1-2 years! Refer to CMG GardenNotes #635, *Care of Newly Planted Trees*.

Sinker Roots

Sinker roots follow natural openings into deeper soil as soil oxygen levels allow. It is unknown to what extent trees actually have sinker roots in the compacted soils of a landscape setting.

Sinker roots have the ability to extract water from deeper soil depths when the surface soil is dry. This helps explain how trees have good short-term drought resistance. It also helps explain the severe drought stress observed on trees when there are dry seasons with dry subsoil. Sinker roots also provide additional support in strong winds. [Figure 4]

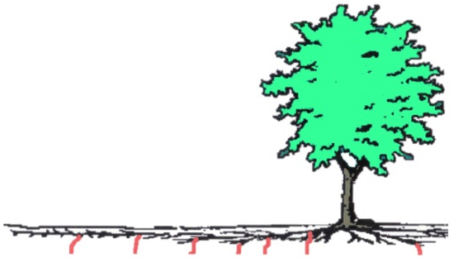


Figure 4. Sinker roots follow cracks in the soil to deeper depths as oxygen levels allow. They extract water when the *absorbing roots* near the surface have dry soil.

Tap Root

The tap root develops from the seed radicle, being the primary root emerging from the germinating seed. Gardeners are very much aware of the tap root as they try to pull seeding maples or elms as weeds in the garden.

However, beyond the seedling stage, the tap root is nonexistent on most trees. As the root system develops beyond the seedling stage, the roots grow into the root plate system due to low soil oxygen. Studies found less than 2% of landscape trees actually have a tap root. In nursery production, the tap root is cut while tiny, forcing a more branching root system that is tolerant of transplanting. [Figure 5]

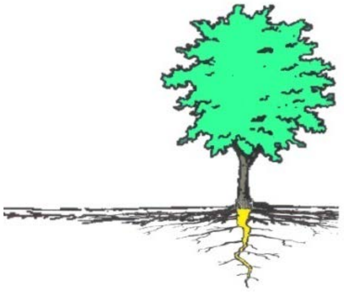


Figure 5. The tap root develops from the seed radicle. In the seedling stage, the tree develops the root plate system due to low soil oxygen. Tap roots are rare in landscape trees.

Depth and Spread

The typical tree rooting system is shallow and wide spreading because roots only grow with adequate levels of soil oxygen. Rooting depth and spread is a factor of 1) the tree's genetic tolerance to soil oxygen levels and 2) soil texture and structure (actual soil oxygen levels).

It is difficult to estimate the actual depth and spread of a tree's root system. Table 1 gives a rule of thumb on root spread. Roots will be more sparse and spreading in dry soils, and more concentrated in moist soils. [Table 1]

Table 1. Estimated Depth and Spread of a Tree's Root System

With good soil tilth
- 90-95% in top 36 inches
- 50% in top 12 inches (absorbing roots)
- Spread 2-3 times tree height and/or canopy spread
- Modified to by actual soil conditions

With compacted/clayey soils
- 90-95% in top 12 inches or less
- 50% in top 4 inches or less (absorbing roots)
- Spread five or more times tree height and/or canopy spread

Tree Protection Zone / Protected Root Zone

Obviously, not every root is essential for tree health. The *Tree Protection Zone, TPZ* (Protected Root Zone, PRZ) defines the rooting area with direct influence on tree health and vigor. The TPZ is the area of focus in tree care activities and evaluating root/soil related disorders.

To protect trees in a construction area, there should be NO grading, trenching, parking, or stock piling of materials in the TPZ. Several methods have been used to estimate the TPZ.

Dripline Method

The drip line (outer reach of branches) is often used in construction activities and by some city ordinances to define the TPZ. It may be suitable for a young tree with a broad canopy in an open lawn area. But it critically underestimates the critical rooting area for most landscape trees. [Figure 6]

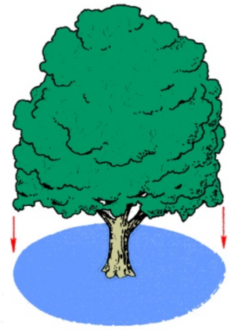
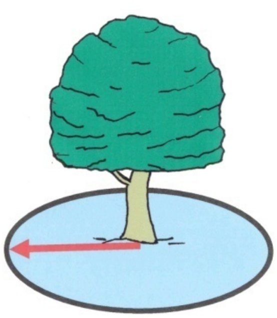


Figure 6. The dip line is the rooting area defined by the outer reach of the branches. It is a poor method for estimating a tree protection zone.

Trunk Diameter Method

The trunk diameter is probably the better method forl use on landscape trees. Size of the TPZ is based on the diameter of the trunk, increasing as the tree ages. It may be calculated by measuring the trunk circumference or diameter at DBH (diameter at breast height, 4.5 feet). For trees with a broad canopy in an open lawn, it is approximately 40% larger in area than the dripline method. [Figure 7]

Figure 7. The Tree Protection Zone defined by the trunk formula method is a good estimate of the rooting area with direct influence in tree health and vigor. It is approximately 40% larger than the area defined by the drip line.



Trunk Diameter Method by Circumference

TPZ radius = 1 feet per 2 inches of trunk circumference

1. Measure the tree’s circumference at DBH (4.5 feet) in <u>inches</u>.
2. Divide the number of inches by 2.
3. This is the radius, <u>in feet</u>, of the TPZ.

For example

1. Circumference = 24 inches
2. 24 / 2 = 12
3. TPZ radius = 12 feet

Area of the TPZ

The area of the TPZ can be calculated by the formula:
[TPZ radius]^2 × π

For example - 12 foot radius:
12 feet × 12 feet × 3.14 = 452 square feet

2. Evaluate Root Spread Potential

The potential for the roots to spread is a primary consideration in evaluating a tree’s root system. The mature size, growth rate and longevity of a tree are directly related to the available rooting space. Many trees in the landscape are predisposed at planting to a short life and limited growth potential due to poor soil conditions and limited rooting space. [Figure 8]

Figure 8 shows the relationship between root space and ultimate tree size. For example, a tree with a 16 inch diameter requires 1000 cubic feet of soil. In a compacted clayey soil, rooting depth may be restricted to 1 foot <u>or less</u>, requiring an 18-foot or greater radius root spread. Anything less will reduce tree size, growth rates, vigor and longevity.

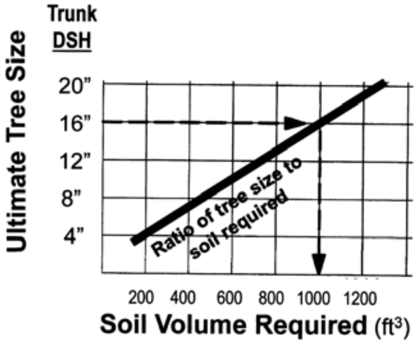
Tree roots can generally cross under a sidewalk to open lawn areas beyond. The ability of roots to cross under a street depends on the road base properties. A good road base does not typically support root growth due to compaction and low soil oxygen levels.

The rooting area does not need to be rounded, but can be about any shape. Trees can share rooting space.

When roots fill the available ‘root vault’ area and cannot spread beyond, 1) root growth slows, 2) canopy growth slows, and 3) trees reach an early maturity and go into decline. Routine replacement may be necessary.

Figure 8. Tree size, growth rate, and longevity are directly related to the size of the available rooting area.

For tree in Colorado’s clayey soils, effective rooting depth is probably less than one foot deep.



3. Evaluating Soil Compaction

Surface roots of trees are an indication of low soil oxygen caused by soil compaction and/or overly wet soil. Soil compaction is often expressed as low vigor and dieback symptoms. Soil compaction is the most common *inciting* factor leading to *contributing* factors in the decline process. (Refer to CMG GardenNotes #101, *Plant Health Care,* for a discussion of the PIC Cycle.)

Soil compaction is a reduction in large pore space, reducing soil oxygen levels and decreasing soil drainage. As a result, rooting depth is reduced. For additional details, refer to CMG GardenNotes #213, *Managing Soil Tilth*, and #214, *Soil Compaction*.
Primary causes of soil compaction include construction activities, foot traffic, and the impact of rain on bare soil. Soils are extremely prone to compaction when wet as the water serves as a lubricant allowing soil particles to slide closer together.

Evaluating Soil Compaction

Soil compaction is somewhat difficult to evaluate. Evaluation tools include the following:

- **Look at the lawn -** It shares the same soil conditions as the tree and may be easier to evaluate. Is the lawn thick or thin?
- **Screwdriver test** – How easy can a screwdriver be pushed into the soil? For this test, the soil needs to have been watered the day before.
- **Soil probe** – With a soil probe, evaluate soil type, texture interfaces, and rooting. It’s best if the soil was watered the day before performing this test.

- **Penetrometer** – This instrument measures the amount of pressure it takes to push the probe into the soil. The colored dial sections indicate when root growth may be slowed or inhibited. The soil must be watered the day before performing this test.

Figure 9. Soil penetrometer measures the pressure it takes to push the probe into the soil. It is a great tool to evaluate soil compaction.

- **Shovel** – Sometimes the only way to evaluate the soil is with a shovel and some hard work.

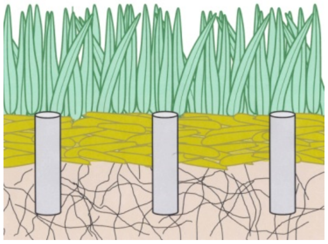
Methods to Deal with Compaction Around Trees

Standard methods of dealing with compaction in a garden setting (adding organic matter, cultivating the soil only when dry, and avoiding excessive tilling) do not apply to tree situations, as we do not cultivate the rooting zone.

Practices Worth Considering

- **Aeration, with plugs at two-inch intervals** – Lawn or soil aeration is helpful for tree root oxygen levels if enough passes are made over the area to have plugs at two-inch intervals.

Figure 10. Core aeration helps reduce soil compaction around trees. To make a difference, plugs needs to be at two-inch intervals.



- **Managing traffic flow** – Established walks help minimize the compaction to other areas. The first time a cultivated soil is stepped on, it can return to 75% maximum compaction. The fourth time a newly cultivated soil is stepped on it could return to 90% maximum compaction. Foot traffic on a compacted soil causes little additional compaction. Soils are much more prone to compaction when wet, as the soil water acts as a lubricant allowing the soil particles to slide closer together.

- **Organic mulch** – A wood/bark chip mulch prevents soil compaction from foot traffic if maintained at adequate depths. When using medium sized chips, the ideal depth is 3-4 inches. Less does not give the protection from compaction; more reduces soil oxygen levels.

- **Soil renovation with an air spade** – This method is used by arborists on high value trees (due to the expense). Steps include the following:

    1. Sod in the TPZ is removed with a sod cutter
    2. Organic matter is spread and mixed into the soil with an air spade. The air spade is a high pressure stream of air that cultivates the soil without cutting the roots.
    3. The area is covered with organic wood/bark chip mulch.

Practices of Questionable Value

- **Vertical mulching with an augur** – The TPZ is drilled with 2" holes, typically at 12-24 inch intervals. Hole may be filled with coarse sand or organic matter. Long-term research finds that is does not aerate enough soil area for a significant increase in tree vigor. [Figure 11]

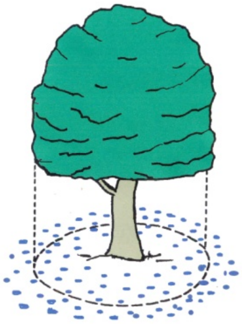
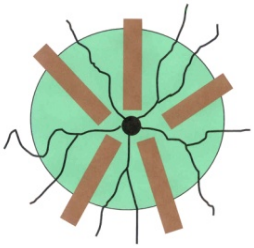


Figure 11. Vertical mulching with hole drilled throughout the tree protection zone.

- **Trenching** – Trenches (dug between primary rooting paths) are backfilled with improved soil. Long-term research finds that while it improves root growth in the backfilled trenches, it does not support a long-term significant increase in overall tree vigor. [Figure 12]

Figure 12. Trenches dug between primary root paths does not result in significant improvements in tree vigor.



- **Punching holes with a pipe, pick, or bar** – This practice compacts the soil around the punch site and does not increase soil oxygen levels. It does not aerate enough soil area for a significant increase in tree vigor. To be effective, the soil cores must be removed.

- **Fracturing** – The soil is subjected to a high-pressure release of air or water, fracturing the soil profile. It has limited effectiveness in sandy soils. It may actually increase the compaction around the fracture lines in clay soils.

    In summary, there is NO quick, easy fix for compacted soils in tree rooting areas.

4. Evaluate Planting Depth

Trunk girdling roots are the most common cause of tree decline and death of landscape trees. Trunk girdling roots are caused by planting the tree too deep. It may show up some twelve to twenty plus years after planting, causing decline and death of trees after they have significant growth. Thus in evaluating the rooting system of a tree, it makes sense to evaluate the tree planting depth. [Figure 13]

Figure 13. Trunk Girdling Roots

Circling/girdling roots may also develop as trees are planted up from pot size to pot size in nursery production. They may be hidden inside the root ball.

For additional information on tree planting, refer to CMG GardenNotes #633, *The Science of Planting Trees.*

Recently Planted Trees

Two considerations are important in evaluating the planting depth of trees: 1) the depth of tree in the root ball, and 2) the depth of root ball in the planting hole. [Figure 14]

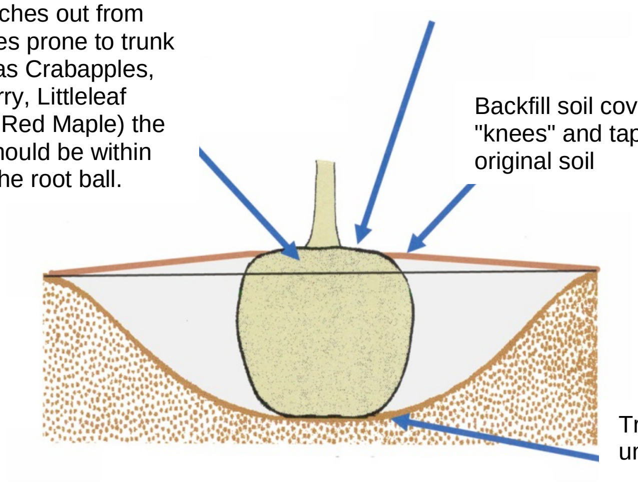
Depth of tree in the root ball – Industry standards include the following:

- Generally, at least two structural roots should be within the top 1-3 inches of the soil surface, measured 3-4 inches from the trunk.
- On species prone to girdling roots (crabapples, green ash, hackberry, littleleaf linden, red maple, poplars, and possibly others), the top structural root should be within the top one inch of the soil surface.

Depth of root ball in planting hole – To deal with the texture interface between the root ball soil and the back fill soil, the root ball must come to the surface with NO backfill soil over the root ball. The top of the root ball on newly planted trees should rise 1-2 inches above grade (depending on root ball size). When the root ball settles, it will be at ground level.

On recently planted trees, the height of the root ball should be slightly above grade or at grade level after the root ball settles. The root ball soil should be visible on the surface with the site soil to the sides. With a small trowel, evaluate the planting depth of the root ball in the planting hole. With a small trowel or screwdriver, evaluate the planting depth of the tree in the root ball.

Figure 14.
Summary: Planting Hole Specifications



Top of root ball rises 1-2" above grade.
No backfill soil covers top of root ball.

Generally, at least two structural roots should be found in the top 1-3 inches of soil, 3-4 inches out from the trunk. On species prone to trunk circling roots (such as Crabapples, Green Ash, Hackberry, Littleleaf Linden, Poplar, and Red Maple) the top structural root should be within the top one inch of the root ball.

Backfill soil covers root ball "knees" and tapers down to original soil

Saucer-shaped planting hole, three times root ball diameter.

Tree sits on undisturbed soil.

Recently planted tree, planted too deep

- If the tree is stressed with poor vigor, replace the tree.
- If the tree is currently in good health:
  - Live with possible consequences of slower growth and trunk girdling roots. Check for circling/girdling roots.
  - Replant the tree – 1) Dig around the tree exposing the root ball. 2) Wrap the root ball in burlap and twine to hold it together. 3) Lift the root ball from the hole. 4) Replant at correct depth. This would be difficult to do!

Established Trees Planted Too Deep

The lack of a visible root flare is an indication of planting too deep (or that soil has been added over the root system). If the root flare is not visible, check for trunk circling/girdling roots. Circling/girdling roots may be several inches below ground.

Circling roots not embedded into the trunk should be cut and removed. For girdling roots putting pressure on the trunk, cut and remove the root without causing injury to the trunk. The tree will likely recover without any long-term effects.

When girdling roots embedded into the trunk, cut the root without causing injury to the trunk, if possible. However, do not remove the girdling root section if it is embedded into the trunk, as this opens the trunk to decay and the trunk will be structurally weak. The tree may or may not survive; only time will tell.

5. Evaluate Root/Shoot Hormone Balance

Auxins (plant hormones) produced in the twig’s terminal buds stimulate root growth. Gibberellins (plant hormones) produced in the root tip stimulate canopy growth. The tree balances root growth versus canopy growth by these hormones. [Figure 14]

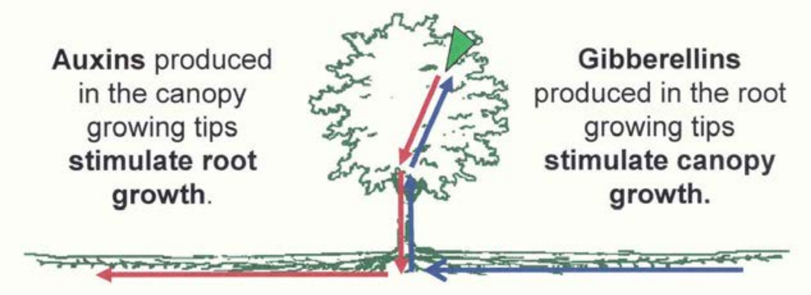


Figure 14. Trees balance shoot and root growth based on the concentration of auxins and gibberellins.

Soil factors that limit root growth will influence canopy growth.

Storm damage or excessive pruning may reduce auxins, slowing root growth. Following storm damage, trees often develop a large amount of water sprout growth due to a low auxin/high gibberellin ratio (coupled with unobserved, limited root growth). This is followed by a decline in the canopy caused by the reduced root growth.

Author: David Whiting, Extension Consumer Horticulture Specialist (retired), Department of Horticulture & LA, Colorado State University. Artwork by David Whiting; used by permission. Revised by Mary Small, CSU Extension

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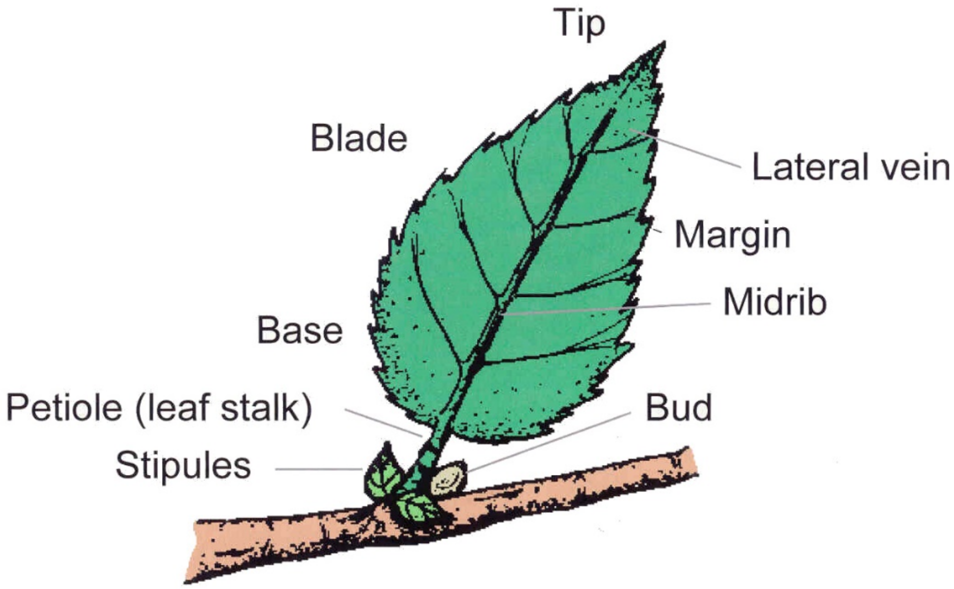
MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION



Botany

Reference / Supplemental Reading

- **CMG GardenNotes** on Botany available on-line at www.cmg.colostate.edu

#121	Horticulture Classification
#122	Taxonomic Classification
#131	Plant Structures: Cells, Tissues, and Structures
#132	Plant Structures: Roots
#133	Plant Structures: Stems
#134	Plant Structures: Leaves
#135	Plant Structures: Flowers
#136	Plant Structures: Fruit
#137	Plant Structures: Seeds
#141	Plant Growth: Photosynthesis, Respiration and Transpiration
#142	Plant Growth Factors: Light
#143	Plant Growth Factors: Temperature
#144	Plant Growth Factors: Water
#145	Plant Growth Factors: Hormones

- **Reference Books**
  - ***Botany for Gardeners***. Brian Capon. Timber Press.
  - ***Gardener's Latin: A Lexicon.*** Bill Neal.
  - ***Introduction to Botany***. James Schooley. Delmar Publishers.
  - ***Manual of Woody Landscape Plants, Fifth Edition.*** Michael A. Dirr. Stipes. 1998.
  - ***Hartman's Plant Science, Fourth Edition.*** Margaret J. McMahon, Anthon M. Kofranek, and Vincent E. Rubatzky. Prentice Hall.
  - ***The Why and How of Home Horticulture.*** D.R. Bienz. Freeman. 1993.
  - ***Winter Guide to Central Rocky Mountain Shrubs.*** Co. Dept. of Natural Resources, Div. of Wildlife. 1976.

- **Web-Based References on Plant Taxonomy**
  - ***International Plant Name Index*** at www.ipni.org
  - ***U.S. Department of Agriculture Plant Data Base*** at http://plants.usda.gov

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Basic Botany curriculum developed by David Whiting (retired), with Joann Jones (retired), Linda McMulkin, Alison O'Connor, and Laurel Potts (retired); Colorado State University Extension.
Photographs and line drawings by Scott Johnson and David Whiting. Revised by Mary Small, CSU Extension

Revisions July 2016

Learning Objectives

At the end of this unit, the student will:

- Understand importance of using correct terminology to enhance communications about plants.
- Practice skills needed in diagnosis by carefully examining plants and plant parts for plant identification.
- Correlate plant structure and growth processes with common plant disorders.

Review Questions

Note: Class time does not permit the instructor to cover all the topics. Please take time to read and review study materials.

Note: This unit covers many horticultural and botanical terms. The objective is to understand that terms are used to communicate and using terms correctly improves communications.

It is not the purpose of this training to memorize terms or definitions. When you come across a term that you don't understand, you can use the glossary in most botany or horticulture textbooks to look up the meaning.

Classifying Plants

1. Why is it important to understand the concepts of plant taxonomy and classification as a gardener?

2. What is meant by:

    a. Warm season and cool season plants
    b. Tender and hardy plants
    d. Alpine, prairie, woodland, wetland, xeric and native plants
    e. Herbaceous and woody
    f. Trees, shrubs, and vines
    g. Deciduous, evergreen and semi-evergreen
    h. Broadleaf, narrowleaf and needleleaf
    i. Annual, summer annual and winter annual
    j. Biennial
    k. Perennial, herbaceous perennial, spring ephemerals and woody perennials

3. Why is it important to know the difference between monocots and dicots, especially when it comes to applying herbicides?

4. How can you identify monocots and dicots based on leaf venation, flower parts, and seed cotyledons?

5. Give the protocol for writing scientific names.

Plant Structures

6. Describe the relationships of cells to tissues to structures to plants.

7. List the three primary functions of roots.

8. Define and identify the following root terms.

    a. Meristematic zone
    b. Primary roots
    d. Lateral roots
    e. Root tip
    f. Epidermis
    g. Root hairs
    h. Tap root system
    i. Fibrous root system
    j. Adventitious roots

9. List the three primary functions of stems.

10. Identify the following parts of a stem:

    a. Nodes
    b. Internodes
    c. Terminal bud
    d. Lateral bud
    e. Terminal bud scar
    f. Leaf scar
    g. Bundle scar

11. Describe how stem characteristics are used in plant identification.

12. Define the following stem terms:

    a. Shoot
    b. Twig
    c. Branch
    d. Trunk
    e. Cane
    f. Bulb

    g. Corm
    h. Crown
    i. Stolon
    j. Rhizome
    k. Tuber

13. List the two primary functions of leaves.

14. Define and identify the following leaf terms.

    a. Leaf blade
    b. Leaf tip
    c. Leaf base
    d. Mid-vein or midrib
    e. Lateral veins
    f. Leaf stalk or petiole
    g. Stipules
    h. Bud
    i. Pinnate venation
    j. Palmate venation
    k. Parallel venation
    l. Simple leaf
    m. Pinnately compound
    n. Palmately compound
    o. Doubly (bipinnately) compound
    p. Alternate leaf arrangement
    q. Opposite leaf arrangement
    r. Whorled leaf arrangement

15. What is the primary function of flowers?

16. Identify the following parts of a flower:

    a. Sepals
    b. Calyx
    c. Petals
    e. Anthers
    f. Filament
    g. Stamen
    h. Stigma
    i. Style
    j. Ovary
    k. Ovules
    l. Pistil
    m. Floret

17. Define the following flower and plant terms.

    a. Complete flower
    b. Incomplete flower
    c. Perfect flower
    d. Monoecious plant
    e. Dioecious plant

18. Describe how flowers are used in plant identification.

19. What is the primary function of fruit?

20. Identify the following parts of a seed:
    a. Seed coat
    b. Endosperm
    c. Cotyledon
    d. Plumule
    e. Radicle

<u>Plant Growth</u>

21. Define:
    a. Photosynthesis
    b. Respiration
    c. Chloroplasts
    d. Chlorophyll
    e. Transpiration
    f. Stomate

22. Define what is meant by:
    a. Full sun
    b. Filtered shade

23. Define photoperiod.

24. List three factors that influence plant hardiness.

25. What does a hardiness zone map indicate?

26. Define the following terms related to winter injury:
    a. Sunscald
    b. Frost crack
    c. Winter drought

27. How do temperate-zone plants know when to start growing in the spring?

28. List the roles of water in plant growth.

29. Explain how a plant balances shoot growth with root growth.

30. Explain how a plant grows toward the sun.

CMG GardenNotes #121

Horticultural Classification Terms

Outline:

The earth is unique because of *plants*. They were the first complex organisms to evolve and they are credited with making the atmosphere hospitable for animals and other life forms.

Plants make their own food using raw materials from the environment including carbon dioxide, water, soil nutrients, and sunlight in the process of photosynthesis.

Horticulture and Related Fields

Horticulture – The science and art of cultivating flowers, fruits, vegetables, turf and ornamental plants in an orchard, garden, nursery, or greenhouse, on a large or small scale.

Horticultural – An adjective used to describe something relating to horticulture, or produced under cultivation.

Horticulturist – A noun referring to a specialist in horticulture.

The terms "**ornamentals**," "**landscape horticulture**," and "**environmental horticulture**" are common terms used to identify the sub-groupings of horticulture dealing with the landscape setting.

Botany – A branch of biology dealing with plant life, (i.e., anatomy, taxonomy, genetics, physiology, ecology, etc.). The science of applied botany deals with plants grown in uncultivated settings.

Agronomy – A branch of agriculture dealing with field crop production and soil management.

Forestry – The science of developing, caring for, or cultivating forests; the management of growing timber.

Community forestry / urban forestry – A branch of forestry dealing specifically with the unique growth limitations and needs of trees in the landscape setting.

Horticultural Classifications

With hundreds of thousands of plants used by humans, it is impossible to talk about each one individually. Plants are grouped by various common characteristics to help us communicate similar ecological adaptations and cultural requirements. For example, the term "shade plants" indicates plants tolerant to various levels of shade. "Xeric" groups those plants requiring less supplemental irrigation in our climate. It is important to point out that any classification system will have plants that do not exactly fit the groupings.

The following are examples of some common classifications used in horticulture.

Classification by Use

I. Edibles
  A. Fruits
    1) Tree fruits
    2) Small fruits
  B. Vegetables
    1) Warm season vegetables
    2) Cool season vegetables
  C. Herbs
    1) Culinary
    2) Medicinal
  D. Nuts
II . Ornamentals/Landscape Plants
  A. Woody plants
    1) Trees
    2) Shrubs
    3) Vines and ground covers
  B. Herbaceous plants
    1) Flowers
    2) Vines and ground covers
  C. Grass/turf
III. Potted plants, houseplants, gift plants
  A. Flowering gift plants
  B. Foliage plants

Note: Do not confuse the multiple uses of the word "fruit".

In reference to "fruits and vegetables", "fruit" refers to crops primarily used in some European cuisines as a dessert (peaches, apples, strawberries, and raspberries). "Vegetables" refers to crops served as part of the main entrée (potatoes, carrots, corn, and lettuce). In this frame of reference, tomatoes are vegetables.

In reference to "fruit" as a part of plant anatomy (i.e., roots, stems, flowers, fruits, and seeds), tomatoes, squash and watermelons are fruit.

Classification by Climatic Requirements

Temperature Requirements

Tropical plants originate in tropical climates with a year-round summer-like growing season without freezing temperatures. Examples include cocao, cashew and macadamia nuts, banana, mango, papaya, and pineapple.

Sub-tropical plants cannot tolerate severe winter temperatures but need some winter chilling. Examples include citrus, dates, figs, and olives.

Temperate-zone plants require a cold winter season as well as a summer growing season, and are adapted to survive temperatures considerably below freezing. Examples include apples, cherries, peaches, maples, cottonwoods, and aspen. In temperate-zones, tropical and sub-tropical plants are grown as annuals and houseplants.

Cool season plants thrive in cool temperatures (40°F to 70°F daytime temperatures) and are somewhat tolerant of light frosts. Examples include Kentucky bluegrass, peas, lettuce and pansies.

Warm season plants thrive in warm temperatures (65°F to 90°F daytime temperatures) and are intolerant of cool temperatures. Examples include corn, tomatoes and squash. Some warm season plants are sub-tropical and tropical plants grown as annuals in Colorado.

Tender plants are intolerant of cool temperatures, frost, and cold winds (e.g., most summer annuals, including impatiens, squash and tomatoes).

Hardy plants are tolerant of cool temperatures, light frost, and cold winds (e.g., spring-flowering bulbs, spring-flowering perennials, peas, lettuce and cole crops).

Hardiness refers to a plant's tolerance to winter climatic conditions. Factors that influence hardiness include minimum temperature, recent temperature patterns, water supply, wind and sun exposure, genetic makeup and carbohydrate reserves.

Cold hardiness zone refers to the average annual minimum temperature for a geographic area. Temperature is only one factor that influences a plant's winter hardiness.

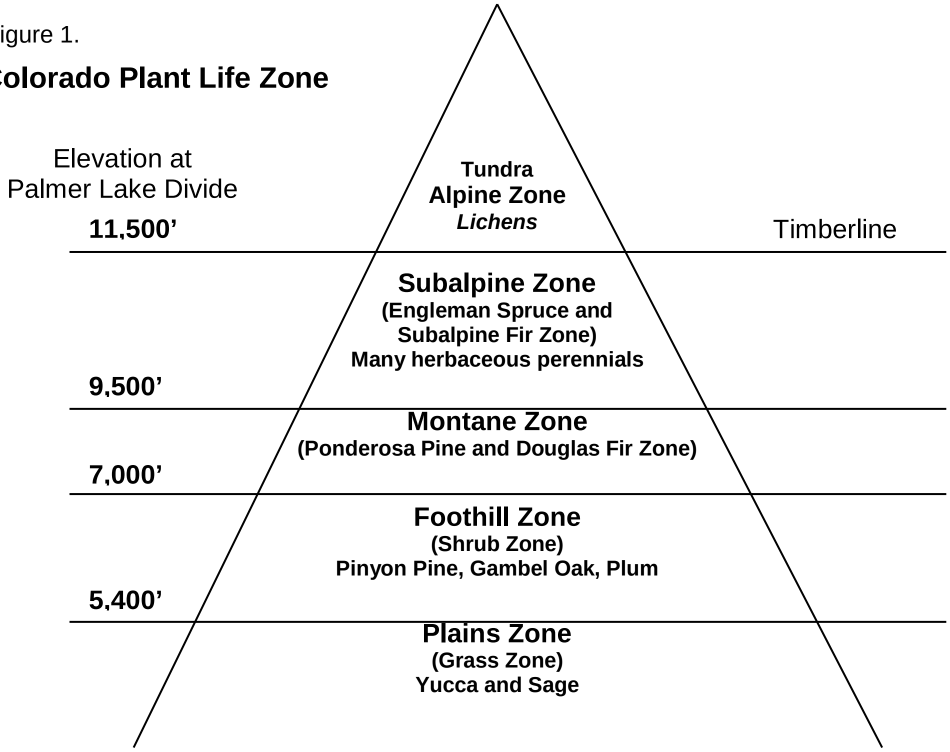
Heat zone refers to the accumulation of heat, a primary factor in how fast crops grow and what crops are suitable for any given area. This is only one factor that influences a plant's heat tolerance.

Classification by Elevation and Plant Life Zones

Higher elevations have increasingly shorter growing seasons due to colder temperatures. High elevations have drier soils, stronger light, persistent winds, and greater temperature changes. Due to this harsh environment, alpine and tundra plants tend to be compact in form. [Figure 1]

Figure 1.

Colorado Plant Life Zone



Note:

1. Elevation of timberline decreases northward.
2. A climb of 1,000’ is roughly equal to a trip of 600 miles northward. Average temperature is decreased approximately 3°F for every 1,000 feet gain in elevation.
3. In New Mexico, corresponding plant life zones will be at higher elevations than those given above, but considerably lower elevations in Montana. This does not apply to Alpine zones.

Classification by Ecological Adaptations

Many of our plant care problems arise as gardeners try to grow plants outside of their natural environment or “ecological adaptation.”

Characteristics of the Colorado high plains include low humidity, limited rainfall, and alkali soils low in organic matter.

In higher mountain communities, the short frost-free season and low summer growing temperatures significantly limit plant selection.

The following are a few examples of terms used to describe classifications based on ecological adaptation.

Alpine plants tolerate the short growing season, cold, and wind of higher mountain elevations. They are typically low-growing, small leaf perennials. Snow cover depth often dictates the plant’s growing height.

Prairie plants are adapted to the open sun and winds of the plains. These plants are further classified into dry, mesic, and wet prairie categories.

Woodland plants are adapted to a low light conditions and soils rich in organic matter. They typically have large leaves and small flowers.

Wetland plants tolerate continually moist soil conditions of a bog or a pond. Wetlands play a primary role in water quality as a filtering system for water-borne pollutants.

Xeric plants tolerate conditions of low water, bright light, and warm temperatures due to a variety of adaptations such as thick, waxy, or fleshy leaves, hairy leaves, small narrow leaves, taproots and succulent stems.

An excellent text on xeriscape gardening is ***Xeriscape Plant Guide***, by Denver Water, published by Fulcrum Publishing.

Native and adapted plants for the urban environment

Native (indigenous) plants refers to plants adapted to a given area during a defined time period. In America, the term often refers to plants growing in a region prior to the time of settlement by people of European descent.

The term is so overused that it has little meaning. With recent interest in water conservation, many gardeners mistakenly consider “native” plants as “xeric” plants, and “xeric” plants as “native” plants. The two terms are not interchangeable”.

The concept of native should not refer to political boundaries, such as state or country, but rather to an ecological habitat during a defined chronological period. For example, Colorado blue spruce and quaking aspen are "native" to the ecological habitat referred to as the montane zone. They are not "native" to the Colorado high plains, or elevations below 8,000 feet. From a chronological reference point, what is now the grassland of the Great Plains was once an inland sea. Therefore, aquatic plants such as kelp would have been "native" at one time. Over time, the ecological habitat changed, changing the "native" plants along with it. Environmental change is an ongoing process, based both on global climatic events and on the activity of all organisms, including humankind.

Adapted (or introduced) plants are those that reliably grow well in a given habitat without specific attention from humans in the form of winter protection, soil amendments, pest protection, water, etc. Adapted plants are considered to be ***low maintenance*** plants.

Urban environment – For gardening purposes, the urban setting needs to be recognized as a unique ecosystem. Characteristics of the urban environment include:

- Soil compaction
- Rooting areas covered with buildings, roads, and parking lots
- Increased surface runoff creating significant water quality problems
- Higher temperatures and lower humidity

- Air pollution

Characteristics of an urban environment cultivated by humans may include:

- Reduced wind
- Increased availability of water due to irrigation
- Increased organic matter and soil fertility
- Reduced pests
- Increased soil stability
- Slower temperature fluctuations

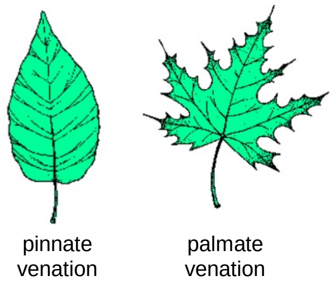
Classification by Stem and Leaf Texture

Herbaceous plants have non-woody stems.
Woody plants have woody stems that generally live for several years, adding new growth each year.

Deciduous plants shed all leaves at approximately the same time annually. [
Evergreen plants retain some leaves longer than one growing season so that leaves are present throughout the year. Seasonal drop of some of the oldest interior leaves is a natural part of the life cycle.
Semi-evergreen refers to plants that may retain their leaves, depending on the winter temperature and moisture.

Broadleaf plants have a broad leaf blade (e.g., ash, maple, lilac, and beans). [Figure 2]
Narrowleaf plants have needle-like (e.g., pine, spruce) or awl-like (e.g. junipers) leaves. [Figure 3]
Grass-like plants have narrow leaves, usually arising from the base of the plant. The leaves may be soft (ornamental grasses) or stiff (yucca).

Figure 2. Venation of broadleaf, deciduous trees



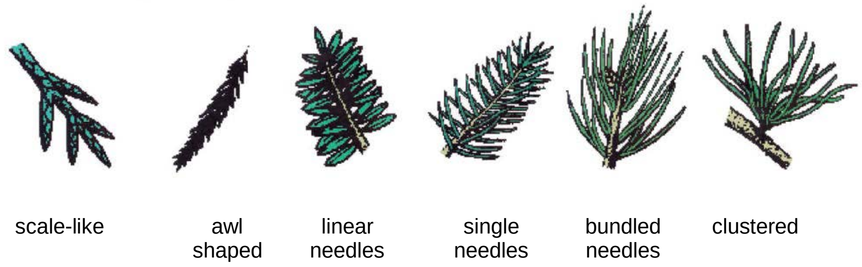


Figure 3. Conifer leaf types

Reminder:

- Some evergreens are broadleaf (e.g., Oregon grape, most true hollies, and evergreen euonymus).
- Some narrow-leaf plants are deciduous (e.g., larch and bald cypress).
- ***Conifer*** refers to cone-bearing. Most conifers are narrow-leaf evergreens. A few conifers are deciduous (larch, bald cypress).

Classification by Growth Habit

Growth habit refers to the genetic tendency of a plant to grow in a certain shape and to attain a certain mature height and spread. [Figure 4.]

Trees typically have a single trunk and mature height over 12 feet.
Shrubs typically have multiple-branches from the ground and a mature height less than 12 feet.
Vines have a climbing, clasping, or self-clinging growth habit.

Note: Many landscape plants could be considered small trees or large shrubs. The terms tree or shrub is applied based on the general appearance of the plant.

Plants have vastly different growth habits. It is important to understand growth habits in order to make knowledgeable decisions regarding plant placement, plant selection, pruning and maintenance requirements.

The species, cultivar, and/or variety name sometimes indicates a particular characteristic of growth habit.

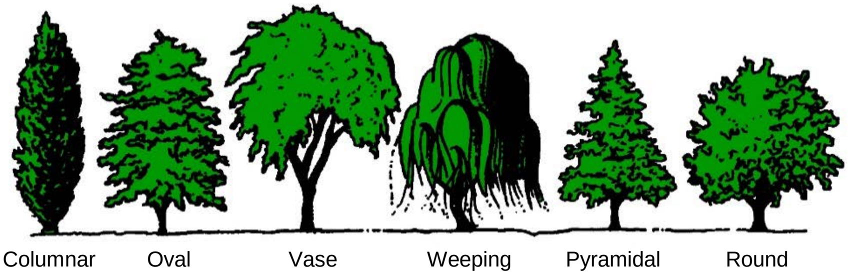


Figure 4. Tree Forms

Classification by Life Span

From a horticultural perspective, life span is a function of climate **and** usage. Many garden plants (including tomatoes and geraniums) grown as annuals in Colorado are perennials in climates without freezing winter temperatures.

Annuals complete their life cycle (from seedling to setting seed) within a single growing season. However, the growing season may be from fall to summer, not just from spring to fall. These plants come back only from seeds.

Summer annuals germinate from seed in the spring and complete flowering and seed production by fall, followed by plant death, usually due to cold temperatures. Their growing season is from spring to fall. Examples include marigolds, squash, and crabgrass.

Winter annuals germinate from seed in the fall, with flowering and seed development the following spring, followed by plant death. Their growing season is from fall to summer. Examples include winter wheat and annual bluegrass. Many weeds in the lawn (such as chickweed and annual bluegrass) are winter annuals.

Biennials complete their life cycle within two growing seasons. Biennials germinate from seed during the growing season and often produce an over-wintering storage root or bulb the first summer. Quite often, they maintain a rosette growth habit the first season, meaning that all the leaves are basal. They flower and develop seeds the second summer, followed by death. Many biennial flowers self-seed, giving the appearance of a perennial growth habit.

In the garden setting, we grow many biennials as annuals (e.g., carrots, onions, and beets) because we are more interested in the root than the bloom. Some biennial flowers may be grown as short-lived perennials (e.g., hollyhocks).

Perennials live through several growing seasons, and can survive a period of dormancy between growing seasons. These plants regenerate from root systems or protected buds, in addition to seeds.

Herbaceous perennials develop over-wintering woody tissue only at the base of shoots (e.g., peony and hosta) or have underground storage structures from which new stems are produced. Note: Golden Vicary Privet and Blue Mist Spirea (*Caryopteris* spp.) can be either herbaceous or woody as grown in Colorado.

Spring ephemerals have a relatively short growing season but return next season from underground storage organs (e.g., bleeding heart, daffodils).

Woody perennials develop over-wintering tissue along woody stems and in buds (e.g., most trees and shrubs grown in Colorado).

Combinations – Plants are usually classified as annual, biennial, or perennial on the basis of the plant part that lives the longest. For example, raspberries have biennial canes and perennial roots.

Author: David Whiting, Extension Consumer Horticulture Specialist (retired), Department of Horticulture & LA, Colorado State University. Artwork by Scott Johnson and David Whiting; used by permission.

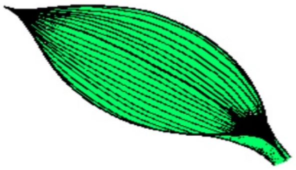
- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- U.S. Department of Agriculture and Colorado counties cooperating.

- Revised May 2016

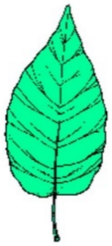
Monocots

Dicots

Leaf venation



Parallel venation



Pinnate
venation

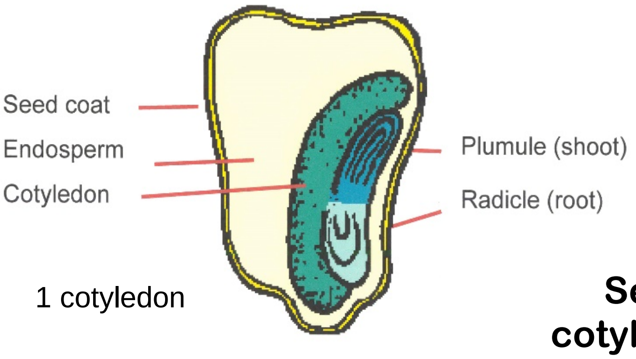
Palmate
venation

Flower parts

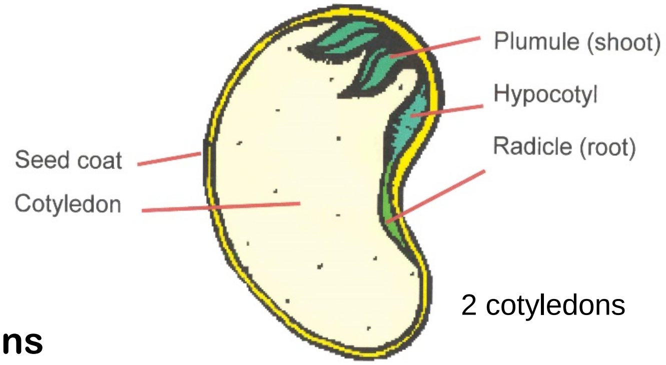
Flower parts
in 3s

Flower parts
in 4s or 5s

Seed cotyledons

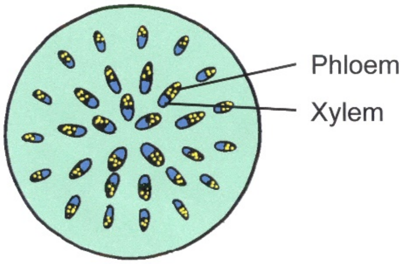


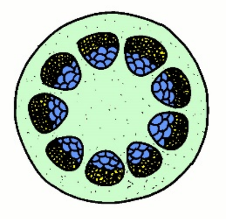
1 cotyledon



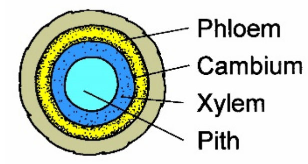
2 cotyledons

Vascular bundle arrangement

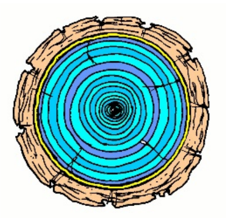




Cross-section
of herbaceous
dicot plant stem



Cross-section
of young woody
dicot plant stem



Cross-section
of older woody
dicot plant stem

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #122

Taxonomic Classification

One of the most useful classification systems utilizes plant taxonomy. Taxonomy is the science of systematically naming and organizing organisms into similar groups. Plant taxonomy is an old science that uses the gross morphology (physical characteristics, [i.e., flower form, leaf shape, fruit form, etc.]) of plants to separate them into similar groups. Quite often the characteristics that distinguish the plants become a part of their name. For example, *Quercus alba* is a white oak, named because the underside of the leaf is white.

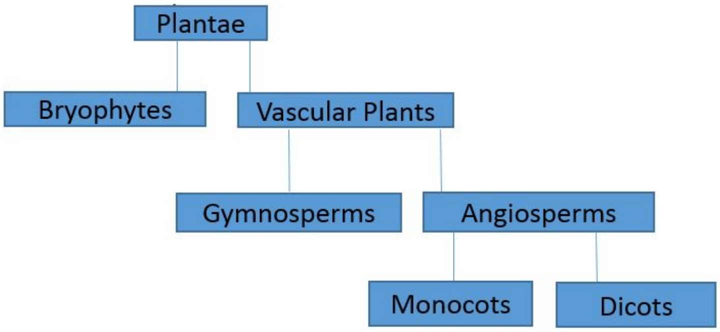
The science of plant taxonomy is being absorbed into the new science of systematics. The development of more sophisticated microscopes and laboratory chemical analyses has made this new science possible. Systematics is based on the evolutionary similarities of plants such as chemical make-up and reproductive features.

It should be noted that plant taxonomic classification changes with continuing research, so inconsistencies in nomenclature will be found among textbooks. Do not get caught-up in which is correct, as it is moving target. Rather focus on “are you communicating?”

An overview of plant taxonomy helps the gardener understand the basis of many cultural practices. For example, fire blight is a disease of the rose family; therefore, it is helpful to recognize members of the rose family to diagnose this disease.

Common Taxonomic Divisions

The scientific system of classification divides all living things into groups called **taxa** (singular, **taxon**). Plants are in the kingdom of ***Plantae***. Other kingdoms include ***Fungi***, ***Protista*** (one-celled organisms including yeasts, bacteria, and protozoans), and ***Animalia*** (animals).



The plant kingdom is divided into two taxa: **broyophytes** (including mosses and liverworts) and **vascular plants** (plants with a vascular system of xylem and phloem).

Vascular plants (sometimes called higher plants) are divided into two subgroups: seedless and seeded. The seeded plants divides into two taxa, **Gymnospermae (Gymnosperms)** and **Angiospermae (Angiosperms).** These make up most of the plants in the landscape.

Gymnosperms (meaning naked seed) do not produce flowers, but rather produce seeds on the end of modified bracts, such as pine cones. Many have scale or needle-like leaves. Arborvitae, junipers, Douglas-fir, fir, pine, and spruce are examples of gymnosperms.

Angiosperms (*Magnoliophyta* or broadleaf flowering plants) produce seeds through flowering. Most have broadleaf leaves. Angiosperms are divided into two taxa: ***monocotyledon*** (monocots) and ***dicotyledon*** (dicots). Distinguishing between monocots and dicots is a common practice in landscape management. For example, some of our common herbicides work at the monocot/dicot level. Lawn weed sprays (such as 2,4-D and dicamba) kill dicots (broadleaf plants like dandelions) but not monocots (the grass). Other herbicides will kill monocots but not dicots, allowing the gardener to kill grass (a monocot) in the shrub or flowerbed (dicots).

These taxa divide into ***Divisions*** (or Phylum). Division names end in 'phyta'. Examples of phyla include *Ginkgophyta* (ginkgo), *Pinophyta* (conifers), and *Magnoliophyta* (flowering plants).

Additional taxa in descending order include **family, genus,** and **species**.

Families

Families of higher plants are separated from one another by characteristics inherent in their reproductive structures (flowers, fruit, and seed). Many family members share common characteristics in plant appearances, seed location and appearance and growth habit. However, some families have a lot of diversity in appearance.

Families have primary importance in gardening as they generally share comparable cultural requirements and similar insect and disease problems. Pest management and cultural techniques are often discussed at the family level.

Family names end in '*aceae'*. Examples of common families include the following:

- ***Caprifoliaceae*** – Honeysuckle family, including elders, honeysuckle, snowberry and viburnum
- ***Fabaceae*** – Pea family, including Japanese pagoda, locust and Siberian peashrub
- ***Oleaceae*** – Olive family, including ash, forsythia, lilac and privet
- ***Rosaceae*** – Rose family, including apple, cotoneaster, crabapple, potentilla, peach, plum, mountain ash and 250 common landscape plants

Genus and Species

The taxonomic divisions beyond the family level are the genus and specific epithet names, together called the species. Plants are named using a binomial system. The genus name comes first and is analogous to a person's last name (like Smith). The specific epithet names follows as a more specific identifier. It would be analogous to a person's first name (like John).

Genus	Specific epithet
Smith	John
Catalpa	*speciosa*

Genera (plural of genus) are groupings whose members have more characteristics in common with each other than they do with other genera within the same family. Similarity of flowers and fruits is the most widely used feature, although roots, stems, buds, and leaves are also used.

Common names of plants typically apply to genera. For example *Acer* is the genus of maples, *Fraxinus* of the ash, and *Juniperus* of the junipers.

Specific epithet generally refers to interbreeding sub-groups of a genus or groupings of individual plants that adhere to essential identification characteristics but show sufficient variation so as not to be categorized as duplicates of one another. The specific epithet name is always used in conjunction with the genus.

When genus and specific epithet names are written, they should always be underlined or italicized to denote they are Latin words. The genus name is always capitalized, but the specific epithet name is not.

The singular and plural spelling of *species* is the same. In writing, the abbreviation "sp." following the genus indicates a single unidentified species and "spp." indicates multiple species. For example, "*Acer* sp." would indicate an unidentified species of maple, and "*Acer* spp." refers to multiple species in the maple genus. The "sp." or "spp." is not underlined or italicized.

In technical papers, the person who first identified the species, called the **Authority**, follows the specific epithet names. For example, Japanese maple would be written *Acer palmatum* Thunberg or *Acer palmatum* T. The Irish potato would be written *Solanum tuberosum* Linnaeus or *Solanum tuberosum* L.

Some suggested sources of scientific names include the following:

- *USDA Plant Data Base* at http://plants.usda.gov/
- *Manual of Woody Landscape Plants*
- *Hortus Third* or *Hortus Fourth*

Variety and Cultivar

The taxonomic divisions beyond the genus and species level are variety or cultivar. This is an even more specific identifier, similar to a person's middle name.

Genus	Species	Cultivar
Smith	John	'David'
Quercus	*rubra*	'Aurea'
Salvia	*greggii*	'Furman's Red'

Variety or **subspecies** is a sub-grouping of species assigned to individuals displaying unique differences in natural populations. The differences are inheritable and reproduce true-to-type in each generation. For example cauliflower and cabbage are varieties of the same species *Brassica oleracea.*

In technical writing, variety and subspecies names must be denoted with 'var.' or 'ssp.' when following a species name. Names are italicized or underlined, while var. or ssp. is not italicized or underlined. For example, the thornless variety of honeylocust would be written *Gleditsia triacanthos* var. *inermis*. The bigfruit evening primrose would be written *Oenothera macrocarpa* ssp. *incana*.

Cultivar is a sub-grouping of species assigned to cultivated plants ("cultivated variety") that display rather unique differences and, when reproduced by seeds or cuttings, retain its distinguishing characteristics. For example, 'Early Girl' and 'Big Boy' are cultivars of tomatoes.

In technical writing, the cultivar name follows the genus and specific epithet and is always capitalized and written inside single quotes but not italicized or underlined. For example, October Glory Red Maple is *Acer rubrum* 'October Glory'.

It is possible to have a cultivar of a variety. For example, *Cornus florida* var. *rubra* 'Cherokee Chief'.

> **Strain** is a sub-group of cultivar with specific characteristics, like resistance to a disease or better color. An example is 'Early Girl VFN' tomato.

Clone is a sub-group of a cultivar derived by asexual propagation (i.e., cuttings). The offspring have one parent and therefore are identical to the parent because no exchange of genetic materials has occurred.

Line is a sub-group of a cultivar propagated by seed

Form is based on selection by growth habit, not reproducible by seed. For example, Columnar Norway Maple.

Scientific Names

Carl Linnaeus (1707-1778) was a Swedish botanist and is known as the father of modern taxonomy. When Linnaeus published the first books on classification, Latin was used in Western Europe as the language of science. Scientific names of plants are Latinized. Linnaeus continued this trend using Latin and Greek names.

Latin is still a part of science, medicine, law, and philosophy. For example, a prescription for a medication may use, "*quater in die*" (Q.I.D.) meaning "four times a day". "*E Pluribus Unum*", an early motto of the United States, means "out of many, one". Today, Latin has the advantage that it provides lingual neutrality between countries and languages.

Pronouncing Scientific Names

Genus and specific epithet names are universal in spelling (that is, each plant has a single genus and specific epithet name, spelled the same worldwide). By using Latin, plants can be positively identified from over 200,000 known plant species.

However, pronunciation of scientific names is not universal and will vary based on the local language. For example, the tomato may be pronounced 'toe-may-toe' or 'toe-mah-toe'. Based on the native language and local dialect of the user, scientific names may actually sound rather different in various countries.

Many Latin names have become 'generic' common names. For example: anemone, rhododendron, crocus, and viburnum.

Here are a few basic guidelines for American-English:

- Latin was meant to be entirely phonetic. There are no silent letters. What you see is what you say.
- Consonants are pronounced as you normally would. The letters 'c' and 'g' are normally in front of the vowels 'a', 'o' and 'u'. When in front of 'i' and 'e', the sound becomes soft ('Cecil" and "Gentle").
- The letters "ch" are pronounced like "k".
- Vowels are long in an accentuated syllable. For example, *Acer* becomes AY-ser and *Pinus* become PIE-nus.
- There are no silent syllables. For example, *Rudbeckia* becomes rood-BEK-ee-uh and *Miscanthus sinensis* becomes miss-can-thus seye-NEN-sis

- Where the accent goes is a matter of local language styles. Here are some suggestions for American-English.
    - In two syllable words, generally accentuate the first syllable. For example, *Cornus* become KOR-nus.
    - In most other words, accentuate the syllable before the last syllable. For example, *Rhododendron* becomes row-doe-DEN-dron.
    - If the last syllable contains two vowels, accentuate on the third to last syllable. For example, *Buddleia* becomes BUD-lee-ah and *Campanula* becomes kam-PA-nu-la.
- When pronouncing a name based on a person's name, try not to change the sound; accentuate on the first part of the name.
- Examples
    - *Quercus macrocarpa* (bur oak) – KWER-kus ma-crow-CAR-pa
    - *Elaeagnus angustifolia* (Russian olive) – eel-a-EE-ag-nus an-gus-tih-FOL-ee-uh
    - *Ptelea trifoliata* (hoptree/wafer ash) – Tea-LEE-uh try-foal-lee-AH-tuh

Latin Names Add Meaning

Latin names often add meaning about the plant's description, for example:

- ***americana* =** of America – *Fraxinus americana* (white ash)
- ***baccata*** = berry bearing – *Taxus baccata* (common yew)
- ***micro*** = little, small – *Antennaria microphylla* (littleleaf pussytoes)
- ***officinalis* =** medicinal – *Rosemarius officinalis* (rosemary)
- ***repens*** = creeping, crawling – *Mahonia repens* (creeping Oregon grape)
- ***undulata*** = wavy – *Quercus undulata* (wavyleaf oak)
- ***variegatus*** = variegated – *Miscanthus sinensis* 'Variegatus' (variegated Japanese silver grass)
- ***vulgaris*** = common **--** *Syringa vulgaris* (common purple lilac)
- ***alba*** = white – *Quercus alba* (white oak)
- ***niger*** = black – *Pinus nigra* (black pine)
- ***rubra*** = red – *Acer rubrum* (red maple), *Quercus rubra* (red oak)
- ***sanguineus*** = blood-red – *Geranium sanguineum*

Common Names

On the other hand, common names are often local in use and many times do not clearly identify the specific plant. For example, *Liriodendron tulipifera* is known as the tulip tree in the north and as yellow poplar in the south. *Carpinus caroliniana* goes by American hornbeam, blue beech, musclewood, water beech and ironwood. The European white lily, *Nymphaea alba*, has 15 English common names, 44 French common names, 105 German common names, and 81 Dutch common names.

References on Plant Taxonomy

Books

- *Gardener's Latin: A lexicon* by Bill Neal.
- *Manual of Woody Landscape Plants* by Michael Dirr

Web based

- *International Plant Name Index* at www.ipni.org/
- *Royal Botanic Gardens, Kew Resource Page* at www.kew.org./data/subjects.html
- *USDA Plant Data Base* at http://plants.usda.gov/

Several web-based sites offer pronunciation guides for plant names. For example, http://www.finegardening.com/pguide/pronunciation-guide-to-botanical-latin.aspx

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Authors: David Whiting (retired) and Alison O'Connor with Joanne Jones (retired), Linda McMulkin, and Laurel Potts (retired); Colorado State University Extension. Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

Revised July 2016

Examples of Taxonomic Classification

Vascular plants

- Seedless
  - *Pteridophyta (Pterophyta)* – ferns
- Seeded
  - *Gymnospermae* – **Gymnosperms** (naked seed plants)
    - *Cycadophyta* – Cycads
    - *Pinophyta (Coniferophyta)* – **Conifers** (cone bearing plants)
      - *Cupressaceae* (cypress family)
        - *Juniperus* spp. – **junipers**
          - *Juniperus horizontalis* (creeping Juniper)
            - *Juniperus horizontalis* ‘Blue Chip’ (blue chip juniper)
        - *Thuja spp*. – **arborvitae**
      - *Pinaceae* (pine family)
        - *Abies* spp. – **fir**
        - *Larix* spp. – **larch**
        - *Picea* spp. – **spruce**
          - *Picea pungens* – Colorado spruce
            - *Picea pungens* ‘Bakeri’ – Bakeri Colorado spruce
        - *Pinus* spp. – **pines**
          - *Pinus ponderosa* – ponderosa pine
        - *Pseudotsuga menziesii* – **Douglas-fir**
  - *Angiospermae* – **Angiosperms** (flowering plants) / ***Magnoliophyta (Anthophyta)***
    - *Aceraceae* – Maple family
      - *Acer* spp. – **maples**
        - *Acer platanoides* – Norway maple
          - *Acer platanoides* ‘Crimson King’ – Crimson King Norway maple
    - *Salicaceae* – Willow family
      - *Populus* spp. – **cottonwood, poplar, and aspen**
        - *Populus deltoides* – eastern cottonwood
          - *Populus deltoides* ‘Siouxland’ – Siouxland eastern cottonwood
        - *Populus tremuloides* – quaking aspen
    - *Rosaceae* – rose family
      - *Rosa* spp. – **roses**
        - *Rosa rugosa* – Rugosa rose
          - *Rosa rugosa* ‘Hansa’ – Hansa rugosa rose
      - *Cotoneaster* spp. – **cotoneasters**
        - *Cotoneaster apiculatus* – cranberry cotoneaster

MASTER GARDENER
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EXTENSION

CMG GardenNotes #131

Plant Structures:
Cells, Tissues, and Structures

Outline: Cells, Tissues, and Structures

Plant cells are grouped into tissues based on similar characteristics, then into five distinct structures (organs).

Cells – Individual building blocks for life processes and growth. Common cells contain genetic matter (deoxyribonucleic acid, or DNA) and metabolic organelles but they are mostly water. In green plants, they are the site of sugar production (photosynthesis). [Figure 1]

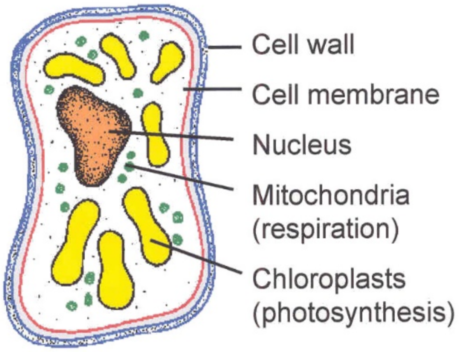

Figure 1.
Plant cell

Tissues – Groups of cells that are similar in appearance and function, for example:

- **Epidermis** is the single exterior layer that protects the stems, leaves, flowers, and roots. The outside surface of the epidermis tissue is usually covered with a waxy substance called cutin, which reduces water loss.

- **Parenchyma** tissues are made of simple, thin-walled cells. In a carrot, for example, the parenchyma cells become a storage unit called the cortex. In leaves, a layer of parenchyma tissues under the epidermis is active in photosynthesis. When wounded, parenchyma cells can become meristematic and proliferate to grow over the wound.

- **Meristematic** tissues are comprised of actively dividing cells.
- **Sclerenchyma** tissues are thick-walled support cells found throughout the plant as fiber.
- **Xylem** is a structurally complex tissue that conducts water and nutrients from the roots to all parts of the plant. In woody plants, the xylem tissue becomes the wood.
- **Phloem** tissue conducts food and metabolites from photosynthesis throughout the plant, including down to the roots.

Structures (organs) – Groups of tissues working together with a common function, (e.g., **roots, stems, leaves, flowers, fruits**, and **seeds)**.

Plant – Made up of a number of coordinated structures to form a working unit.

Authors: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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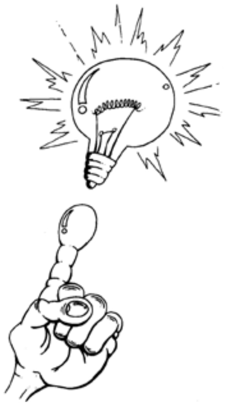
CMG GardenNotes #132

Plant Structures: Roots



Thought questions:

Explain the science behind the question.

- Last summer during a home remodeling project we raised the soil level 12” in the yard. This summer my trees look stressed with small yellowish leaves. I don’t see any insects. Could the problems be related to the soil change? My contractor assured us that trees are deep rooted.
- Since you can’t see the root system, what are the above ground symptoms of root and soil related

---

The roots are the beginning of the vascular system pipeline that moves water and minerals from the soil up to the leaves and fruits. Roots make up around one-fourth to one-third of the total dry weight of a plant. The total length of root tissues in a single rye plant is around 380 miles!

To function, roots must have adequate levels of soil oxygen. Soil compaction or waterlogged soil situations, reducing soil oxygen levels, will kill roots and lead to a shallow root system.

The structure and growth habits of roots have a pronounced effect on

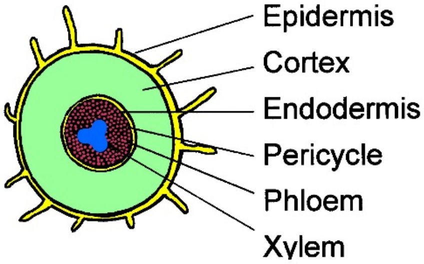
- Size and vigor of the plants
- Adaptation to certain soils
- Response to cultural practices

Because they are out of sight, roots are often out of mind. They are widely overlooked as to their significance in plant health. <u>The majority of all plant problems start with soil/root problems.</u>

Functions

- Anchor and support plants
- Absorb and conduct water and minerals
- Store products of photosynthesis (carbohydrates, sugars, proteins)
  - Winter survival of perennials
- Horticultural uses
  - Food and feed
  - Propagation
  - Soil erosion control

Structure



Epidermis – The outer layer of cells

Root hairs – Absorptive unicellular extensions of epidermal cells of a root. These tiny, hair-like structures function as the major site of water and mineral uptake. Root hairs are very delicate and subject to desiccation. Root hairs are easily destroyed in transplanting. [Figure 1.]

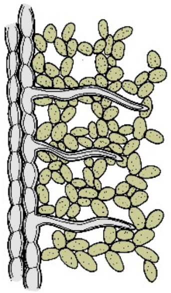


Figure 1. Root hairs are an extension of the epidermis.

Cortex – Primary tissues of a root bordered on the outside by the epidermis and on the inside by the endodermis. In a carrot, the cortex becomes a storage organ.

Endodermis – A single layer of cells in a root that separates the cortex tissues from the pericycle.

Pericycle – A layer of cells immediately inside the endodermis. Branch roots arise from the pericycle.

Vascular system

Phloem tissue conducts products of photosynthesis from leaves throughout plant including down to the roots.
Xylem tissue conducts water and minerals up from the roots up through the plant.

Zone of maturation – Area where cells form distinct tissues that become functioning roots.

Zone of elongation – Area where new cells are enlarging.

Meristematic zone

Root tip meristem – Region of cell division that supports root elongation, found at the root tips just behind the root cap.

Root cap – A thimble-shaped group of thick-walled cells at the root tip serves as a “hard hat” to push though soil. The root cap protects the tender meristem tissues.

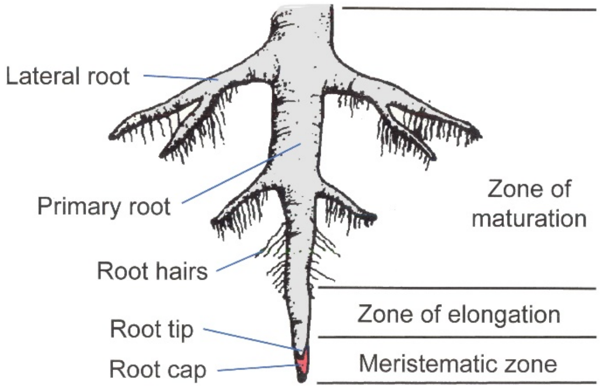


Figure 2. Lateral view of root

Types of Roots

Fibrous – Profusely branched roots that occupy a large volume of shallow soil around a plant's base (petunias, beans, peas).

Taproot – Main, downward- growing root with limited branching, where soils permit (carrots, beets, radishes).

Adventitious roots arise at an unexpected place. For example, the brace roots on corn and the short whitish bumps along a tomato stem are adventitious roots.

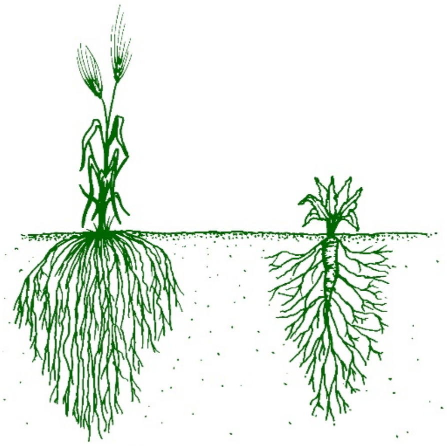


Figure 3. Root types –
Left: Fibrous root system of corn
Right: Taproot system of carrot

Aerial roots arise from above-ground stem tissues. On English ivy and poison ivy, the aerial roots support the vine. Aerial roots are **common on philodendrons, pothos, and Christmas cactus.**

Lateral root – Side root

Sinker roots make a sharp dive into deeper soils, following soil cracks where oxygen is available. Sinker roots are common on some tree species.

Storage or Tuberous root – Enlarged roots that serve as storage organs (Canada thistle, morning glory, sweet potato, dahlia).

Depth and Spread

The depth and spread of roots are dependent on the inherent growth characteristics of the plant <u>and</u> the soil's texture and structure. Roots require adequate levels of soil oxygen, so growth habit will be a factor of the soil's large pore space where oxygen is available.

- In compacted and clayey soils, roots will be shallow, remaining near the surface where oxygen is available.

- In droughty soils, the root system will spread farther, mining a larger soil area for moisture and minerals.

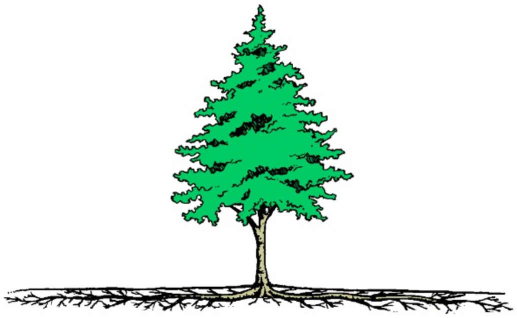


Figure 4. Typical rooting pattern of trees, shallow and spreading

It is difficult to predict root spread of any plant. Under favorable growing conditions, the typical root spread of a tree includes:

- 90-95% in top 36 inches
- 50% in top 12 inches
- Spreads 2-3 times tree's height or canopy (drip-line) spread

In compacted clayey soils, the typical root spread of trees includes:

- 90-95% in top 12 inches or less
- 50% in top 4 inches
- Potentially spreads five plus times the tree's height or canopy (drip-line) spread

Some plants are genetically programmed to have very deep, spreading root systems (i.e., they are more tolerant of low soil oxygen levels). This growth habit is an environmental adaptation. Examples include bindweed and prairie grasses.

Soil type is a key factor in water penetration and root uptake. Where soil allows, the primary water extraction depth extends to:

• Flowers	18-24"
• Turf	24"
• Vegetables	24"
• Shade trees	24-60"

Beneficial Microorganism Associations

<u>Mycorrhizae</u> are specific beneficial soil fungi forming symbiotic (mutually beneficial) associations with roots. While the role of mycorrhizae is not fully understood, they function to expand the root's contact with the soil profile, enhancing water and nutrient uptake. For additional information, refer to the CMG GardenNotes #212, *The Living Soil*.

<u>Rhizobium</u> is a beneficial soil bacterium that forms a symbiotic relationship with plants, primarily those in the bean/pea family. These bacteria make atmospheric nitrogen available to plants. *Rhizobium* typically forms nodules on the roots of plants. These may be mistaken for insect injury or deformity. When alfalfa, a member of the bean/pea family, is left to mature then tilled into a field, it is considered "green manure" because the plant is rich in nitrogen due to the R*hizobium* in the roots.

Authors: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan, Mary Small, CSU Extension.

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CMG GardenNotes #133

Plant Structures: Stems

Thought questions:

(Explain the science behind the questions.)

- My trees have been severely drought stressed for the past few years. Why are they still showing stress when we had good moisture this year?
- Over the winter, rabbits girdled my tree all the way around down to the wood. My neighbor said it would die, but it leafed out nicely. Will it be OK?
- I planted several new trees over the past few years. How can I evaluate how they are growing? How can I tell if roots are established so I can begin structural pruning?

Stems are the part of a plant that bear leaves and flowers, and they are the continuation of the vascular system pipeline that starts in the roots.

Functions

- Framework for leaves, flowers and seeds
- Continuation of vascular system carrying water and minerals from the soil, and sugars manufactured in leaves throughout the plant.
- Green stems also manufacture food.
- Food storage
- Horticultural uses
  - Aesthetic (winter interest in the landscape, appealing bark, etc.)
  - Feed and food
  - Fuel
  - Plant identification
  - Propagation (cuttings and layering)
  - Wildlife habitat
  - Wood industry and construction

Common Types of Stems

Woody Plants

Shoot – First year growth on a woody or herbaceous plant.
Twig – Woody stem less than one year old.
Branch – Woody stem more than one year old.
Trunk – Main support stem(s) of woody plants.
Water sprouts – Juvenile adventitious shoots arising on a branch. Generally very rapid, upright-growth, and poorly attached to the main limb.
Suckers – Juvenile adventitious shoots arising from the roots, generally rapid, upright-growing.
Canes – Stems with relatively large pith and usually living for only one to two years (roses, grapes, blackberries, and raspberries).

Structure

Internal Features

Apical meristem – Tissues at the tip of a stem capable of cell division, gives rise to stem elongation.
Epidermis – Outer layer of wax-coated cells that provides protection and covering
Cortex – Primary tissues of a stem externally bound by the epidermis and internally by the phloem.

Vascular bundle

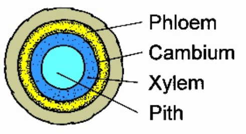
Phloem tissues (inner bark) – distribute sugars (products of photosynthesis) throughout the plant. It is important to understand what happens when the phloem is blocked, as when a tree is girdled with a tie or rope. The stem often enlarges just above the blockage due to the sugars moving down from the leaves for distribution throughout the plant. Tissues below the blockage slowly starve. Roots die back, eventually leading to death of the plant.

Cambium tissues are the single-celled layer of meristematic (dividing) tissues that continually divides to form phloem tissues toward the outside and xylem tissues toward the inside. Cell division of the cambium tissues adds width to the stem.

Xylem tissues – Distribute water and minerals from the roots up through the plant. Xylem provides the structural support in plants, becoming the "woody" tissue.

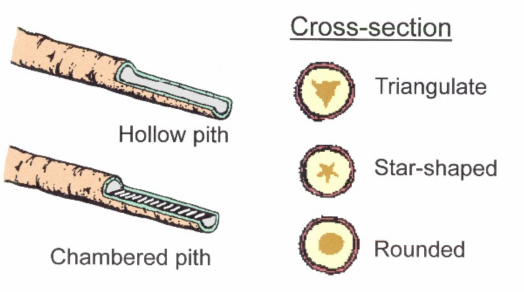
Pith – Center of dicot plant stems. In some plants the pith breaks down forming a hollow stem. In older woody plants, the pith is filled with rigid xylem wood fiber.

Figure 1. Cross section of stem



Woody dicot stems are used in tree and shrub identification. Features to look at include the cross section shape of the pith (rounded, star, or triangular) and whether the pith is solid, hollow, or chambered.

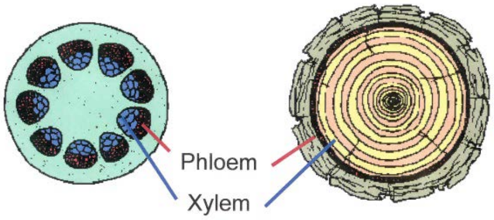
Figure 2. Stem pith is used in plant identification. It may be solid, hollow or chambered. In a cross section, the pith may be rounded, triangular or star shaped.



Tree Rings

In woody dicot plants, the rings grow to make a complete ring around the stem. Xylem growth makes the “annual rings” used to tell a tree’s age. In woody dicot plants, water and mineral movement occurs in the more recent years of xylem rings. Drought reduces the size of the annual rings (size of xylem tubes) and thus the potential for water and nutrient movement. Multi-year droughts, with their corresponding reduction in xylem size, have long-term impacts on plant growth potential. [Figure 3]

Figure 3. Cross section of herbaceous (left) and woody (right) dicot stems



External Features

Bud – A stem's primary growing point. Buds can be either leaf buds (vegetative) or flower buds (reproductive). These buds can be very similar in appearance, but flower buds tend to be plumper than leaf buds.

Terminal bud – Bud at the tip of a stem. In many plants, auxin (a plant hormone) released from the terminal bud suppresses development of lateral buds, thereby focusing the growth of the plant upward rather than outward. If the terminal bud is removed during pruning (or natural events) the lateral buds will develop and the stem becomes bushy. [Figure 5]

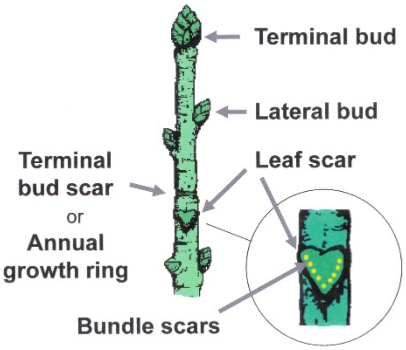


Figure 5. External features of a stem

Lateral buds grow from the leaf axils on the side of a stem.

Leaf scar – Mark left on stem where leaf was attached. Often used in woody plant identification.

Bundle scar – Marks left in the leaf scar from the vascular tissue attachment. Used in woody plant identification.

Lenticel – Pores that allow for gas exchange

Terminal bud scale scars or **annual growth rings –** Marks left on stem from the terminal bud scales in previous years. Terminal bud scale scars are an external measure of annual growth. Therefore, they are important in assessing plant vigor. [Figure 6]

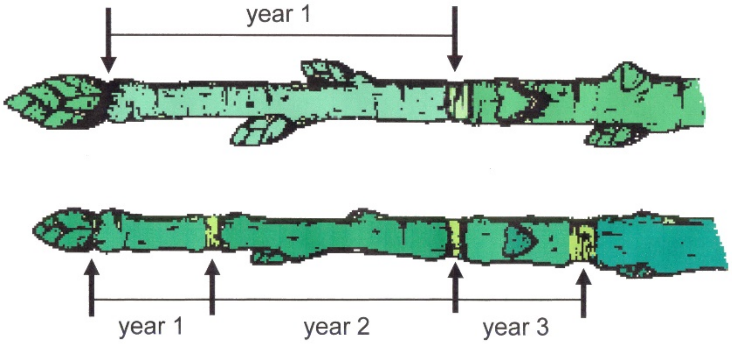


Figure 6. Terminal bud scars or annual growth rings

Node – Segment of stem where leaves and lateral buds are attached. [Figure 7]

Note: Roots do not have nodes.

Internode – Section of a stem between two nodes

Bark – Protective outer tissue that develops with age. Used in woody plant identification.

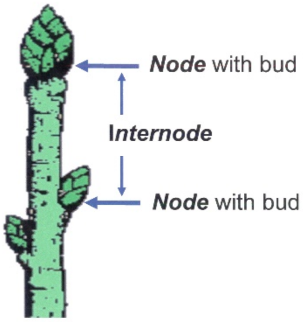


Figure 7. Node and internode

Bud type – The type of bud is also used in plant identification. Figure 8 illustrates bud types used in the *Manual of Woody Landscape Plants*. [Figure 8]

All the features previously described can tell a great deal about a plant pertinent to its identification and health. These are common terms that frequently appear in literature.

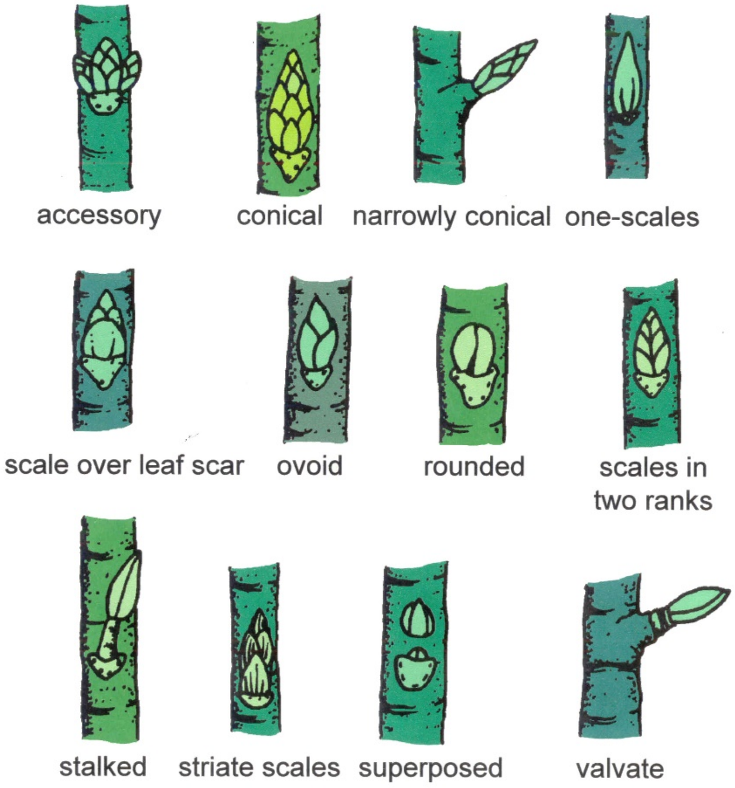
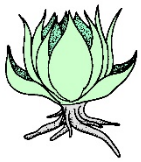


Figure 8. Bud types

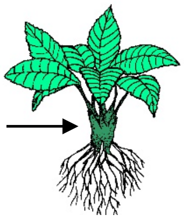
Modified Stems

Bulb – Thickened, underground stem with fleshy storage leaves attached at base (tulips, lilies, onions).

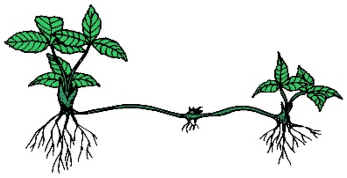


Corm – Short, thickened, underground stem with reduced scaly leaves (gladiolus).

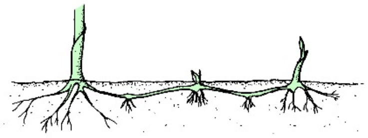
Crown – Compressed stem having leaves and flowers growing above and roots beneath (strawberry plant, dandelion, African violet).



Stolon (or runner) – Horizontal, above-ground stems often forming roots and/or plantlets at their tips or nodes (strawberry runners, spider plants).

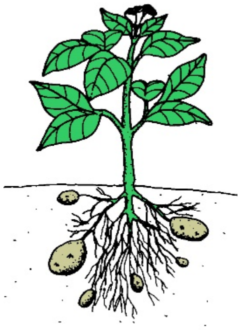


Rhizome – Horizontal, underground stem, typically forms roots and plantlets at tips or nodes (iris, bentgrass, cannas).



Spur – Very compressed, fruiting twig found on some apples, pears, cherries and ginkgo.

Twining stems – Modified stems used for climbing. Some twist clockwise (hops, honeysuckle); others twist counter-clockwise (pole beans, Dutchman's pipe).



Tuber – Enlarged rhizome containing stored food. (Irish potato; the eyes of the potato are modified buds.)

Tuberous stem – Short, flattened, modified storage stem (tuberous begonias, dahlias). Unlike tubers, which have buds scattered all over, tuberous stems only have leaf buds on the "up" end.

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CMG GardenNotes #134

Plant Structures: Leaves

Thought question:

(Explain the science behind the question.)

- Last spring my tulips were beautiful. As the plants faded, I removed the blossoms and foliage so it wouldn't detract from the landscape.This year, most of the tulips didn't grow back. Why?

Leaves are the principle structure, produced on stems, where photosynthesis takes place. Cacti are an exception. The leaves are reduced to spines, and the thick green, fleshy stems are where photosynthesis takes place.

Functions

- To compete for light for photosynthesis (the manufacture of sugars).
- Evapotranspiration from the leaves to move water and nutrients up from the roots.
- Regulate moisture, gas exchange and temperature through small openings on the leaf, known as ***stomata.***
- Horticultural uses
  - Aesthetic qualities
  - Feed and food
  - Mulch and compost
  - Plant identification

- Propagation from cuttings

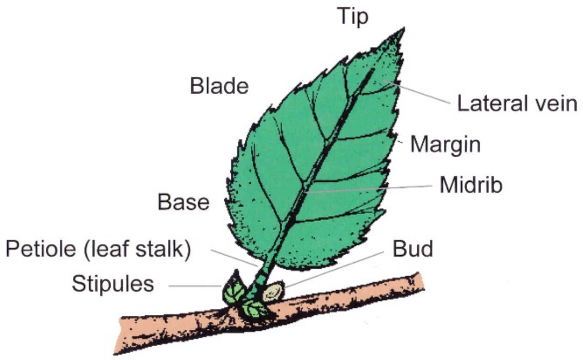
- Summer cooling (Evaporative cooling accounts for 70-80% of the shading impact of a tree.)
- Wildlife habitat
- Wind, dust and noise reduction

Structure

External Features

Leaf blade – Flattened part of the leaf
Petiole – Leaf stalk
Stipules – Leaf-like appendages at the base of the leaf.

Figure 2. External Features of a Leaf



For plant identification purposes, the shape of the leaf margin, leaf tip and leaf base are key features to note. Remember, a leaf begins at the lateral or auxiliary bud.

Leaf Arrangement on Stems

Alternate – Arranged in staggered fashion along stem (willow)
Opposite – Pair of leaves arranged across from each other on stem (maple)
Whorled – Arranged in a ring (catalpa)
Rosette – Spiral cluster of leaves arranged at the base (or crown) (dandelion)

Figure 3. Leaf Arrangement on Stem

Leaf Type

Simple – Leaf blade is one continuous unit (cherry, maple, and elm).

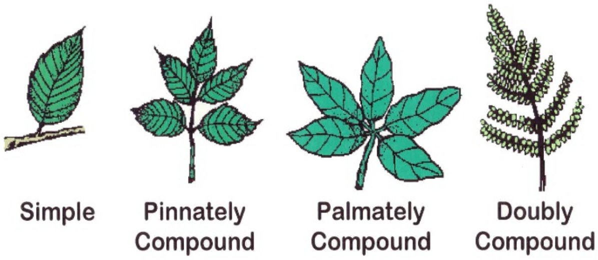
Compound – Several ***leaflets*** arise from the same petiole.

Palmately compound – Leaflets radiate from one central point (Ohio buckeye and horse chestnut).

Pinnately compound – Leaflets arranged on both sides of a common rachis (leaf stalk), like a feather (mountain ash)

Bi-pinnately (doubly) compound – Double set of compound leaflets.

Figure 3. Leaf Types

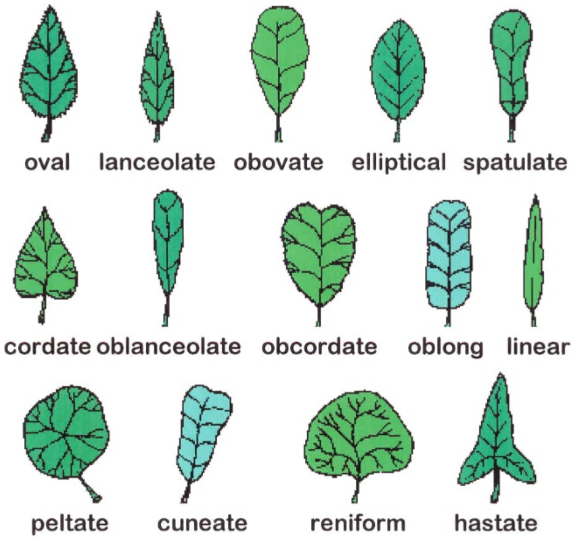


Note: Sometimes identifying a "leaf" or "leaflet" can be confusing. Look at the petiole attachment. A leaf petiole attaches to the stem at a bud node. There is no bud node where leaflets attach to the petiole.

Overall Leaf Shape

Leaf shape is a primary tool in plant identification. Descriptions often go into minute detail about general leaf shape, and the shape of the leaf apex and base. Figure 5 illustrates common shapes as used in the *Manual of Woody Landscape Plants.*

Figure 5. Leaf Shapes



Leaf Shape Descriptions

Cordate- heart-shaped
Cuneate – leaves with small width at base, widening near the top (think wedge)
Elliptical – leaves widest in the middle, tapering on both ends
Hastate – arrowhead shaped leaves
Lanceolate – leaf is 3x or more longer than width and broadest below the middle
Linear- leaves narrow, 4x longer than width and have the same width
Obcordate – reverse appearance of cordate leaves. (Heart shape is upside down)
Oblanceolate – leaf is 3x longer than wide and broadest above the middle
Oblong – leaf is 2-3x as long as it is wide and has parallel sides
Obovate – leaf is broadest above the middle and about 2x as long as the width
Ovate- leaf is broadest below the middle and about 2x as long as the width (egg shaped)
Peltate – leaves rounded with petiole attached under the leaf base
Reniform – leaves wider than they are high
Spatulate – generally narrow leaves widening to a rounded shape at the tip

Shape of Leaf or Leaflet Apex

Shape of the leaf apex (tip) and base is another tool in plant identification. Figures 6 and 7 illustrate common tip and base styles as used in the *Manual of Woody Landscape Plants*.

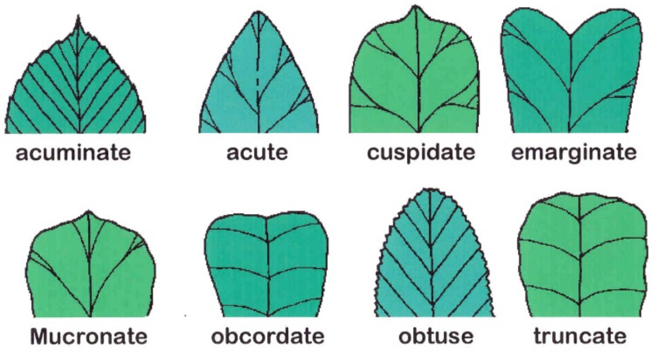


Figure 6. Leaf Tip Shapes

Leaf Apex Descriptions

Acuminate – leaf margins forming a terminal angle of less than 45 degrees
Acute – leaf margins forming a terminal angle of 45 to 90 degrees
Cuspidate – tip is sharp; looks like 2 curves meeting at the tip
Emarginate – tips is slightly indented
Mucronate – tip ends in a small sharp point that is actually continuation of leaf midrib
Obcordate – upside down heart shape
Obtuse – leaf tip is blunt with an angle greater than 90 degrees
Truncate – leaf tip appears to be square-like

Shape of Leaf Base

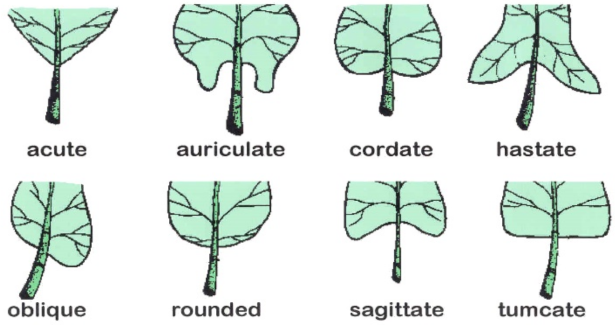


Figure 7. Leaf Base Shapes

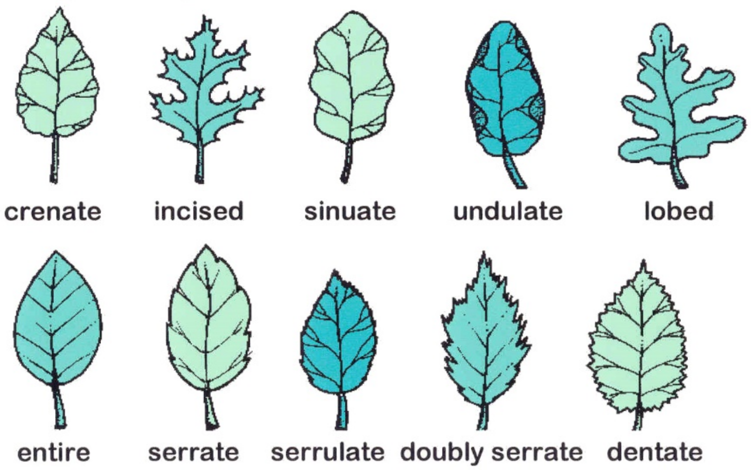
Leaf Base Descriptions

Acute – base is pointed, having less than a 90 degree angle
Auriculate- base has ear-shaped appendages near the petiole
Cordate- base is heart shaped
Hastate- base has pointed, flaring lobes at base
Oblique- base has one side lower than the other
Rounded- circular with no point
Saggitate- lower lobes of leaf are folded or pointed down

Leaf Margins

The leaf margin is another tool in plant identification. Figure 8 illustrates common margin types as used in the *Manual of Woody Landscape Plants*.

Figure 8. Leaf Margins



Leaf Margin Descriptions

Crenate – leaf edge has blunt, rounded teeth
Dentate- leaf has triangular or tooth-like edges
Doubly serrate – edges with saw like teeth that have even smaller teeth within the larger ones
Entire – leaf edge is smooth
Incised – leaf margins have deep, irregular teeth
Lobed – leaf edges are deep and rounded
Serrate – leaf edges are sharp and saw-like (think serrated knife)
Serrulate – leaf edges with smaller, more evenly spaced serrations than a serrated leaf
Sinuate – margins are slightly wavy
Undulate – very wavy margins

Conifer and Ginkgo Leaves

Conifer types

Scale-like – Mature leaves common on most junipers and arborvitae
Awl-shaped – Juvenile leaves common on some junipers
Linear-shaped – Narrow flat needles of spruce, fir, and yews
Needle-like – The cluster of needles in pines creates a rounded shape.

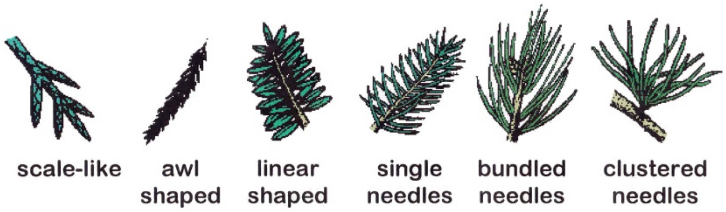


Figure 9. Conifer leaf types

Ginkgo type

Dichotomous venation – Somewhat parallel vein sections, forming a 'Y', found in Ginkgo trees. [Figure 10]

Figure 10. Dichotomous veined Ginkgo leaf

Leaf Venation

Monocots

Parallel venation – Veins run in parallel lines (monocot plants, e.g. grasses, lilies, tulips). [Figure 11]

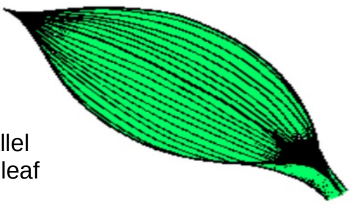


Figure 11. Parallel veined monocot leaf

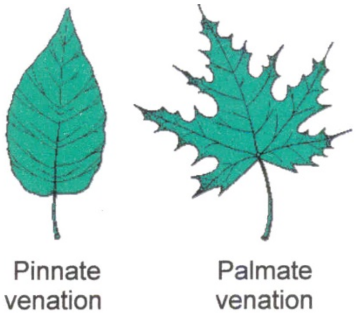
Dicots

Net-veined or reticulate-veined – Leaves with veins that branch from the main rib and then subdivide into finer veinlets (dicot plants**.** [Figure 12]

Pinnate venation – Veins extend from a midrib to the edge (elm, peach, apple, cherry).

Palmate venation – Veins radiate fan-shaped from the petiole (maple, grapes).

Figure 12. Venation of dicot leaves



Modified Leaves

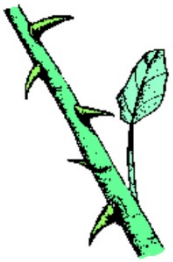
Adhesive disc – Modified leaf used as an attachment mechanism. Sometimes referred to as a holdfast (Boston ivy).

Bract – Specialized, often highly colored leaf below flower that often serves to lure pollinators (poinsettia, dogwood).

Thorn – Modified leaf (barberry, pyracantha).

Tendril – Modified sinuous leaf used for climbing or as an attachment mechanism (Virginia creeper, peas, grapes).

Figure 13. Thorns are modified leaves.



Internal Features

The leaf blade (flattened part of leaf) is composed of several layers.

Epidermis – Outer layer of tissues

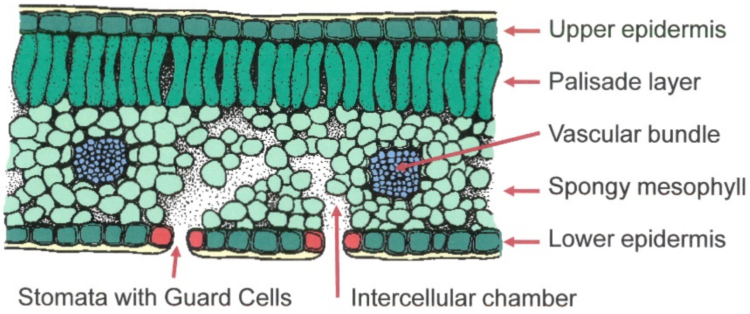
Cuticle – Waxy protective outer layer of epidermis that prevents water loss from leaves, green stems, and fruits. The amount of cutin or wax increases with light intensity.
Leaf hairs – Part of the epidermis

Vascular bundle – Xylem and phloem tissues, commonly known as leaf veins.

Stomates (Stomata) – Natural openings in leaves and herbaceous stems that allow for gas exchange (water vapor, carbon dioxide and oxygen) and plant cooling.

Guard cells – Specialized kidney-shaped cells that open and close the stomata.

Figure 1. Leaf Cross Sectional View with Stomates.



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MASTER GARDENER
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CMG GardenNotes #135

Plant Structures: Flowers

Thought question:

- My zucchini is blooming but doesn't set any fruit. Why?

Flowers are the reproductive structures of a flowering plant. Flowers are the primary structures used in grouping plant families.

Function

- Reproduction, beginning with pollination and fertilization.
- Advertisement and rewards to lure a pollinator.
- Horticultural uses
  - Aesthetic qualities
  - Cut flowers and potted blooming plants
  - Edible flowers and herbs
  - Plant identification

Structure

Pistil – Central female organ of the flower. It is generally bowling-pin shaped and located in the center of the flower. [Figure 1]

Stigma – Receives pollen, typically flattened and sticky
Style – Connective tissues between stigma and ovary
Ovary – Contains ovules (unfertilized, immature seeds) or embryo sacs
Ovules – Unfertilized, immature seeds

Stamen – Male flower organ [Figure 1]

Anthers – Pollen-producing organs
Filament – Stalk supporting anthers

Petals –Usually colorful modified leaves that make up the "flower", collectively called the ***corolla.*** They may contain perfume and nectar glands and are designed to attract pollinators. [Figure 1].

Sepals – Protective leaf-like enclosures for the flower buds, usually green, collectively called ***calyx.*** Sometimes highly colored like the petal as in iris [Figure 1].

Receptacle – Base of the flower [Figure 1]

Pedicel – Flower stalk of an individual flower in an inflorescence [Figure 1].

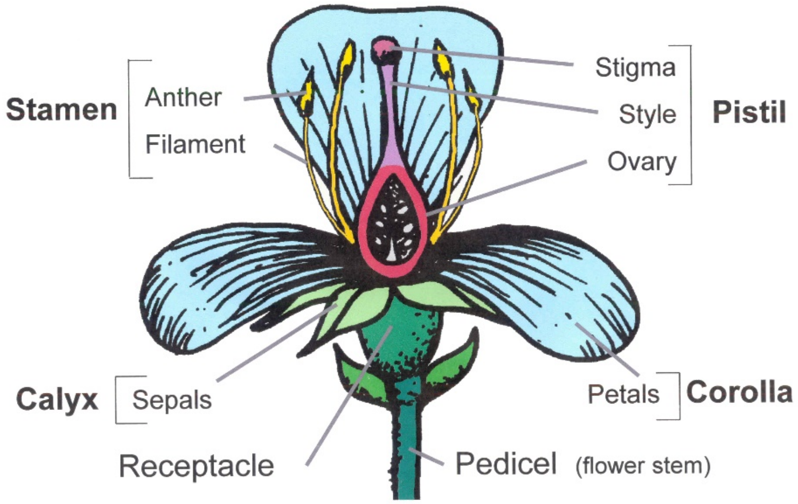

Figure 1. Parts of a Flower

Terms Defining Flower Types

Flowers

Complete – Flower containing sepals, petals, stamens and pistil
Incomplete – Flower lacking sepals, petals, stamens and/or pistils

Perfect – Flowers containing male and female parts
Imperfect – Flowers that lack either male or female parts

Pistillate – Flowers containing only female parts
Staminate – Flowers containing only male parts

Plants

Monoecious (mə-nē'shəs) – Plants with separate male flowers and female flowers on the same plant (corn, squash, and pine)
Dioecious (dī-ē'shəs) – Plants with male flowers and female flowers on separate plants (maple, holly, and salt brush)

Inflorescence (flower arrangement on a stem) [Figure 3]

Catkin – A spike with only pistillate or staminate flowers (poplar, walnut**,** willows)

Composite or Head – A daisy-type flower composed of ray flowers (usually sterile with attractive, colored petals) around the edge and disc flowers that develop into seed in center of the flat head (sunflower and aster) In some composites, the ray and disc flowers are similar (chrysanthemums, dahlias)

Corymb – Stemlets (*pedicels*) arranged along main stem. Outer florets have longer pedicels than inner florets giving the display a flat top. (yarrow, crabapple)

Cyme – A determinate, flat or convex flower, with inner floret opening first.

Panicle – An indeterminate flower with repeated branching. It can be made up of racemes, spikes, corymbs or umbels(begonia).

Raceme – A modification of a spike with flowers attached to a main stem (*peduncle*) by stemlets (*pedicel*) (snapdragon, bleeding heart)

Solitary (or single) – One flower per stem (tulip, crocus)

Spadix – Showy part is a bract or *spathe,* partially surrounding the male and female flowers inside. (calla, caladium)

Spike – Flowers attached to main stem, without stemlets, bottom florets open first. (gladiolus, ajuga and gayfeather)

Umbel – Florets with stemlets attached to main stem at one central point, forming a flat or rounded top. Outer florets open first. (dill, onion)

Symmetrical – Symmetrical flowers (lily)

Asymmetrical – Asymmetrical flowers (snapdragon)

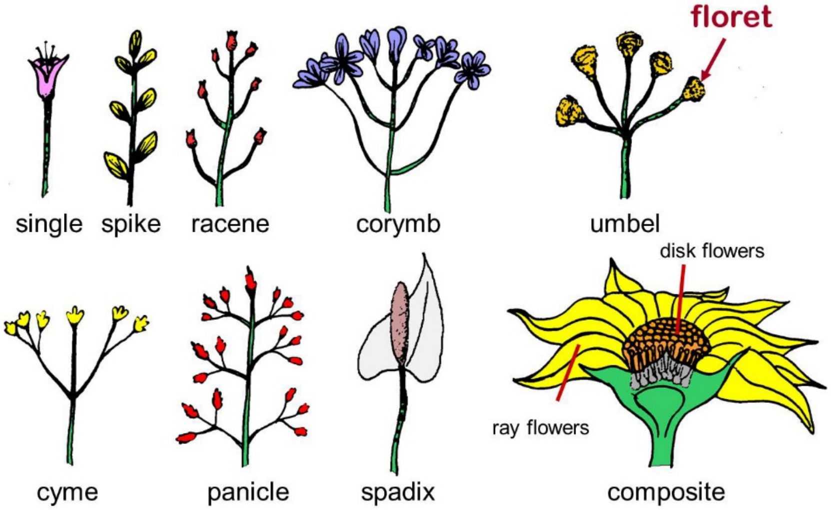

Figure 3. Flower Inflorescences

Nectar guides

To produce fruit and seed and insure their survival, plants need to be pollinated. Some flowers are wind pollinated (anemophilous), but most are not. They must attract an animal to assist with the process of moving pollen from the anthers to the stigma. Nectar, an energy rich fluid produced by flowers, along with the protein rich pollen, is the prize.

When pollinators collect nectar, the hairs on their bodies brush against the pollen and hold it tightly. As the pollinator moves to other flowers of the same species, the pollen can brush off onto the stigma and thus, pollination occurs.

To help bees and other pollinators find their way to their nectar, many plants have "nectar guides" on their flower petals. These may or may not be visible to humans. Often they are not; many are only visible in the ultraviolet range. Fortunately most insect pollinators can see in this light range and quickly find their way to the nectar. It's an example of mutualism which ensures efficient pollination for the plant and fast nectar and pollen collection for the insects.

Fig.4 Nectar guides on *Penstemon* (lines on flower)

Authors: David Whiting, Extension Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

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CMG GardenNotes #136

Plant Structures: Fruit

Thought question:

- Why are fading flowers removed from spring flowering bulbs and other flowering ornamental plants?

Fruit evolves from the maturing ovary following pollination and fertilization. Fruits can be either fleshy or dry. They contain one or more seeds**.**

Function

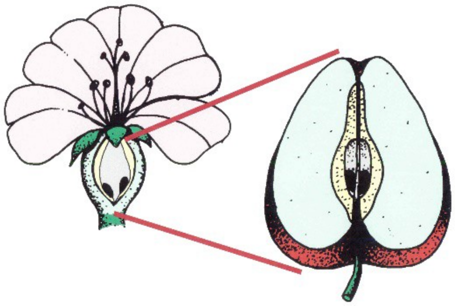
- Reproduction
- Horticulture uses
  - Feed, food, and oils
  - Aesthetic qualities
  - Plant identification

Structure

Fruit consists of carpels where the ovules (seeds) develop and the ovary wall or **pericarp**, which may be fleshy (as in apples) or dry and hard (as in an acorn). Some fruits have seeds (mature ovules) enclosed within the ovary (apples, peaches, oranges, squash and cucumbers). The peel of an orange, the pea pod, the sunflower shell, and the skin flesh and pit of a peach are all derived from the pericarp.

Other fruit have seeds that are situated on the periphery of the pericarp (corncob, strawberry flesh).

Figure 1. In apples, the ovary wall becomes the fleshy part of the fruit. Notice the small fruit structure in the blossom.



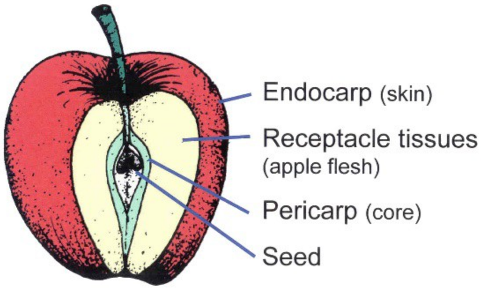
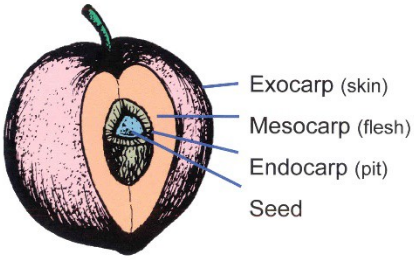


Figure 2. Pome fruit (apple)

Figure 3. Stone fruit (peach)

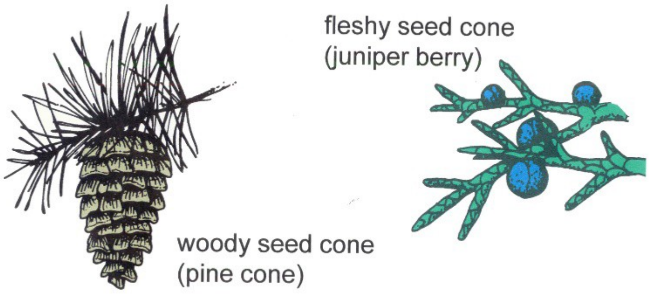


Fruit Types

Conifers

Conifers are best known for their woody cones, pinecones. Junipers are an example of a conifer with a fleshy cone (juniper berry). Upon close examination, the overlapping scales can be observed.

Figure 4. Fruit of conifers – Left: Woody seed cone (pinecone). Right: Fleshy seed cone (Juniper berry).



Flowering Plants

Depending on flower structure and inflorescence type, fruits may be either simple, aggregate**,** or multiple.

Accessory- fruit having some flesh derived from tissue exterior to the carpel.
Simple – Fruit formed from one ovary.
Aggregate – Fruit formed from a single flower with many ovaries. If not all ovaries are pollinated and fertilized, fruit will be misshapen (raspberry, magnolia).
Multiple – Fruit developed from a fusion of separate, independent flowers borne on a single structure (mulberry, pineapple, beet seed).

Fruit Growth Terms

Pollination – Transfer of pollen from the male flower to the stigma of the female flower.

Fertilization – Union of the pollen grain from the male flower with the egg cell in the female flower.

Drop – Fruit drops when not pollinated or fertilized and when too much fruit sets on a tree.

Growth –Primarily cell enlargement as the cells fill with water.

Climacteric – Point when a fruit will continue to ripen if removed from a plant; for example, pumpkins turning orange after being harvested.

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CMG GardenNotes #137

Plant Structures: Seeds

A seed (mature ovule) is a miniature plant with a protective cover in a suspended state of development. Most seeds contain a built-in food supply called endosperm (orchid is an exception). The endosperm can be made up of proteins, carbohydrates**,** or fats.

Function

- Propagation
- Feed
- Horticultural uses
  - Feed, food and oil

Structure and Emergence

Seeds of monocots and dicots differ in structure.

Monocot Seeds

Seed coat – Forms the wall of the embryo sack (mother tissue)

Endosperm – Food supply containing 3 sets of chromosomes (2 from the mother and 1 from the father)
Embryo – Immature plant

Cotyledon – Seed leaf
Plumule – Shoot

Radicle – Root

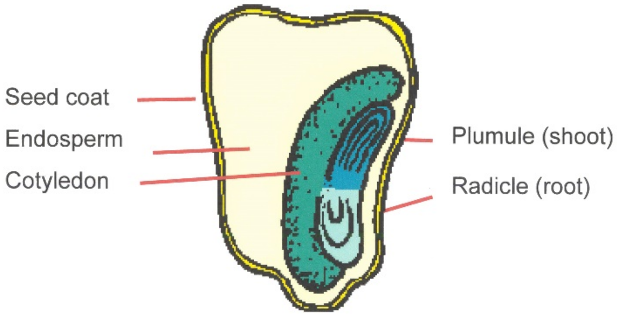


Figure 1. Cross section of monocot seed (corn).

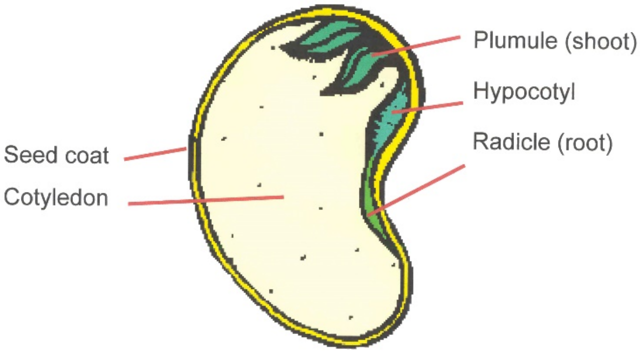
Dicot Seeds

Seed coat – The protective outer covering of a seed.

Embryo – Immature plant

Cotyledon – Food storing seed leaf
Plumule – Shoot
Hypocotyl – Stem
Radicle – Root

Figure 3. Cross section of dicot seed (bean).



Seed Growth and Development Terms

Dormancy – State of suspended growth to survive adverse conditions and aid in dispersion. Adapting plants to a variety of hostile environments, nature programs a variety of germination blocks. The following are common types.

Seed coat dormancy – When the seed coat is impermeable to water, and gases (oxygen). It requires action by weathering, microorganisms, passage through an animal's digestive track**,** or fire to soften the seed coat.

Embryo dormancy – Due to physiological conditions or germination blocks in the embryo itself. It requires a specific period of cold (or heat) with available moisture and oxygen. Embryo dormancy is common in woody plants.

Double dormancy – Condition of both seed coat and embryo dormancy.

Chemical inhibitor dormancy – Seed contains some type of chemical that blocks germination. Many desert plants contain chemical germination inhibitors that are leached out in a soaking rain.

Germination – Sprouting of seed following exposure to correct environmental conditions for the species

Stratification – Techniques used to overcome dormancy.

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CMG GardenNotes #141

Plant Physiology:
Photosynthesis, Respiration, and Transpiration

Thought question

Explain the science behind the following question

1. What's the impact on air temperatures when restrictions in landscape irrigation create droughty urban landscapes?

The three major functions that are basic to plant growth and development are:

- **Photosynthesis –** The process of capturing light energy and converting it to sugar energy, in the presence of chlorophyll using carbon dioxide (CO_2) and water (H_2O).
- **Transpiration –** The loss of water vapor through the stomates of leaves
- **Respiration –** The process of metabolizing (burning) sugars to yield energy for growth, reproduction**,** and other life processes

Photosynthesis

A primary difference between plants and animals is the plant's ability to manufacture its own food. In ***photosynthesis,*** carbon dioxide from the air and water from the soil react with the sun's energy to form ***photosynthates*** (sugars, starches, carbohydrates, and proteins) and release oxygen as a byproduct. [Figure 1]

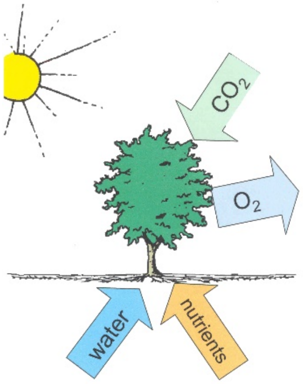

Figure 1. In photosynthesis, the plant uses water and nutrients from the soil and carbon dioxide from the air, with the sun's energy to create photosynthates. Oxygen is released as a byproduct.

Photosynthesis literally means *to put together with light.* It occurs only in the ***chloroplasts***, tiny sub-cellular structures contained in the cells of leaves and green stems. A simple chemical equation for photosynthesis is given as follows:

carbon dioxide + water + light energy = glucose + oxygen
$6CO_2$ + $6H_2O$ + light energy = $C_6H_{12}O_6$ + $6O_2$
.

This process is directly dependent on the supply of water, light**,** and carbon dioxide. Limiting any **one** of the factors on the left side of the equation (carbon dioxide, water, or light) can limit photosynthesis regardless of the availability of the other factors. An implication of drought or severe restrictions on landscape irrigation is a reduction in photosynthesis and thus a decrease in plant vigor and growth.

In a tightly closed greenhouse there can be very little fresh air infiltration and carbon dioxide levels can become limiting, thus limiting plant growth. In the winter, many large commercial greenhouses provide supplemental carbon dioxide to stimulate plant growth.

The rate of photosynthesis is somewhat temperature dependent. For example, when temperatures rise above 96°F in tomatoes, the rate of food used by respiration rises above the rate of food manufacture through photosynthesis. Plant growth comes to a stop and produce loses its sweetness. Most other plants are similar. [Figure 2]

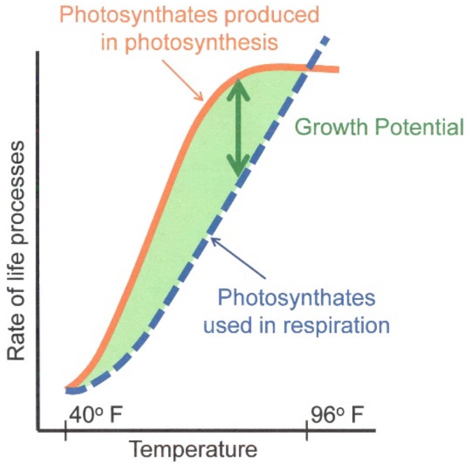

Figure 2. In the tomato plant, rates of photosynthesis and respiration both increase with increasing temperatures. As the temperature approaches 96°F, the rate of photosynthesis levels off, while the rate of respiration continues to rise.

Transpiration

Water in the roots is pulled through the plant by **transpiration** (loss of water vapor through the stomates of the leaves). Transpiration uses about 90% of the water that enters the plant. The other 10% is an ingredient in photosynthesis and cell growth.

Transpiration serves three essential roles:

- **Movement of minerals** up from the root (in the xylem) and sugars (products of photosynthesis) throughout the plant (in the phloem). Water serves as both the solvent and the avenue of transport.
- **Cooling** – 80% of the cooling effect of a shade tree is from the evaporative cooling effects of transpiration. This benefits both plants and humans.

- **Turgor pressure** – Water maintains the turgor pressure in cells much like air inflates a balloon, giving the non-woody plant parts form. Turgidity is important so the plant can remain stiff and upright and have a competitive advantage when it comes to light. Turgidity is also important for the functioning of the guard cells, which surround the stomates and regulate water loss and carbon dioxide uptake. Turgidity also is the force that pushes roots through the soil.

Water movement in plants is also a factor of osmotic pressure and capillary action.

Osmotic pressure is defined as water flowing through a permeable membrane in the direction of higher salt concentrations. Water will continue to flow in the direction of the highest salt concentration until the salts have been diluted to the point that the concentrations on both sides of the membrane are equal.
A classic example is pouring salt on a slug. Because the salt concentration outside the slug is highest, the water from inside the slug's body crosses the membrane that is his "skin". The slug dehydrates and dies. Envision this same scenario the next time you gargle with salt water to kill the bacteria that are causing your sore throat.

Fertilizer burn and dog urine spots in a lawn are examples of salt problems. The salt level in the soil's water becomes higher than in the roots, and water flows from the roots into the soil's water in an effort to dilute the concentration. So what should you do if you accidentally apply too much fertilizer to your lawn?

Capillary action refers to the chemical forces that move water as a continuous film rather than as individual molecules. Water molecules in the soil and in the plant cling to one another and are reluctant to let go. You have observed this as water forms a meniscus on a coin or the lip of a glass. Thus when one molecule is drawn up the plant stem, it pulls another one along with it. These forces that link water molecules together can be overcome by gravity.

Respiration

In ***respiration***, plants (and animals) convert the sugars (photosynthates) back into energy for growth and other life processes (metabolic processes). The chemical equation for respiration shows that the photosynthates are combined with oxygen releasing energy, carbon dioxide, and water. A simple chemical equation for respiration is given below. Notice that the equation for respiration is the opposite of that for photosynthesis.

$$\text{glucose} + \text{oxygen} = \text{energy} + \text{carbon dioxide} + \text{water}$$
$$C_6H_{12}O_6 + 6O_2 = \text{energy} + 6CO_2 + 6H_2O$$

Chemically speaking, the process is similar to the **oxidation** that occurs as wood is burned, producing heat. When compounds combine with oxygen, the process is often referred to as "burning", for example, athletes "burn" energy (sugars) as they exercise. The harder they exercise, the more sugars they burn so the more oxygen they need. That is why at full speed, they are breathing very fast. Athletes take in oxygen through their lungs. Plants take up oxygen through the stomates in their leaves and through their roots.

Again, respiration is the burning of photosynthates for energy to grow and to do the internal "work" of living. It is very important to understand that both plants and animals (including microorganisms) need oxygen for respiration. This is why overly wet or saturated soils are detrimental to root growth and function, as well as the decomposition processes carried out by microorganisms in the soil.

The same principles regarding limiting factors are valid for both photosynthesis and respiration.

Comparison of photosynthesis and respiration

Photosynthesis	←→	**Respiration**
Produces sugars from energy		Burns sugars for energy
Energy is stored		Energy is released
Occurs only in cells with chloroplasts		Occurs in most cells
Oxygen is produced		Oxygen is used
Water is used		Water is produced
Carbon dioxide is used		Carbon dioxide is produced
Requires light		Occurs in dark and light

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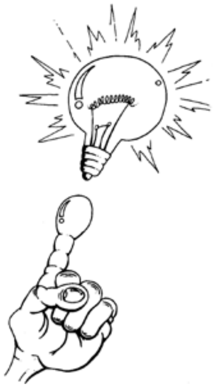
CMG GardenNotes #142

Plant Growth Factors: Light



Thought questions

Explain the science behind the following gardening questions.

- Why won't my African violets bloom? They are on a table near a bright northern window.
- Why is my flowerbed doing poorly? I planted it with a variety of semi-shade annuals since it gets sun only in the afternoon. Plant growth is minimal and foliage is bleached out. The impatiens wilt even when the soil is moist.
- I shear my shrubs a couple of times a year into nice rounded shapes. Why are they becoming thick woody stems at the base with lots of dead twigs?
- Why won't my Christmas cactus blossom? It is in front of a bright window and the plant is full and robust. It is a cutting from my mother's plant that she keeps in the guest bedroom and which blooms profusely each Christmas and again in the spring.

The quality, intensity, and duration of light directly impact plant growth.

Light Quality

Light quality refers to the color or wavelength reaching the plant's surface. A prism (or raindrops) can divide sunlight into respective colors of red, orange, yellow, green, blue, indigo and violet.

Red and blue have the greatest impact on plant growth. Green light is least effective (the reflection of green light gives the green color to plants). Blue light is primarily responsible for vegetative leaf growth. Red light, when combined with blue light, encourages flowering.

Light quality is a major consideration for indoor growing.

- Fluorescent cool white lamps are high in the blue range, and the best choice for starting seeds indoors.
- For flowering plants that need more red light, use broad spectrum fluorescent bulbs.
- Incandescent lights are high in red and red-orange, but generally produce too much heat for use in supplementing plant growth.

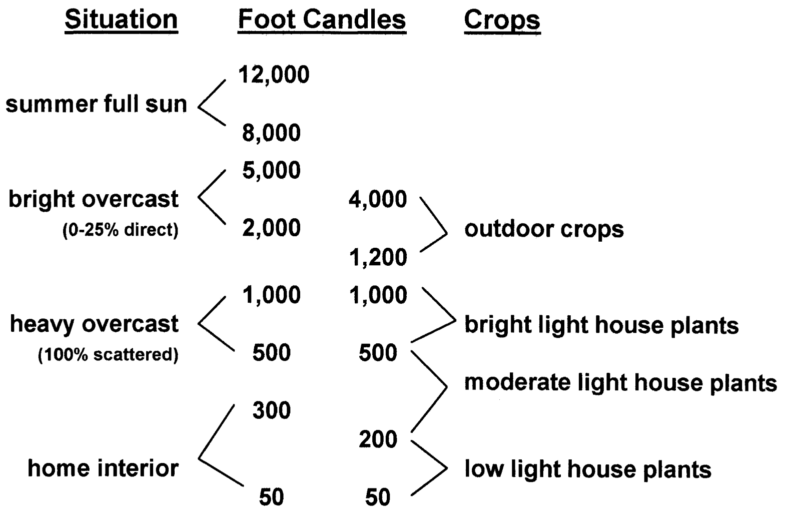
Figure 1. Relative efficiency of various light colors in photosynthesis.

Light Intensity

The more sunlight a plant receives, to a degree, the higher the photosynthetic rate will be. However, leaves of plants growing in low light readily sun scorch when moved to a bright location. Over time, as the wax content on a leaf increases, it will become more sun tolerant.

Figure 2. Light Intensity for Various Situations

Light intensity is measured in *lux* or *foot-candles*.



As illustrated in Figure 2, light levels in most homes are below that required for all but low light house plants. Except for rather bright sunny rooms, most house plants can only be grown directly in front of bright windows. Inexpensive light meters are available in many garden supply stores to help the indoor gardener evaluate light levels.

Landscape plants vary in their adaptation to light intensity. Many gardening texts divide plants into sun, partial sun and shade. However the experienced gardener understands the differences between these seven degrees of sun/shade:

Full sun – Direct sun for at least 8 hours a day, including from 9 a.m. to 4 p.m.

Full sun with reflected heat – Where plants receive reflected heat from a building or other structure, temperatures can be extremely hot. This situation significantly limits the choice of plants for the site.

Morning shade with afternoon sun – This southwest and west reflected heat can be extremely hot and limiting to plant growth.

Morning sun with afternoon shade – This is an ideal site for many plants. The afternoon shade protects plants from extreme heat.

Filtered shade – Dappled shade filtered through trees can be bright shade to dark shade depending on the tree's canopy. The constantly moving shade pattern protects under-story plants from heat. In darker dappled shade, only the more shade-tolerant plants will thrive.

Open shade – Plants may be in the situation where they have open sky above, but direct sunlight is blocked during the day by buildings, fences and other structures. Only more shade-tolerant plants will thrive here.

Closed shade – The situation where plants are under a canopy blocking sunlight is most limiting. Only the most shade-tolerant plants will survive this situation, like under a deck or covered patio.

In hot climates, temperature is often a limiting factor related to shade. Some plants, like impatiens and begonias, may require shade as an escape from heat. These plants will tolerate full sun in cooler summer climates.

Light penetration is a primary influence on correct pruning. For example, dwarf apple trees are pruned to a Christmas tree shape. This gives better light penetration for best quality fruit. Mature fruit trees are thinned each spring for better light penetration. A hedge should be pruned with a wider base and narrow top. Otherwise the bottom thins out due to the shade from above. A common mistake in pruning flowering shrubs is to shear off the top. The resulting regrowth gives a thick upper canopy that shades out the bottom foliage.

Figure 3. Light penetration is a primary influence in pruning. Left: Dwarf apple trees pruned to a Christmas tree shape allow better light penetration for best quality fruit. Right: Regrowth on flowering shrubs that are sheared on top is a very heavy upper canopy growth. This shades out the bottom creating a woody base.

Light Duration

Light duration refers to the amount of time that a plant is exposed to sunlight. Travelers to Alaska often marvel at the giant vegetables and flowers that grow under the long days of the arctic sun even with cool temperatures.

Plants are generally intolerant of continuous light for 24 hours.

Photoperiod

The flowering response of many plants is controlled by the ***photoperiod*** (the length of uninterrupted darkness). Photoperiod response can be divided into three types.

Short day plants flower in response to long periods of night darkness. Examples include poinsettias, Christmas cactus, chrysanthemums, and single-crop strawberries.

Long day plants flower in response to short periods of night darkness. Examples include onions and spinach.

Day neutral plants flower without regard to the length of the night, but typically flower earlier and more profusely under long daylight regimes. Day neutral strawberries provide summer long harvesting (except during heat extremes).

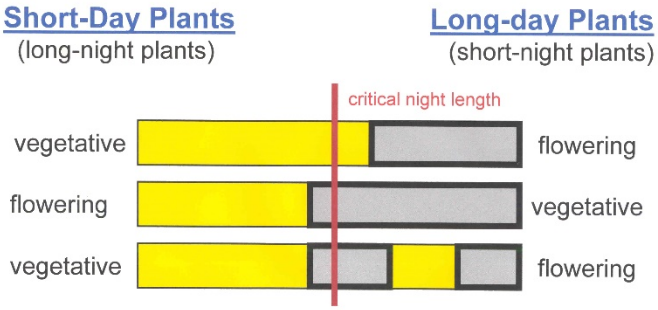


Figure 4. Photoperiod and Flowering - Left side: Short day plants flower with uninterrupted long nights. Right side: Long-day plants flower with short nights or interrupted long nights.

Authors: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson, David Whiting, and USDA. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

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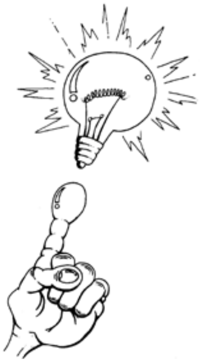
CMG GardenNotes #143

Plant Growth Factors: Temperature



Thought questions

Explain the science behind the following gardening questions.

- Why was there so much winter injury on my trees and shrubs? While it was dry and windy, temperatures were not extremely cold.
- My arborvitaes are bleached tan from the winter. Will they green-up with spring temperatures?
- With the rather hot summer, will the apple and peach crop be as sweet as normal?

Temperature Considerations

Temperature factors that figure into plant growth potentials include the following:

- Maximum daily temperature
- Minimum daily temperature
- Difference between day and night temperatures
- Average daytime temperature
- Average nighttime temperature

Microclimates

Microclimates are small areas where environmental conditions may be different than the general surrounding area. The microclimate of a garden plays a primary role in actual garden temperatures. In mountain communities, changes in elevation, air drainage, exposure, and thermal heat mass (surrounding rocks) will make some gardens significantly warmer or cooler than the temperatures recorded for the area. In mountain communities, it is important to know where the local weather station is located so gardeners can factor in the difference in their specific location to forecast temperatures more accurately. Examples of factors to consider include the following:

Elevation – A 300 foot rise in elevation accounts for approximately 1°F drop in temperature.

Drainage – At night, cool air drains to low spots. Valley floors may be more than 10°F cooler than surrounding gardens on hillsides above the valley floor. That is why fruit orchards are typically located on the benches rather than on the valley floor.

Figure 1. This garden on the hillside above Steamboat Springs, Colorado (a mountain community with a short frost-free season) has good drainage giving it a growing season that is several weeks longer than down in town.

Exposure – Southern exposures absorb more solar radiation than northern exposures. In mountain communities, northern exposures will have shorter growing seasons. In mountain communities, gardeners often place warm season plants, like tomatoes, on the south side of buildings to capture more heat.

Based on local topography, buildings, fences, plantings and garden areas may be protected from or exposed to cold and drying winds. They may also be exposed to or protected from warm and drying winds.

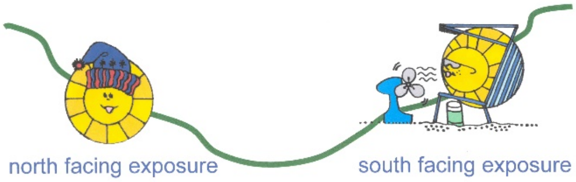


Figure 2. Temperatures and growing season vary greatly based on exposure. A north facing exposure will typically be cooler and moist. A south facing exposures will typically be hot and dry.

Thermal heat mass (surrounding rocks) – In many Colorado communities, the surrounding rock formations can form heat sinks creating wonderful gardening spots for local gardeners. Nestled in among the mountains, some gardeners have growing seasons several weeks longer than neighbors only a half mile away.

In cooler locations, rock mulch may give some frost protection and increase temperatures for enhanced crop growth. In warmer locations, rock mulch can significantly increase summer temperatures and water requirements of landscape plants. [Figure 3]

In Phoenix, Arizona, the urban heat island (with all the rock mulch instead of grass and trees) has significantly raised day and night temperatures. The upward convection of heat has become so strong that summer storms go around the city and are not raining on the urban heat island.

Figure 3. The sidewalks and stone walls of this intercity plaza creates a heat pocket with a frost free periods three months longer than the surrounding neighborhood.

Influence of Heat on Crop Growth

Temperature affects the growth and productivity of plants, depending on whether the plant is a warm season or cool season crop.

<u>Photosynthesis</u> – Within limits, rates of photosynthesis and respiration both rise with increasing temperatures. As temperatures reach the upper growing limits for the crop, the rate of food used by respiration may exceed the rate at which food is manufactured by photosynthesis. For tomatoes, growth peaks at 96°F.

<u>Temperature influence on growth</u>

Seeds of cool season crops germinate at 40º to 80º. Warm season crop seeds germinate at 50°F to 90°F. In the spring, cool soil temperatures are a limiting factor for plant growth. In mid-summer, hot soil temperatures may prohibit seed germination.

<u>Examples of temperature influence on flowering</u>

- Tomatoes
    - Pollen does not develop if night temperatures are below 55°F.
    - Blossoms drop if daytime temperatures rise above 95°F before 10 a.m.
    - Tomatoes grown in cool climates will have softer fruit with bland flavors.
- Spinach (a cool season, short day crop) flowers in warm weather with long days.
- Christmas cacti and poinsettias flower in response to cool temperatures and short days.

Examples of temperature influence on crop quality

- High temperatures increase respiration rates, reducing sugar content of produce. Fruits and vegetables grown in heat will be less sweet.
- In heat, crop yields reduce while water demand goes up.
- In hot weather, flower colors fade and flowers have a shorter life.

Table 1 illustrates temperature differences in warm season tomatoes and cool season cole crops.

Table 1.
Temperature Comparison of Cool Season and Warm Season Crops

Temperature for	**Cool Season:** broccoli, cabbage, and cauliflower	**Warm Season:** tomatoes, peppers, squash, and melons
Germination	40°F to 90°F, 80°F optimum	50°F to 100°F, 80°F optimum
Growth	Daytime • 65°F to 80°F preferred • 40°F minimum Nighttime • >32°F, tender transplants • > mid-20s°F, established plants	Daytime • 86°F optimum • 60°F minimum • A week below 55°F will stunt plant, reducing yields Nighttime • >52°F
Flowering	Temperature extremes lead to bolting and buttoning.	• Nighttime <55°F, non-viable pollen (use blossom set hormones) • Daytime >95°F by 10 a.m., blossoms abort
Soil	Cool • Use organic mulch to cool soil. • Since seeds germinate best in warm soils, use transplants for spring planting, and direct seeding for mid-summer plantings (fall harvest).	Warm • Use black plastic mulch to warm soil, increasing yields and earliness of crop.

Heat Zone Map

A new concept in plant selection is ***heat zone mapping***, a measurement of the typical summer heat accumulation. It will help identify geographic areas that have adequate heat accumulation to mature various crops.

The American Horticultural Society's Heat Zone Map can be viewed online at: www.ahs.org/publications/heat_zone_map.htm.

Heat zones can be sorted by zip codes. To look up a heat zone by zip code, go

online at www.ahs.org/publications/heat_zone_finder.htm.
It should be recognized that in mountain communities, minor changes in elevation and exposure (for example, south slopes versus north slopes) make significant differences in heat accumulation. A heat zone for a community's zip code may not reflect the actual growing conditions in any specific garden.

Influence of Cold Temperatures

Hardiness Zone Map

Hardiness zone maps indicate the average annual minimum temperature expected for geographic areas. While this is a factor in plant selection, it is only one of many factors influencing plant hardiness.

In 2012, the U.S. Department of Agriculture released a new USDA Hardiness Zone Map. It can be found at http://planthardiness.ars.usda.gov/PHZMWeb/. It documents a climate zone creep, that is zones moving northwards in recent years. Zones are based on a 10°F difference in average annual minimum temperature.

Average Annual Minimum Temperature	
Zone 4	-20°F to –30°F
Zone 5	-10°F to –20°F
Zone 6	0°F to –10°F

Most of the Colorado Front Range area falls into Zone 5, with cool mountain areas in Zone 4. Warmer locations in the Denver Metro, Fort Collins, El Paso, and Pueblo Counties fall into Zone 6. Warmer areas of western, southwestern, and southeastern Colorado are in Zone 6.

Plant Hardiness

Hardiness refers to a plant's tolerance to cold temperatures. Low temperature is only one of many factors influencing plant hardiness (ability to tolerate cold temperatures). Key hardiness factors include the following: [Figure 4]

- Photoperiod
- Genetics (source of plant material)
- Low temperature
- Recent temperature pattern
- Rapid temperature changes
- Moisture
- Wind exposure
- Sun exposure
- Carbohydrate reserve

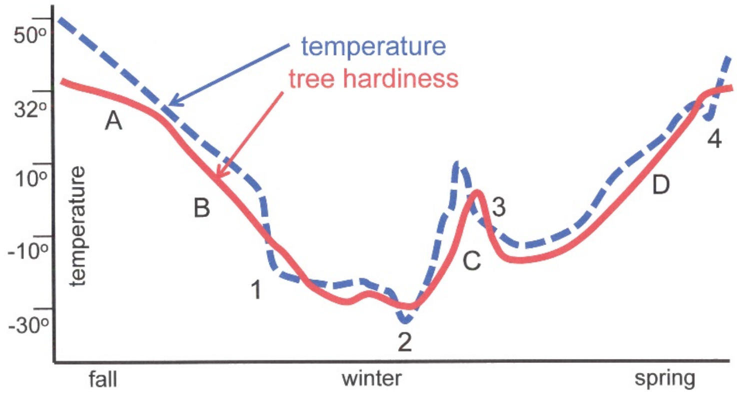


Figure 4. Influence of temperature change on winter hardiness of trees – The solid line represents a tree's hardiness. Regions A-D represents various stages of hardiness through the winter season. The dotted line represents temperature. When the dotted (temperature) line drops below the solid (hardiness) line, damage occurs. Points 1-4 represent damage situations.

A. Increased cold hardiness induced by shorter day length of fall.
B. Increased cold hardiness induced by lowering temperatures.
C. Dehardening due to abnormally warm mid-winter temperatures.
D. Normal spring dehardening as temperatures warm.

1. Injury due to rapid drop in temperatures with inadequate fall hardening.
2. Injury at temperatures lower than hardening capability.
3. Injury due to rise and fall of midwinter temperatures.
4. Injury due to spring frosts.

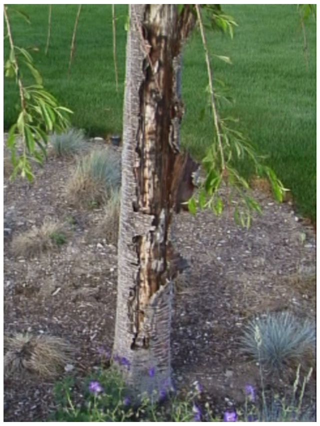
Examples of Winter Injury

Bud kill and dieback – From spring and fall frosts

Root temperature injury – Roots have limited tolerance to sub-freezing temperatures. Roots receive limited protection from soil, mulch, and snow. Under extreme cold, roots may be killed by the lack of snow cover or mulch. Street trees are at high risk for root kill in extreme, long-term cold.

Soil heaving pushes out plants, breaking roots. Protect with snow cover or mulch.

Trunk injury – Drought predisposes trunks to winter injury.



Sunscald – Caused by heating of bark on sunny winter days followed by a rapid temperature drop, rupturing membranes as cells freeze. Winter drought predisposes tree trunks to sunscald. [Figure 5]

Figure 5. Southwest bark injury is common on trees that are drought stressed, such as this tree with a restricted root spread.

Frost shake – Separation of wood along one or more growth rings, typically between phloem (inner bark) and xylem (wood), caused by sudden rise in bark temperature.

Frost crack – Vertical split on tree trunk caused by rapid drop in bark temperature. [Figure 6]

Figure 6. Vertical frost crack is common on trees when the temperature drops rapidly. In Colorado it is common to go from a nice spring day back to cold with a 40 to 60 degree temperature drop in an hour!

Winter injury on evergreens

Winter drought – Water transpires from needles and cannot be replaced from frozen soils. It is more severe on growing tips and on the windy side of trees. [Figure 7]

Sunscald – Winter sun warms needles, followed by rapid temperature drop rupturing cell membranes. It occurs typically on southwest side, side of reflected heat, or with sudden shade.

Photo-oxidization of chlorophyll – Foliage bleaches during cold sunny days. Needles may green-up again in spring.

Tissue kill – Tissues killed when temperatures drop below hardiness levels.

Figure 7. Winter drought, sunscald, and photo-oxidization of chlorophyll are common on arborvitae. It's a poor plant choice for this windy site with little winter moisture.

Rest Period

An accumulation of cool units controls the flowering period of temperate-zone woody plants. The winter rest period (hours below 45°F) required to break bud dormancy includes:

Apricot	350-900 hour	Peach	800-1200 hours
Apple	250-1700 hours	Pear	200-1500 hours
Cherry, sour	600-1400 hours	Plum, European	900-1700 hours
Cherry, sweet	500-1300 hours	Plum, Japanese	300-1200 hours

Author: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension.

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MASTER GARDENER
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CMG GardenNotes #144

Plant Growth Factors: Water

Outline:
Role of water, page 1
Common symptoms of water stress, page 2
Relative humidity, page 3

Thought Question

1. Review how water stress impacts plant growth processes, then list common symptoms of drought stress.

In Colorado, water availability and quality can be a limiting factor in plant growth. Quality issues are generally related to excessive sodium or other soluble salts.

Available water limits potential for crops and gardens in many areas of the west. In cities, the cost of the infrastructure to supply water drives the need for water conservation.

Water management is a topic of other Colorado Master Gardener training classes. For additional information on water management, refer to CMG GardenNotes on Irrigation Management and Water-Wise Landscape Design.

Role of Water

Plants are over 90% water. Roles of water are summarized in Table 1.

Table 1.
Role of Water in Plant Growth

Role of water in plants	Impact of water shortage
• Primary component of photosynthesis and transpiration	• Reduced growth and vigor
• Turgor pressure (pressure to inflate cells and hold plant erect)	• Wilting
• Solvent to move minerals from the soil up to the plant o NO_3^-, NH_4^+, $H_2PO_4^-$, HPO_4^{-2}, K^+, Ca^{+2}, Mg^{+2}, SO_4^{-2}, $H_2BO_3^-$, Cl^-, Co^{+2}, Cu^{+2}, Fe^{+2}, Fe^{+3}, Mn^{+2}, MoO_4^{-2}, and Zn^{+2}	• Reduced growth and plant vigor • Nutrient deficiencies
• Solvent to move products of photosynthesis throughout the plant, including down to the root system	• Reduced health of roots which leads (over time) to reduced health of plant
• Regulation of stomatal opening and closure, thus regulating transpiration and photosynthesis	• Reduced plant growth and vigor • Reduced cooling effect = warmer micro-climate temperatures
• Source of pressure to move roots through the soil	• Reduced root growth = reduced plant growth and vigor
• Medium for biochemical reactions	• Reduced plant growth and vigor

Common Symptoms of Water Stress

Drought

- Decreased growth
- Small, off-colored leaves
- Decline from top down
- Early fall color
- Reduced xylem growth = long-term growth reduction
- Stress may show up five or more years later

Water Logged Soils

- Root activity slows or shuts down, and plants show symptoms of drought
- Decline in root growth slows plant growth processes
- Leaves may wilt from lack of water uptake
- Root rots are common in some species

- Lower interior leaves may yellow

Leaf Scorch (short-term water deficiency in leaves)

- Marginal burning
- Often from the top down, on southwest side, or from the side with root injury or root restrictions

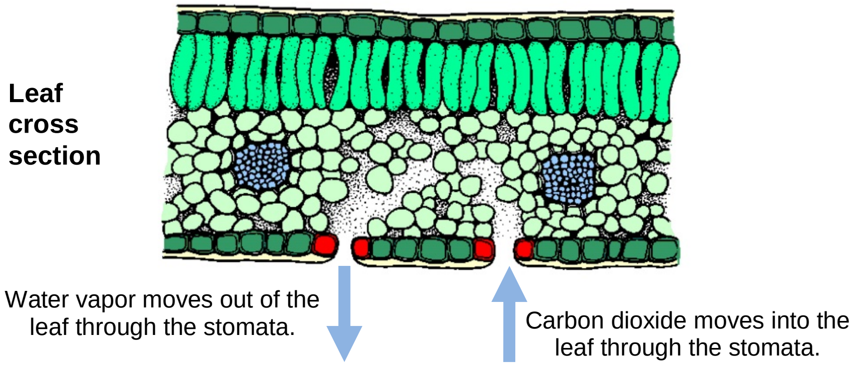
Contributing factors to leaf scorch

- Dry or overly wet soils
- Compacted soils
- Limited root spread
- Root injury
- Structural damage to xylem tissues
- Trunk and branch injury
- Excessive wind and heat
- Excessive canopy growth (from heavy fertilization)

Relative Humidity

Water moves from areas of high relative humidity to areas of lower relative humidity. Inside a leaf, the relative humidity between cells approaches 100%. When the stomata open, water vapors inside the leaf rush out forming a bubble of higher humidity around the stomata on the outside of the leaf.

The difference in relative humidity around the stomata and adjacent air regulates transpiration rates and pulls water up through the xylem tissues. Transpiration peaks under hot dry and/or windy conditions. When the supply of water from the roots is inadequate, the stomata close, photosynthesis shuts down, and plants can wilt.



Outdoors – In the arid climate of the west, low summer humidity helps manage some insect and disease problems and can aggravate others. The relative humidity returns to normal levels within a few minutes of watering/irrigation.

Indoors – With forced air heating, many homes have very low relative humidity in the winter. Some homes can have excessively high relative humidity due to a large number of houseplants, cooking and frequent long showers. Both extremely high and low indoor relative humidity are health concerns.

Authors: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

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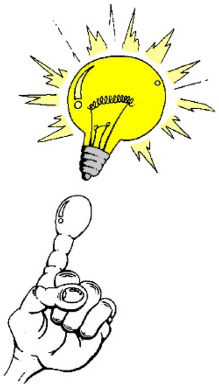
CMG GardenNotes #145

Plant Growth Factors: Plant Hormones



Thought questions

Explain the science behind the following gardening questions:

- A couple of times a year, I shear my shrubs into rounded shapes. Now the shrubs have large woody stems with a lot of dead branches. How do I correct this?
- I put a stake next to a small tree trunk to keep it straight. When I took it off a year later the trunk had a worse bend than before. Why?

Plant Hormones and Plant Growth Regulators

Another factor in plant growth is the influence of plant hormones. ***Hormones*** are chemicals produced by plants that regulate the growth processes.

Plant growth regulators are chemicals applied to regulate plant growth. In plant propagation, cuttings are dipped in a rooting hormone to stimulate root development. In greenhouse production, many potted flowering plants (like poinsettias and Easter lilies) may be treated with plant growth regulators to keep them short. Seedless grapes are treated with plant growth regulators to increase the size of the fruit. In certain situations, turf may be treated to slow growth and mitigate the need for mowing. Because plant growth regulators are effective in parts per million or parts per billion, they have little application in home gardening.

Plant Hormones

Different hormones affect different plant processes. Understanding how hormones work allows horticulturists to manipulate plants for specific purposes.

Auxins produced in the terminal buds suppress the growth of side buds. This focuses the growth of the plant upward rather than outward. If the terminal bud is removed during pruning (or natural events) the lateral buds will develop and the stem becomes bushy. Auxins also stimulate root growth and affect cell elongation (tropism), apical dominance, fruit drop or retention.

Figure 1. Auxins produced in the rapidly growing terminal buds suppress growth of side buds, giving a young tree a more upright form. As growth rates slow with age, reduction in apical dominance gives the maturing tree a more rounded crown.

Gibberellins affect:

- The rate of cell division
- Flowering
- Increase in size of leaves and fruits
- Seed and bud dormancy
- Induction of growth at lower temperatures (used to green up lawns 2 to 3 weeks earlier)

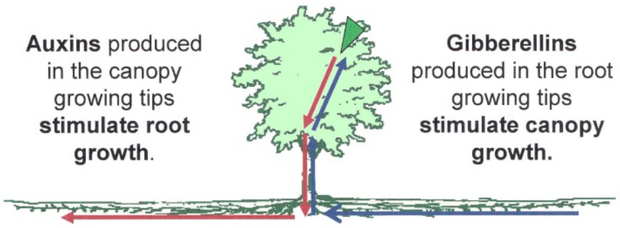
Cytokinins promote cell division, and influence cell differentiation and aging of leaves.

Abscisic acid is considered the “stress” hormone. It inhibits the effects of other hormones to reduce growth during times of plant stress.

Hormone Influence On Pruning

Understanding hormones is key to proper pruning. **Auxin** produced in the terminal buds suppresses growth of side buds and stimulates root growth. **Gibberellins** produced in the root growing tips stimulate shoot growth. Pruning a newly planted tree removes the auxin, slowing root regeneration.

Figure 2. Trees balance canopy growth with root growth by concentrations of auxinx and gibberellins.



Heading cuts (removal of a branch tip) releases the apical dominance caused by auxins from the terminal bud. This allows side shoots to develop and the branch becomes bushier. On the other hand, ***thinning cuts*** remove a branch back to the branch union (crotch). This type of cut opens the plant to more light. Most pruning should be limited to thinning cuts. For details on pruning, refer to CMG Pruning fact sheets.

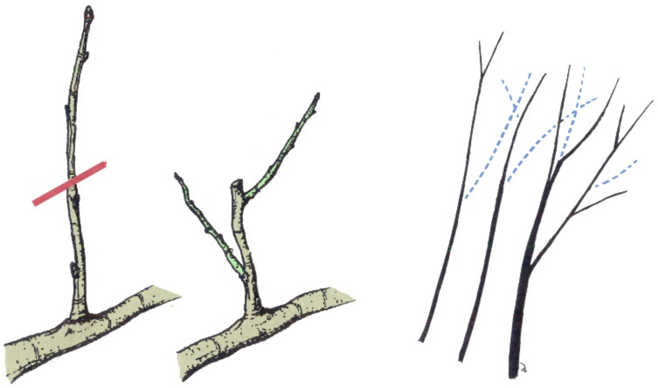


Figure 3. Left: A **heading cut** releases apical dominance and the branch becomes denser as the lateral buds begin to grow. Right: A **thinning cut** removes a branch back at a branch union (crotch), opening the plant for better light penetration. Thinning cuts promote an open growth habit by redirecting sugars to the terminal shoots.

Tropisms

Auxins also play a key role in ***tropism*** (controlling the direction of plant growth).

Figure 4. ***Geotropism*** – Under the influence of gravity, auxins accumulate in the lower side of a horizontal stem, causing cells to enlarge faster, turning the stem upright.

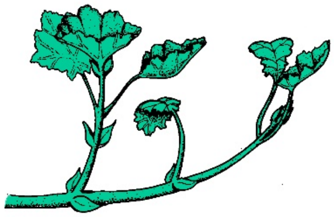
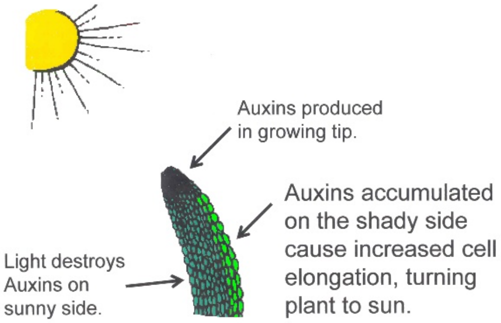


Figure 5. ***Phototropism*** – Auxin concentrations on the shaded side stimulates cell elongation, turning the stem to the sun.



Authors: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension; with Michael Roll and Larry Vickerman (former CSU Extension employees). Line drawings by Scott Johnson and David Whiting. Revised by Patti O'Neal, Roberta Tolan and Mary Small, CSU Extension.

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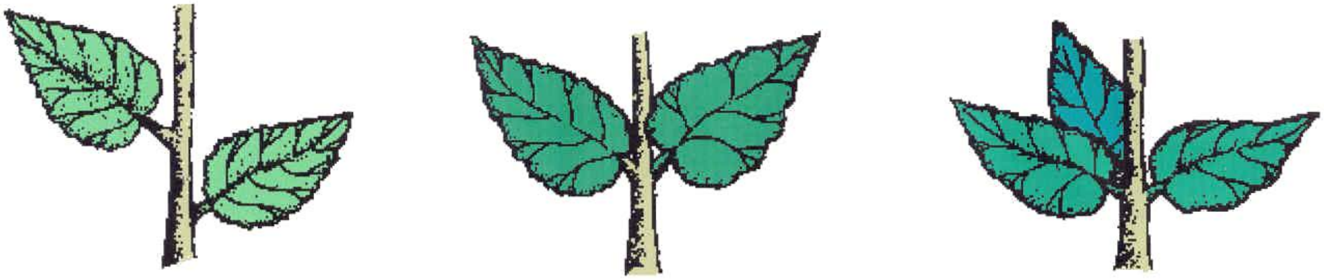
Identifying Trees and Shrubs

References and Review Questions



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  - ***Manual of Woody Landscape Plants, Sixth Edition.*** Michael A. Dirr. Stipes. 1998
  - ***Trees and Shrubs of Colorado.*** Jack L. Carter. Second edition, 2006
  - ***Winter Guide to Central Rocky Mountain Shrubs.*** Colorado Department of Natural Resources, Division of Wildlife. 1976

- **Web**
  - *USDA Plant Data Base* at https://plants.usda.gov/java/
  - Colorado State University Online Herbarium at https://herbarium.biology.colostate.edu/collection/specimens/
  - International Plant Name Index at http://www.ipni.org/ipni/plantnamesearchpage.do
  - Royal Botanic Gardens, Kew Resource Page at https://www.kew.org/science/data-and-resources/names

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Identifying Trees and Shrubs curriculum developed by Alison O'Connor, David Whiting, Linda McMulkin, and Christine Prins, CSU Extension. Line drawings by Scott Johnson and David Whiting.

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CMG GardenNotes #171

Identifying Trees and Shrubs

Outline:

I. Introduction

Plant identification is a skill that takes time and patience to develop. There are a myriad of rewards for developing this skill including:

- Serving your community as an informed plant expert
- Confidently communicating with clients about plant ID-related questions
- Enhanced ability to utilize plant diagnostics materials (most are based on plant identification)
- Obtaining the personal satisfaction of knowing the names of plants in gardens, landscaping, and in natural areas

The steps to plant identification involve observation, questioning, and research, similar to the process learned in diagnosing tree disorders (*CMG GardenNotes* #112).

Colorado Master Gardeners are often asked to identify plants either over the phone, with photos, or with a single leaf or plant part. Asking informed questions about the plant may provide the details needed for successful identification, but more than likely you will need to see a sample. Good samples include the stem with leaves attached, and flowers or fruit whenever possible.

For details on the taxonomic system, including use of scientific names, refer to *CMG GardenNotes* #122, **Taxonomic Classification**.

II. Plant Identification Tools

The most important skill used in successful plant identification is the ability to observe and define the characteristics of an individual plant. Examine the plant and note the overall appearance, and the structure, shape, and texture of stems, leaves, flowers and fruit, as well as any available roots. Use visual clues as well as the texture and scent of the plant. However, use caution, as some plants or plant parts are known to be irritating or toxic. One thing to keep in mind when observing plant characteristics is that even on the same plant, there is variation in each of the leaves, stems, flowers, etc. Your chances of a correct identification increase when you look at the characters as an average from the whole plant, not just from one or two leaves.

Simple tools such as a hand lens, ruler, and a sharp blade (knife, scalpel or pruning shears) are helpful for examining plant parts. For more detailed work, a dissecting microscope is useful, especially for observing the details of small hairs or floral parts.

If you aren't able to identify a plant on the spot, you can collect samples (with permission only) for future identification or simply maintaining a visual collection of your own! Samples can be stored short-term in resealable plastic bags in the refrigerator for 1-2 weeks. Long-term storage involves pressing the sample between layers of newspaper in a plant press or between flat, heavy objects (stacks of books work well). When the specimen is completely dried, it can be mounted on special herbarium paper.

There are many references available for plant identification, both print and electronic. While photo books are easy to use, they often only contain the most common of species (otherwise photo books would large, heavy, and very expensive). Website search features often require that the user already know something about the family or the name of the plant, but they are very useful in confirming identification or to obtain additional information regarding characteristics.

a. Plant Identification Keys

Plant Identification keys are designed to systematically compare plant structures until the identification of a plant species is reached. Authors of plant keys use the most up-to-date and scientific references to design a series of choices based on differing plant characteristics. In most cases, keys attempt to use easily distinguishable characteristics. However, when groups are more similar (i.e. determining between species or subspecies), the characters used in sorting out groups will require closer inspection and greater attention to detail.

i. Dichotomous Keys

The term "dichotomous" comes from the Greek word *dikhotomos*, which means "to cut in two". The premise of a dichotomous key is to give two choices, and only two choices, at each step. The step is called a couplet and will compare variations in similar plant characteristics, such as

1a. Leaves narrow, less than ½ inch……..….go to 2
1b. Leaves wider than ½ inch……………….go to 7

Read both statements in the couplet and choose the statement that best describes the plant being examined. Each statement is followed by a number, which indicates the next couplet you will read. If the leaf width is less than ½ inch, move down to the couplet labeled 2a and 2b. If the leaf width is more than ½ inch, skip couplets 2 through 6 and resume the process at 7a and 7b. Remember: try to look at the average appearance of the plant as a whole to answer questions about individual characteristics.

When you reach a couplet that gives you a plant name instead of a number, you have reached your identification. Check with your online and print resources to check that your identification is correct!

ii. Outline Keys

In outline keys, the options you compare are at each indentation level. More often these options not be adjacent in line order. For example, from the key below the first choice would be either I (needles single) or II (needles in clusters). If the needles were single, the next choice would be a (needles flat) or b (needles square).

- I. Needles single
  - a. Needles flat in cross-section and flexible
    - **i.** Leaf scar oval, bud tips pointed – ***Pseudotsuga*** **(Douglas fir)**
    - ii. Leaf scar round, bud tips roundish – ***Abies*** **(fir)**
  - b. Needles square in cross-section and stiff – ***Picea*** **(spruce)**
- II. Needles in clusters of 2 or more – ***Pinus*** **(pine)**

There are many key formats that give you more than just two options to evaluate each subsequent level. Select the characteristics that best describe the plant as a whole.

III. Terminology

The terminology of plant identification can be intimidating to a beginner, as well as the experienced plant taxonomist. There are specific terms for the tiniest of traits. For example, in ***Plant Identification Terminology: An Illustrated Glossary***, James Harris lists 35 terms that describe the hairs on the surfaces of stems and leaves. Because there are so many specific terms, most plant taxonomists have specific glossaries with drawings (such as the one listed above).

Most keys and photo references also often contain a glossary with definitions of the botanical terms used in that publication. With practice, commonly used words become familiar; however, there are some terms that are used infrequently. There is no need to memorize all botanical terms! Use your resources and look them up as needed. When you are first learning to use botanical terms, it is often helpful to draw a picture of the structures or paraphrase the definitions in your own words.

IV. The Plant Identification Process

Plant identification is a process that begins with observing the plant as a whole, followed by systematically evaluating the details of the plant parts. When observing the whole plant, take some notes and draw some pictures of the larger features. Attention to detail is important in plant identification, but at the beginning of the process, try not to get overwhelmed with those details. There are an unlimited numbers of features on each plant, but you will only require some of them to identify the plant. The necessary details can be determined as you work through the key. Follow these first steps to get you started in your plant identification process—these will provide you with the larger features that will narrow down your possibilities before diving into more detailed observations.

a. Step 1: Collect Basic Information Regarding the Plant

i. Determine if the Tree/Shrub is a Conifer or a Broadleaf Flowering Plant

- **Conifers** are woody trees and shrubs generally with <u>needle-like or scale-like foliage</u>, and usually evergreen. Seeds are produced in cones, which are generally woody, (like a pine cone) but sometime fleshy and berry-like (juniper fruit) (see **Figure 1**). Examples include arborvitae, Douglas fir, fir, junipers, larch, pine, spruce, and yews.

  Conifers are *Gymnosperms* (along with *Ginkgo biloba* and cycads), which are a group of plants that do not flower, but instead produce seed in a 'cone' structure made of modified leaves called scales. The term 'Gymnosperm' literally means "naked seed" and refers to the exposure of the female reproductive structure during pollination (instead of wrapped in an ovary as in flowering plants) rather than the actual seed being uncovered.

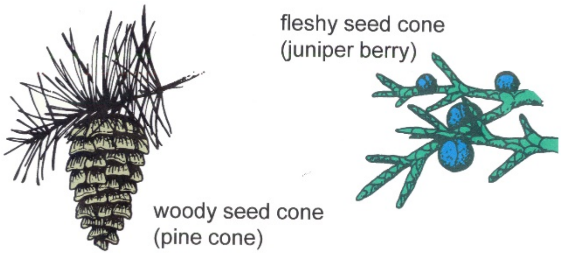

Figure 1: Woody and fleshy cones of conifers

- **Broadleaf flowering plants** are *Angiosperms*, which is a highly diverse group of plants that produce flowers and seeds enclosed in fruits. Flowers range from tiny and inconspicuous to large and showy.. This group includes woody trees, shrubs, and vines and is often referred to as broadleaf plants due to the <u>large, flattened leaf blade</u> (see **Figure 2**).

Figure 2: Large, flattened leaf blade common of Angiosperms

ii. Determine if the Plant is Deciduous or Evergreen

- **Deciduous** plants shed leaves in the fall. Most broadleaf flowering plants in Colorado are deciduous, along with a few conifers such as some *Larix* (Larch).
- **Semi-evergreen** plants may retain some leaves, depending on winter temperatures and moisture.
- **Evergreen** plants retain leaves for multiple seasons. Leaves (needles) will be present throughout the year. Most conifers are evergreen, along with some broadleaf plants such as *Mahonia* (Oregon grape).

iii. Determine the Growth Habit of the Plant.

Growth habit refers to the genetic tendency of a plant to grow in a certain shape and to attain a certain mature height and spread.

- **Trees** typically have a single trunk and mature height over 12 feet.
- **Shrubs** typically have multiple-branches from the ground and a mature height less than 12 feet.
- **Vines** have a climbing, clasping, or self-clinging growth habit.

Note: Many landscape plants could be considered small trees <u>or</u> large shrubs. The term "tree" or "shrub" would be applied based on the general appearance of the plant. The species, cultivar, or variety name sometimes indicates plant characteristic, including form.

b. Step 2 – Consult a Key to Lead You Through the Identification Process.

Each region of the county has a variety of keys written for trees in that region. Examples of keys for the Colorado region include the following:

- ***Key to Common Landscape Trees and Shrubs of Colorado***, CMG GardenNotes #177 at http://www.cmg.colostate.edu/TreeID/177.html
- ***Identifying Conifers***, CMG GardenNotes #172 at http://www.ext.colostate.edu/mg/Gardennotes/172.pdf
- ***Flora of Colorado*** Jennifer Ackerfield. Brit Press. 2015
- ***Trees and Shrubs of Colorado.*** Jack L. Carter. Second edition, 2006

CMG GardenNotes #172, **Identifying Conifers**, gives more details on

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<u>Authors:</u> Linda McMulkin, David Whiting, Alison O'Connor, and Christine Prins, Colorado State University Extension. Line drawings by Scott Johnson and David Whiting; used by permission.

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CMG GardenNotes #172

Identifying Conifers

(Arborvitae, Douglas Fir, Fir, Juniper, Pine, Spruce, and Yew)

Outline:

I. Characteristics of Conifers

a. Leaves

Most conifers (cone bearing plants) have characteristic leaf shape and arrangement that allow them to be quickly identified to the genus level.

- The *Pinaceae* family contains members such as pine, spruce, fir and Douglas fir. This family has the classic needle-shaped leaves you think of when you think of Conifers (i.e. pine needles). The genera of the *Pinaceae* family are further sorted by how the needles are clustered on the stem (see **Figure 1**).

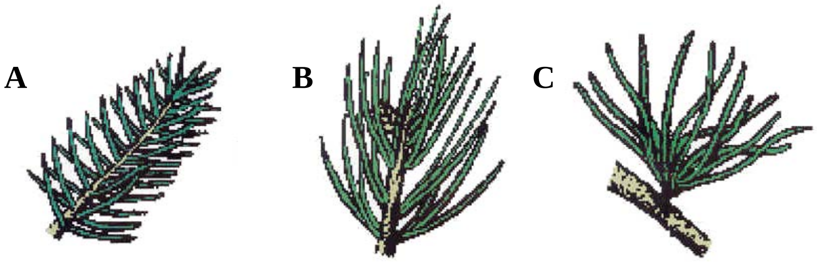

Figure 1: A) Single needles characteristic of the genera *Picea* and *Pseudotsuga*. B) Bundled needles characteristic of the genus *Pinus*. C) Clustered needles characteristic of the genus *Larix*.

- The *Cupressaceae* family includes members such as juniper and arborvitae. This family has leaves that are more scale-like or awl-like (see **Figure 2A –B**)
- The *Taxaceae* family is the Yew family. The leaves of these Conifers are flat and arranged along the stem in a manner that resembling a feather (see **Figure 2C**)

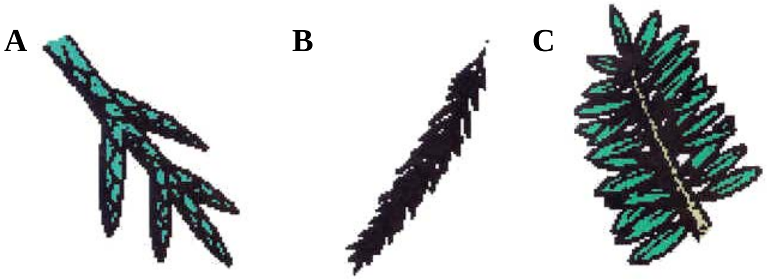

Figure 2: A) S**cale**-like leaves characteristic of *Juniperus* and *Thuja*. B) Awl-shaped leaves characteristic of *Juniperus*. C) Linear, feather-like leaves characteristic of *Taxus*.

b. Seed Production

Conifers are **Gymnosperms** (along with *Ginkgo biloba* and cycads), which are a group of plants that do not flower, but instead produce seed in a 'cone' structure made of modified leaves called scales. The term 'Gymnosperm' literally means "naked seed" and refers to the exposure of the female reproductive structure during pollination (instead of wrapped in an ovary as in flowering plants) rather than the actual seed being uncovered.

Members of the *Pinaceae* family and arborvitae are **monoecious** plants. These plants have separate male and female cones on the same plant (the term "monoecious" is Greek for 'one house'). Male cones produce pollen and are normally short lived. Female cones are generally larger and longer-lived, remaining on the tree until the seeds are mature and distributed. Junipers and Yews are **dioecious** plants, which have separate male and female plants ("dioecious" is Greek for 'two houses').

Cones of pines, spruce, and fir are made up of leathery or woody scales, which open to distribute the seed when the see is mature. The cones of junipers have fused scales around the see, resulting in a more berry-like appearance (see **Figure 3**).

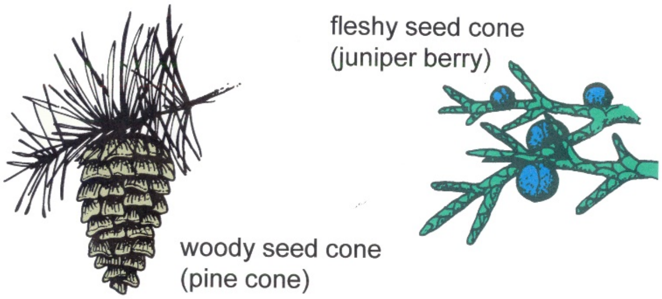

Figure 3: Woody cones of the *Pinaceae* family and fleshy cones of the *Juniperus* genus.

II. Key to Conifers

- **a.** **Leaves scale-like or awl-like.** Fruit is a berry-like cone with scales fused together – *Cupressaceae* family (Junipers and Arborvitae)
  - **i.** Leaves scale-like or awl-like, often closely pressed to the branches. Foliage arranged around the branch, rather than flattened. Cones are berry-like with scales pressed close together – ***Juniperus* (Junipers)**
  - **ii.** Leaves small, scale-like, hugging the stem. Foliage in flattened plate-like display. Cones are berry-like with thick scales – ***Thuja* (Arborvitae) – visit the Key to *Thuja*** on page 5
- **b.** **Leaves needle-like.** *Pinaceae* family (pine, spruce, fir, and Douglas fir)
  - **i.** Needles single
    - **1.** Needles flat in cross-section and flexible
      - **a.** Leaf scar oval, bud tips pointed. Cones have three-prong lobed tongue-like "bract" that extend out beyond the scales – ***Pseudotsuga menziesii* (Douglas Fir)**
      - **b.** Leaf scar round, bud tips roundish. Cones grow upright on the branch, usually disintegrating before falling to the ground – ***Abies* (Fir) – visit the Key to *Abies*** on page 3
    - **2.** Needles square in cross-section and stiff. Older twigs studded with the persistent stumps of fallen needles – ***Picea* (Spruce) – visit the Key to *Picea*** on page 3
  - **ii.** Needles sheathed at the base in bundles of two to five. Cone scales thick and woody with swollen tips – ***Pinus* (Pine) – visit the Key to *Pinus*** on page 4
  - **iii.** Short needles in tufts of ten or more. May be deciduous – ***Larix* (Larch)**
- **c.** **Leaves flat, linear-shaped in a feather-like arrangement.** Shrubs with dark green leathery leaves. Red, berry-like fruit – ***Taxus* (Yew)**

III. Key to *Abies* (Fir)

- **a.** Young stems not hairy. Needles usually longer than 1 inch (but can be misleading). Cones grayish green, 2 ½ to 5 inches long. Bracts of the cone scales with a short, triangular tip – ***Abies concolor* (White Fir)**
- **b.** Young stems hairy. Needles usually shorter than 1 inch. Cones dark brown/purple, 2 to 4 inches long. Bracts of the cones scale are long with sublated tip. Native to higher elevations – ***Abies lasiocarpa* or *Abies bifolia* (Subalpine Fir)**

IV. Key to *Picea* (Spruce)

- **a.** Needles very stiff, sharp, ¾ to 1½ inch long, often bluish, pointing outwards from stem. Stems not hairy. Cones 2½ to 4 inches long. Cone scales papery, furrowed, pointed/ragged. Bark black to dark grey furrowed. Native, generally below 9000 feet elevation – ***Picea pungens* (Colorado Spruce)**

b. Needles somewhat blunt, not as stiff or sharp, pointed toward end of twig. Young stems somewhat hairy. Cones less than 2½ inches long. Cone scales rounded. Bark smooth, with purplish-brown to russet red scales on mature trees. Native. – ***Picea englemannii*** **(Englemann Spruce)**

c. Needles ¼ to ½ inches long. Each branch very short (2-4 inches long). Landscape shrub. – ***Picea glauca*** **'Conica' (Dwarf Alberta Spruce)**

V. Key to *Pinus* (Pine)

a. Two needles per bundle

- i. Needles ½-1 ½ inches long, curved, medium green with white lines, some resin droplets. Cones small, rough, without prickles on scale. Seeds large (pine nuts). Shrubby tree. Native to the plateaus and mesas – ***Pinus edulis*** **(Pinon Pine)**
- ii. Needles 1-2 inches long, finely toothed, slightly twisted, curved, dark green, persisting 5 plus years. Branches out abruptly from trunk base, central leader not obvious, more shrub-like – ***Pinus mugo*** **(Mugo Pine)**
- iii. Needles 1-3 inches long, yellowish-green, slightly twisted. Cones small, less than 2 inches long, hard, one-sided with prickled tips on scales. Branches slender, slightly flexible. Bark scaly, not becoming platy. Native in dense forest stands in higher elevations – ***Pinus contorta*** **(Lodgepole Pine)**
- iv. Needles 1½ -3 inches long, twisted, persistent 2-4 years. Cones 1½inches long, scatter throughout the tree, without prickles on the scales. Older bark orange – ***Pinus sylvestris*** **(Scotch Pine, Scots Pine)**
- v. Needles 3-6 inches long, stiff, dark green, dense on the branch, persisting 4 plus years. Cones 2-3 inches long with small prickles on scales. Buds whitish. Older bark dark gray, furrowed – ***Pinus nigra*** **(Austrian Pine)**

b. Two and three needles per bundle, 3-10 inches long, medium green, crowded at end of branches on older trees, persisting 3 years. Cones 3-5 inches long, armed with sharp prickles on scales. Bark furrowed, eventually breaking into reddish plates. Native from outer foothills to subalpine regions – ***Pinus ponderosa*** **(Ponderosa Pine)**

c. Five needles per bundle – **White Pines** group

- i. White resin dots scattered on dark green needles, 1-1½ inches (25-38 mm) long. Cone scales long, sharp prickles. Native to higher elevations – ***Pinus aristata*** **(Bristlecone Pine)**
- ii. Needles 1-3 inches long, rigid, dark green, often clustered near branch ends, margins smooth, pointing forward, persist for 5-6 years. Cones 4-8 inches long on short stalk, with no prickles on scales. Branches very flexible. Bark silvery white to light gray. Small tree with irregular trunk and branching pattern Native to higher elevation and high plains, often on open sites – ***Pinus flexilis*** **(Limber Pine)**
- iii. Needles 2-5 inches long, blue-green, very soft, thin, margin toothed, persistent 2 years. Branches green-brown. Cones 3-8 inches long with 1 inch long stalk. Cone scales thin, don't bend back – ***Pinus strobus*** **(Eastern White Pine)**
- **iv.** Needles with a few small teeth near tip, not as soft as Eastern White Pine. Branchlets yellow-brown or red-brown. Cones are short-stalked. Cone scales bend back. Tall tree with straight, unbranched trunks. Native to San Juan Mountains. Sangre de Cristo and Rampart ranges – ***Pinus strobiformis*** **(Southwestern White Pine)**

VI. **Key to *Thuja* (Arborvitae)**

a. Foliage in vertical plate-like displays – ***Thuja orientalis* (Oriental Arborvitae)**

b. Foliage in horizontal plate-like displays – ***Thuja occidentalis* (American or Eastern Arborvitae)**

Authors: David Whiting, Linda McMulkin, Joanne Jones, Alison O’Connor, Laurel Potts, and Christine Prins, CSU Extension. Artwork by Scott Johnson and David Whiting; used by permission.

- Colorado Master Gardener *GardenNotes* are available online at http://www.cmg.colostate.edu/GardenNotesUpdate.shtml#WoodyID
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
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CMG GardenNotes #173

Identifying Broadleaf Flowering Trees and Shrubs

Outline:

Identification of broadleaf trees and shrubs is a skill mastered with practice and knowledge of the plant families. Most trees and shrubs can be readily identified to family and genus with a basic knowledge of the plant's characteristics and the use of a key. There are always a few exceptions with plants that do not look like their relatives. Identification to specific epithet requires more skill and a closer look at plant characteristics. Identification to variety and cultivar can be very difficult, as the defining characteristics may not be clearly observable from plant samples. Identify the plant to the level you are comfortable and to what the task requires!

Keys can be arranged in a variety of ways, but most start by separating Gymnosperms from Angiosperms (the key to the common Conifers was covered in GardenNotes #172), then start with broad, easily identifiable characteristics to narrow the plant to family level. Usually, the more specific and smaller plant characteristics will be used to narrow the plant down to genus and specific epithet. The following sections will cover the most common characteristics you will encounter in a plant key. Some of these characteristics you will come across with every plant you key, and you should be comfortable using these terms.

Note: This should be a general review from the ***Botany*** trek, but the information is vital to the plant ID process.

I. Leaf Characteristics

a. Leaf Arrangement (see **Figure 1)**

- **Alternate** – Arranged in staggered fashion along stem (i.e. Willow)
- **Opposite** – Pair of leaves arranged across from each other on stem (i.e. Maple)
- **Whorled** – Arranged in a ring around the stem (i.e. Catalpa)

Figure 1: Leaf arrangement on the stem

b. Leaf Form (see **Figure 2**)

- **Simple –** Leaf blade is one continuous unit (i.e. Cherry, Maple, and Elm)
- **Compound** – Several ***leaflets*** arranged on one petiole
    - **Pinnately compound** – Leaflets arranged on both sides of a rachis an extension of the petiole, like a feather (i.e. Honeylocust).
    - **Palmately compound** – Leaflets radiate from one central point at the tip of the petiole (i.e. Ohio Buckeye and Horse Chestnut).
    - **Doubly pinnately (or bipinnately) compound** – leaflets are arranged on a branches off of the rachis (i.e. Kentucky Coffee Tree).

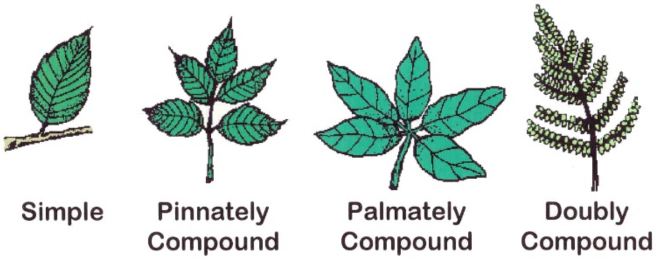


Figure 2: Variety of leaf forms

Note: Sometimes identifying a "leaf" or "leaflet" can be confusing. Look at the petiole attachment. A leaf petiole attaches to the stem at a bud node. There is no bud node where leaflets attach to the petiole.

c. Leaf Venation (see **Figure 3**)

- **Pinnately** veined leaves have a central vein down the center with smaller veins branching off and extending to the leaf margin (i.e. Elm, Peach, and Linden).
- **Palmately** veined leaves radiate smaller veins out in a fan-shaped pattern from a central point at the petiole leaf stem (i.e. Maple, Mulberry, and Poplar).

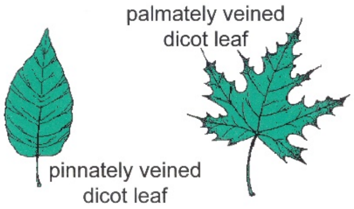


Figure 3: Variety of leaf venation

d. **Leaf Shape** (see **Figures 4-7**)

Leaf shape is a primary tool in plant identification. Descriptions often go into fine detail about general leaf shape, and the shape of the leaf apex and base. There is no hard and fast dividing line where one type suddenly becomes another type; rather it is a judgment call. When using keys, look at several leaves from the plant, select the average shape, and be flexible in your description. The authors of thes plant identification keys are aware of the variation within plants, and will often write several options into the key. The following figures show the common overall shapes, leaf apexes and bases, and leaf margins:

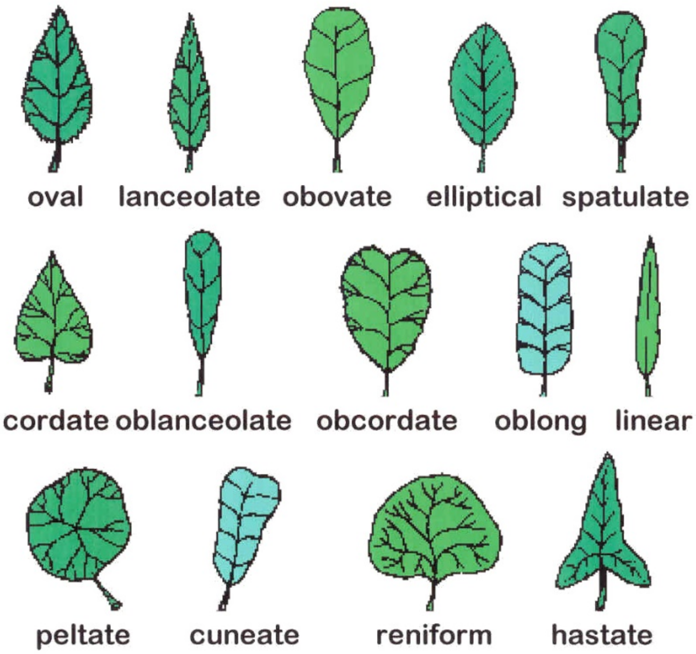


Figure 4: Variety of overall leaf shapes

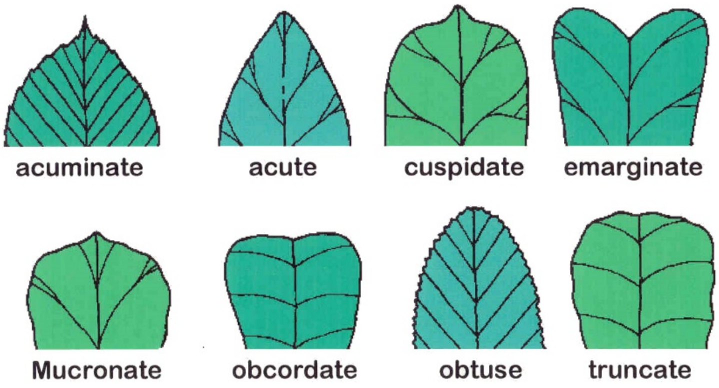


Figure 5: Variety of Leaf Apex shapes

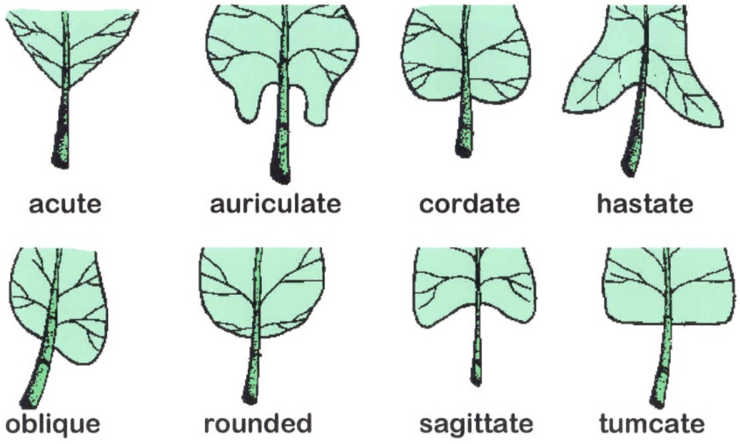


Figure 6: Variety of leaf base shapes

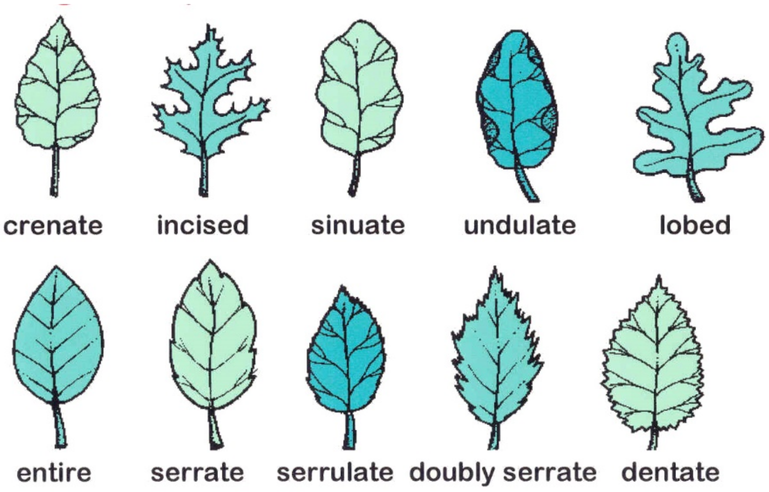


Figure 7: Variety of leaf margins

e. Leaf Surface Texture

Look at all the leaf surfaces, above and below. Note the location, color, density and length of scales and hairs. These terms are commonly encountered when describing leaf surface texture

- **Ciliate –** Orderly, widely spaces hairs along the edge (margin), also called fringed
- **Glandular –** Hairs bearing glands
- **Glutinous –** Sticky to the touch
- **Scabrous –** Hairs very short
- **Stellate –** Star shaped hair (needs magnification)
- **Velutinous –** Dense hairs of equal height, like velvet

II. **Stem Characteristics**

Stems contain several features important to identifying plants. Cut into the stem to see the pith. Look at the epidermis, buds, arrangement of the nodes and any surface coating or texture. For winter identification of woody plants, look at the pattern of the scales on the terminal and lateral buds and the shape of the leaf scars.

a. External Stem Features (see **Figure 8**)

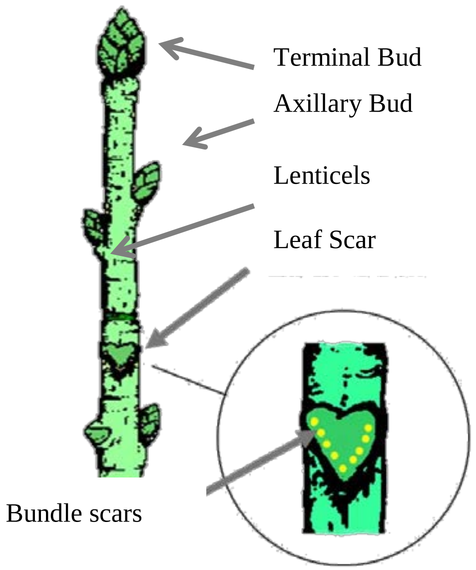


Figure 8: External Stem Features

- **Terminal bud** – This bud is where growth that lengthens the stem happens. The young, dividing cells are protected by **Terminal bud scales**
- **Axillary bud** – These buds, when actively dividing, will become a new branch. They are smaller versions of the terminal bud and can also be protected by scales
- **Leaf scar** – The mark left on stem where leaf was attached. The shape of the leaf scar is often used in woody plant identification.
- **Bundle scar** – Marks left in the leaf scar from the vascular tissue attachment. The shape of the bundle scare is often used in woody plant identification.
- **Lenticels** – Woody twigs have these pores in the bark to allow for gas exchange. These look like little dots along the stem.

b. Axillary Bud Type

The type of axillary bud (the way the scales are arranged over the bud) is another feature used in plant identification. Figure 9 illustrates bud types used in the *Manual of Woody Landscape Plants*. (See **Figure 9**)

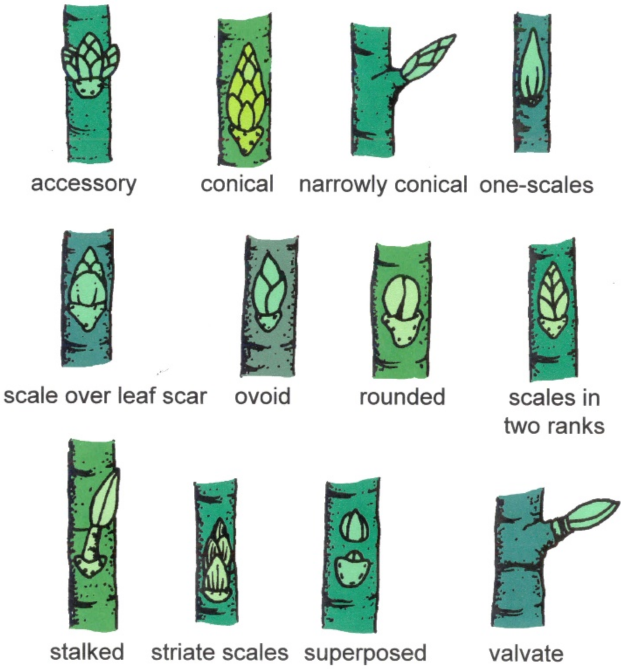


Figure 9: Axillary Bud types

c. Stem Surface Texture

The surface of woody twigs may have a texture that can be used to distinguish one plant from another. Terms used to describe the surfaces of stems can also apply to leaves.

- **Farinose** – Covered with a mealy , powdery substance
- **Glabrous** – Smooth
- **Glaucous** – Having a bloom or whitish covering, often waxy
- **Hirsute** – Covered with coarse, stiff hairs, rough enough to break the skin
- **Pubescent** – Covered with hairs
- **Scurfy** – Covered with small scales
- **Tomentose** – Covered with short, matted or tangled, soft, wooly hairs

d. Internal Stem Features

Pith is the tissue found at the center of stems and roots. Pith characteristics may provide identification clues. A diagonal cut across the stem reveals if the center of the stem is hollow or if the pith is solid or chambered. A straight cut across the stem reveals the shape of the pith (rounded, star or triangle). (See **Figure 10**).

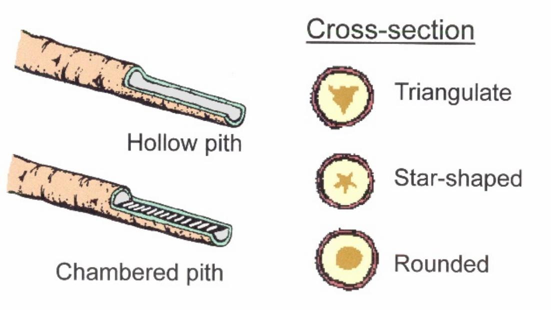


Figure 10:
Internal stem features used in plant identification

III. Fruit Characteristics

Generally, the identification of trees and shrubs is done without fruit, as the fruit is only around for a short season. However, when fruit is present, it can be a tool in plant identification. For example, legumes are characteristic of the Pea family (*Fabaceae)*. The following is an outline key defining the different fruit types you may see on trees and shrubs.

A note on floral terms here: the pistil refers to the female part of a flower. A pistil can have one ovary (chamber) or several ovaries fused together. Single flowers can also have multiple pistils. The pistil is the part of the flower that the fruit is derived from, so these differences in fruit types come from differences in the arrangement of the pistil. A good place to practice your fruit identification is at the grocery store!

a. Key of Fruit Types

1. **Simple fruit** – fruit formed from one pistil

   A. Dry fruit

   1) *Dehiscent* fruits—these fruits split open when mature to release seeds

      a) **Capsule** – Many seeded fruits formed from more than one united carpels.

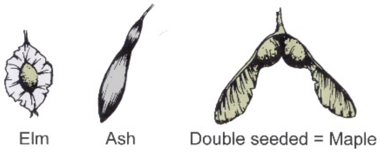
      b) **Follicle** – Composed of one carpel but splits open at maturity along one suture exposing seeds.

      c) **Legume** (Pod) – Composed of one carpel that splits open along two sutures (like a pea pod). Characteristics of most members of the *Fabaceae* family.

   2) *Indehiscent* fruits – these fruits do not split open when mature; the seed stays intact inside

      a) **Achene** – One seeded fruit with seed attached at only one place to the pericarp. Pericarp is very close-fitted and does not split open, at least along regular established lines.

      b) **Samara** – One or two seeded with a membranous wing.



      c) **Nut** – A bony, hard, one-seeded fruit.

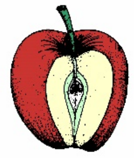
      d) **Nutlet** – A tiny nut.

   B. Fleshy fruits

   1. **Berry** – The entire fruit is fleshy.

   2. **Drupe** – the fruit is clearly differentiated into three layers; the outside layer is the epidermis, the middle layer is fleshy, and the inside layer forms a stony "pit" around the seed.

   3) **Pome** – The pericarp is surrounded by the floral cup (*hypanthium*),which becomes the fleshy edible part of the fruit.



2. **Aggregate fruits** – Develop from a single flower that contains many separate pistils. The fruits from the individual pistils are arranged on one receptacle. Examples:

    - *Fragaria* (strawberry) – aggregate of achenes
    - *Liriodendron* (Tuliptree) – aggregate of samaras
    - *Maclura* (Osage-orange) – aggregate of drupes
    - *Magnolia* (Magnolia) – aggregate of follicles
    - *Rubus* (Raspberry) – aggregate of drupes

3. **Multiple fruits** – Consists of several flowers which are more or less united into one mass. Example: *Morus* (Mulberry), Pineapples

IV. Identification Keys to Landscape Trees

The following is a helpful list of plant identification keys you can use in your broadleaf shrubs and trees identification:

- ***Key to Common Landscape Trees and Shrubs of Colorado***, CMG GardenNotes #177 at http://www.cmg.colostate.edu/TreeID/177.html
- ***Flora of Colorado*** Jennifer Ackerfield. Brit Press. 2015
- ***Trees and Shrubs of Colorado.*** Jack L. Carter. Second edition, 2006

Authors: David Whiting, Linda McMulkin, Joanne Jones, Alison O'Connor, Laurel Potts, and Christine Prins, CSU Extension.
Line drawings by Scott Johnson and David Whiting; used by permission.

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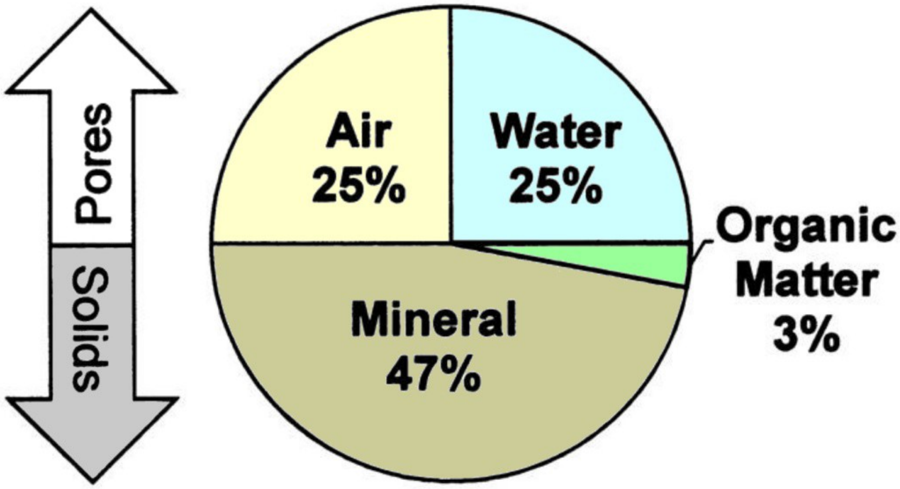

Soils, Fertilizers, and Soil Amendments

Learning Objectives

At the end of this unit, the student will be able to:

- Describe characteristics of a typical landscape soil and how it differs from native or agricultural soils.
- Describe how soil organisms directly and indirectly benefit the soil and plant growth.
- Describe management practices effective in nurturing soil organisms.
- Describe the relationship between soil *texture*, *structure*, *pore space*, and *tilth*.
- Describe effective management practices for sandy soils, clayey soils, and decomposed granite rocky soils.
- Describe effective management practices to prevent and reduce soil compaction.
- Describe considerations in selecting soil amendments.
- Describe considerations in selecting mulch.
- Describe considerations in selecting appropriate fertilizers.

References

Colorado State University Extension

Extension Fact Sheets

- Nitrogen Sources and Transformations – #0.550
- Organic Materials as Nitrogen Fertilizers – CSU-CE #0.546
- Soil Testing – #0.501
- Soil Testing – Selecting an Analytical Laboratory – #0.520
- Soil Testing – Soil Test Explanation – #0.502
- Soil Testing – Soil, water and plant testing – #0.507

Extension Fact Sheets

- Expansive Soils – Landscaping on Expansive Soils – #7.236
- Landscaping on Expansive Soils – #7.236
- Mulches for Home Grounds – #7.214
- Salt – Diagnosing Saline and Sodic Soil Problems – #0.521
- Salt – Managing Saline Soils – #0.503
- Salt – Managing Sodic Soils – #0.504
- Soil Testing – #0.501
- Soil Testing – Selecting an Analytical Laboratory – #0.520
- Soil Testing – Soil Test Explanation – #0.502
- Soil Testing – Soil, Water and Plant Testing – #0.507

Soils, Fertilizes, and Soil Amendments curriculum developed by David Whiting (CSU Extension, retired), Carl Wilson (CSU Extension, retired), Catherine Moravec (former CSU Extension Employee) and Jean Reeder, Ph.D., (USDA-ARS, retired). Revised by Eric Hammond and Dan Goldhammer, CSU Extension

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Review Questions

Introduction To Soils

1. Explain how soils may vary horizontally and vertically. Describe characteristics of the A, B and C soil horizons.

2. Describe how landscape soils differ from agricultural and native soils.

3. Describe the typical percentage of air, water, organic matter, and mineral solids for a native soil. How does this change for a compacted landscape soil?

The Living Soil

4. Describe how organisms directly benefit the soil and plant growth.

5. Describe how organisms indirectly benefit the soil and plant growth.

6. Should gardeners inoculate their soil with rhizobia, mycorrhizae and decomposers?

7. What makes up the soil organic matter? Give a soil scientist's definition of *humus*. What are the benefits of humus?

8. How does a gardener enhance the *living soil*?

Managing Soil Tilth

9. Define the terms soil texture, soil structure, and soil profile. Explain how they are interrelated.

10. Describe characteristics of the following soil types:

    a. Coarse-textured, sandy soil
    b. Fine-textured, clayey soil
    c. Gravelly and decomposed granite soils

11. Explain what is significant about large pore spaces and small pore spaces?

12. Describe how water moves through small pore spaces and large pore spaces.

13. In relation to root growth, air infiltration, and water movement, what happens when the soil has a texture interface?

14. Explain management of fine-textured, clayey soils, coarse-textured, sandy soils, and gravelly and decomposed granite soils.

Soil Compaction

15. Describe soil compaction in terms of pore space, water movement, and air infiltration.

16. List techniques to prevent soil compaction. List techniques to reduce soil compaction.

Soil Drainage Problems

17. Describe drainage problems as related to *pore space*, *surface runoff*, and *leaching*.

18. Why is it so important to identify the causes of a drainage problem before attempting corrections?

19. List common causes of surface drainage problems with possible corrective actions. List common causes of sub-surface drainage problems with possible corrective actions.

Soil Tests

20. List situations when a soil test would be helpful. List examples of plant growth problems for which a soil test would not be helpful.

21. Describe the steps to a soil test.

22. Where does one find a list of soil testing laboratories?

pH and Iron Chlorosis

23. What does soil pH measure? What is an acceptable range for most plants? What are the implications for gardening in Colorado?

24. Describe the function of the "free lime" vinegar test. Can the pH of an alkaline soil be effectively lowered?

25. Describe the symptoms of iron chlorosis. What other situations can be confused with iron chlorosis? How can you tell them apart?

26. List primary factors that contribute to iron chlorosis.

27. What simple method identifies soils prone to iron chlorosis problems?

28. Describe the limitations and application criteria for the following iron treatments.

    - Soil applications of sulfur
    - Soil applications of iron sulfate plus sulfur
    - Soil applications of iron chelates
    - Foliar sprays
    - Trunk injections

Saline Soils

29. Describe plant problems associated with excess soil salt levels.

30. List sources/causes of high soil salts.

31. Describe the leaching process for salty soils. What about situations when excess salts cannot be leached out?

32. Describe other management strategies for salty soils.

Plant Nutrition

33. Define *plant nutrient* and *fertilizer*.

34. Will addition of nitrogen fertilizer help plant growth when soil compaction is the limiting factor? Explain.

35. What are the typical symptoms of nitrogen deficiency? What are the problems associated with excessive nitrogen fertilization?

36. In Colorado soils, under what situations will phosphorus levels likely be adequate and likely be deficient? How does one determine the need for phosphate fertilizer?

37. In Colorado soils, under what situations will potassium levels likely be adequate and likely be deficient? How does one determine the need for potash fertilizers?

Fertilizers

38. Define the following terms: fertilizer, organic fertilizer, certified organic fertilizer, and soil amendment.

39. What does *grade* or *analysis* indicate about a fertilizer? What is a fertilizer *ratio*?

40. What is a fertilizer *formulation*? What is a *complete* fertilizer? When applying a complete fertilizer, what is the application rate always based on?

41. What is the routine application rate for nitrogen fertilizer? How does it change based on soil organic matter? What is the routine application rate when using a) ammonium sulfate, 21-0-0, b) ammonium nitrate, 34-0-0, and c) urea, 45-0-0 fertilizers?

42. Address your answers relative to phosphorus water pollution. What happens to phosphate fertilizers applied 1) to a lawn or garden area, and 2) over-spread onto the street, sidewalk, or driveway? What is the major source of phosphate water pollution from the landscape setting?

Soil Amendments

43. Define *soil amendment, mulch*, and *compost*.

44. Explain how organic soil amendments improve a clayey soil and a sandy soil.

45. Describe considerations in selecting a soil amendment as it relates to the following:

    a. Desired results
    b. Potential for routine application
    c. Longevity
    d. Salt

46. What is the routine application rate for soil amendments? What is a precaution about adding additional amounts?

47. Explain the use and limitations of using manure as it relates to:

    - *E. coli*
    - Nitrogen release rates
    - Salt
    - Weed seeds

48. What are cover crops and green manure crops? List benefits of cover cropping and green manuring.

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CMG GardenNotes #211

Introduction to Soils

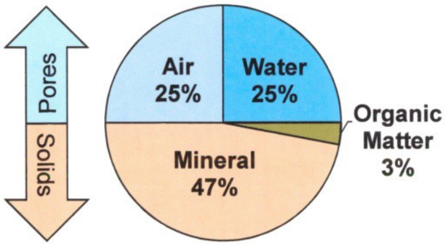
Soil Attributes

What is soil? Gardeners know that soil is more than simply broken up rocks. Rather than being an inert unchanging material, soil is a dynamic living substance in which complex chemical and biological reactions are constantly occurring.

According to the Soil Science Society of America, soil is defined as, "…the unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants..." **Unconsolidated** materials are loose materials composed of multiple units (e.g. sand, gravel, etc.) unlike hard, massive materials like rock. Effective gardeners manage soils to produce healthy and resilient plants.

Soil contains a variety of substances. In a well-managed western soil, usually around 50% percent of the soil's volume is composed of solid particles, while the other 50% is empty space. Soil scientists refer to these empty spaces as "pores." [Figure 1]

Figure 1: A well-managed Western soil has 25% air, 25% water, 1-5% organic matter and 45-49% mineral solids.



Most of the solid particles are derived from mineral sources such as decomposed rocks or sediments. Roughly 1 to 5% of the soil's volume is organic matter—plant, animal and microbial residues in various stages of decomposition. [Figure 1]

The empty space between the solid particles can be occupied by water, air, or a combination of both. In a well-managed soil, about 25% of the soil's volume is air, while the remaining 25% is occupied by water. This combination of components provides a healthy environment for roots to grow.

Soil-Forming Factors

Soils vary across the landscape. A Colorado gardener may have noticed substantial differences between the soil in his or her yard compared to their neighbor’s soil. In Colorado, there are many different types of soils ranging from heavy clays to sands or decomposed granite.

The factors that cause variation in soils in different locations are referred to as soil-forming factors. Soil scientists recognize five soil-forming factors, including:

- Parent material
- Climate (precipitation, temperature, wind)
- Topography
- Biological organisms
- Time

These factors differ in subtle and complex ways over the surface of the earth to create an infinite array of soils.

The term **parent material** refers to the starting material for a soil. It consists of specific minerals (or organic materials) from which a soil is formed. The mineralogy of the parent material has a great effect on the mineralogy and properties of the soil.

Climatic factors influence soil formation in several ways. First, precipitation and temperature cause weathering of rocks. In dry climates like Colorado (unlike warm, moist climates), wind is often more important than water in weathering rocks and transporting parent materials. Second, climatic factors often transport parent materials over long distances. Sometimes the parent material for a soil is **residual**, meaning it disintegrated in place to form soil. In other cases, the parent material is **transported** by water (rivers and streams), wind, gravity, or glaciers. As with weathering, wind is the primary means of transport in Colorado. Once the parent materials land on a stable surface, the process of soil formation can begin. The characteristics of the resulting soil will depend on the interaction of the remaining four soil forming factors on the parent material. Together, these factors act over thousands of years to form soil.

Soil Variation

Soils are three-dimensional entities. Soil not only varies across the landscape, but also varies vertically with depth. Gardeners will notice changes in soil color, physical properties, and chemical properties as they dig deeper. Over time, the soil-forming factors change the undifferentiated parent material into a vertically differentiated soil. Soil scientists recognize **horizons**, or horizontal layers within a soil. Horizons are identified by letter codes. They may blend together gradually or have abrupt borders between layers. [Figure 2]

A Horizon (also referred to as “topsoil”)

The A horizon is usually the surface horizon. This is an area of high biological activity with the greatest organic matter content. It is also a zone of leaching. As precipitation enters the A horizon, it dissolves soluble soil organic compounds and minerals. These dissolved compounds are then moved downward through the soil profile. Most plant roots are found in the A horizon.

B Horizon (also referred to as "subsoil")

The B horizon lies underneath the A horizon. This layer usually contains less organic matter than the surface layer, but accumulates the dissolved materials leached from the A horizon (clays, iron oxides, aluminum, and dissolved organic compounds). For this reason, the B horizon typically contains more clay than the surface layer. The accumulated products in the B horizon increase over time as the soil forms.

C Horizon

The C horizon contains unconsolidated material that has been minimally affected by the soil forming factors. It lies beneath the B horizon, and may or may not be the same as the parent material from which the soil formed.

Figure 2. Soil Profile

Landscape Soils

Landscape soils differ significantly from agricultural or native soils. **Landscape soils** are soils that are found in a typical neighborhood community around homes, parks, schools, offices, parking lots, and buildings. Soil scientists often refer to landscape soils as "urban" soils.

During the construction process, soils in communities are often graded by moving large volumes of soil. This process often removes the A horizon, taking with it the vast majority of organic matter. Furthermore, when construction workers drive large pieces of equipment over soil it becomes compacted.   Thousands of years of soil development can be destroyed in minutes with a bulldozer and other soil moving equipment in a construction site.

Sometimes construction debris, such as wood, trash, drywall, bricks, asphalt, or concrete, is buried in the soil during construction. Other possible landscape soil changes include increased variability, increased surface crusting, increased pH, decreased drainage, decreased soil microbial activity, and increased soil temperature. All of these factors can cause problems when managing soils around buildings.

Native, undisturbed soils typically have well defined A, B and C horizons. In compacted landscape soils, the horizons are scrambled and not defined, organic content is low, and air and water movement is reduced.

In comparison, the compacted unamended landscape soil typically has 10% air, 20% water, 1% organic matter and 69% mineral solids. The most significant aspect of the compacted landscape soil is the reduction in air. Low soil oxygen is the most common limiting factor of plant (root) growth. [Figure 3]

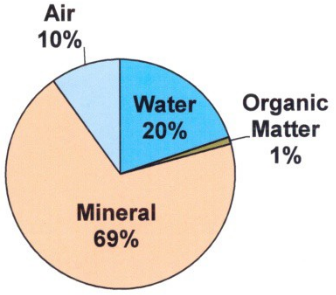


Figure 3: A typical compacted, unamended landscape soil has 10% air, water, 1% organic matter, and 69% mineral solids.

20%

Soil conditions contribute to a large number of plant problems. What can the gardener do?

1. Understand soils as a living ecosystem. Nurture soil organisms by providing their food source (organic matter) and improving aeration and drainage (oxygen and water). For additional information, refer to CMG GardenNotes #212, *The Living Soils*.

2. Understand the soil physical properties of *texture*, *structure*, and *pore space* as they relate to soil *tilth*. Compaction is a reduction in total pore space, but more importantly, compaction is a major reduction in large pore space where the air is located. Gardeners will be more successful in soil management by understanding what properties can be changed and what properties cannot be changed. For additional information, refer to CMG GardenNotes #213, *Managing Soil Tilth.*

In summary, soils are important to gardeners because they strongly influence plant growth. In Colorado, soils vary substantially horizontally across the landscape and vertically with depth. In addition, landscape soils may vary considerably from agricultural or native soils. Landscapers and gardeners must take these changes into account when developing a soil management plan.

Authors: Catherine Moravec (former CSU Extension Employee); David Whiting (Colorado State University Extension, retired); and Jean Reeder, Ph.D., (USDA-ARS, retired). Edited by Dan Goldhamer (CSU Extension). Artwork by David Whiting; used by permission.

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CMG GardenNotes #212

The Living Soil

Outline:

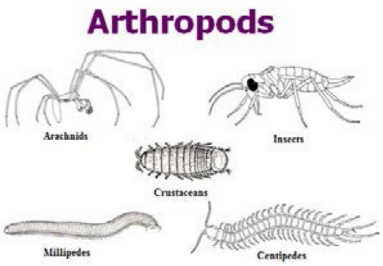
Soil Organisms Improve Garden Tilth

Rather than being an inert material, soil contains a dynamic living ecosystem. The 1-5% **organic matter found in soils includes living organisms**. The soil is thought to actually have the most bio diverse ecosystems, with only about 1 % of the organisms have been identified. Although most soil organisms are invisible to the naked eye, they help gardeners in multiple ways. One major benefit to gardeners is their ability to help improve soil tilth. Soil **tilth** is the suitability of a soil to support plant growth, especially as it relates to ease of tillage, fitness for a seedbed, impedance to seedling emergence and root penetration. Soil organisms also play a central role in making nutrients available to plants. The community of soil organisms is varied, versatile, and adaptable to changing conditions and food supplies.

Types of Soil Organisms

Soil contains an enormous number of living organisms. One cup of undisturbed native soil may contain:

Organism	Number
Bacteria	200 billion
Protozoa	20 million
Fungi	100,000 meters
Nematodes	100,000
Arthropods	50,000



Insects by Bob Hammon

Other organisms that can be found in the soil are earthworms and algae. Soil organisms are naturally active during certain times of the year. Most are active when the soil is warm and moist, like during late spring and early summer. If the soil dries out during the summer months, soil organism activity naturally declines. During fall, if there is rain or snow that moistens the soil while it is still warm, soil organisms may resume partial activity. As the soil cools in the fall, many soil organisms go dormant. Gardeners should note that fertilizers that require processing by soil organisms will be more available to plants when the soil is warm and moist and less available when the soil is cool or dry.

Despite their small size, soil organism activities have a large influence on plant growth. Soil organisms can be grouped into three categories: 1) organisms that are **beneficial** to plants—directly or indirectly, 2) **neutral** organisms—those whose activities have no affect on plants, and 3) organisms that are **harmful** to plants. Harmful organisms are often described as pathogens, such as the soil fungi that cause wilt diseases, or plant pests, such as white grubs that feed on plant roots.

Directly Beneficial Soil Organisms

Some soil organisms have a close, mutually beneficial (**symbiotic**) relationship with plants. Two examples include rhizobia and mycorrhizae. ***Rhizobia*** are bacteria that form symbiotic associations with legumes such as beans and peas. The bacteria form nodules on the roots of the host plant in which they fix nitrogen gas from the air. *Rhizobia* supply the plant with nitrogen and in turn the plant supplies the bacteria with essential minerals and sugars. It may be helpful to add *Rhizobia* in the first planting of beans and peas in a soil area. Afterwards they will be present.

Mycorrhizae are specific fungi that form symbiotic associations with plant roots. Found in most soils, they are very host-specific (i.e., each plant species has specific species of mycorrhizae associated with it).

The Latin word *mycor* means fungus and *rhiza* means root. The terms "mycorrhiza" (singular) or "mycorrhizae" (plural) refer to the tissue that forms when fungi and roots develop a mutually beneficial relationship. Enlarging the surface-absorbing area of the roots by 100 to 1,000 times, mycorrhizae create filaments or threads that act like an extension of the root system. This makes the roots of the plant much more effective in the uptake of water and nutrients such as phosphorus and zinc. In exchange, the fungus receives essential sugars and compounds from the roots to fuel its own growth. Some species of mycorrhizae can be seen on roots, while most are invisible to the naked eye.

Mycorrhizae improve plant health. They enhance the plant's ability to tolerate environmental stress (like drought and dry winter weather) and reduce transplant shock. Plants with mycorrhizae may need less fertilizer and may have fewer soil-borne diseases.

A by-product of mycorrhizal activity is the production of ***glomalin***, a primary compound that improves soil tilth. In simple terms, glomalin glues the tiny clay particles together into larger aggregates, thereby increasing the amount of large pore space, which in turn creates an ideal environment for roots. For additional details, refer to the U.S. Department of Agriculture web site at http://agresearchmag.ars.usda.gov/2002/sep/soil

Mycorrhizal cocktails are sometimes incorporated in planting or post planting care of trees and landscape plants. However results have been mixed from studies that add mycorrhizae to the soils to benefit plants. Over time, additional research will help clarify what procedures result in improved plant health and vigor.

Indirectly Beneficial Soil Organisms

In addition to directly beneficial organisms such as rhizobia and mycorrhizae, there are a large number of soil organisms whose activities indirectly help plants. Soil organisms collectively decompose organic matter, resulting in two principal benefits.

First, as soil organisms decompose organic matter, they transform nutrients into mineral forms that plants can use; thus this process is called ***mineralization***. Without soil microorganisms, insects, and worms feeding on organic matter, the nutrients in organic matter would remain bound in complex organic molecules that plants can't utilize.

Second, as soil organisms break down organic matter, their activities help improve soil structure. Improved soil structure provides a better environment for roots, with less soil compaction and better water and air movement. Many gardeners know that organic matter improves soil, but it is important to note that its beneficial properties are only released after being processed by soil organisms.

Soils naturally contain these decomposers. Adding decomposers to the soil or compost pile is not necessary. Rather nurture them with food (organic matter) and good aeration and drainage (air and water).

Soil Organic Matter

Soil organic matter is composed of a wide variety of organic substances. Derived from plants, animals, and soil organisms, the soil organic matter "pool" can be divided into four categories. First are the living organisms and roots, making up less than 5% of the total pool. Second are the residues from dead plants, animals and soil organisms that have not yet begun to decompose (<10%). Third is the portion undergoing rapid decomposition (20-45%). Fourth is the stabilized organic matter (**humus**) remaining after further decomposition by soil microorganisms (50-80%). [Figure 1]

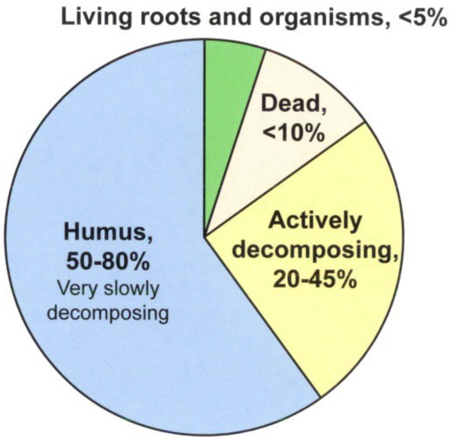


Figure 1. Make-up of soil organic matter

The stabilized organic matter, or humus, is the pool of soil organic matter that has the longest lasting benefits for gardeners. After rapid decomposition occurs, a mix of stable, complex organic compounds remains, which decomposes slowly over time (about 3% per year). Humus is a mix of tiny solid particles and soluble compounds that are too chemically complex to be used by most organisms. Humus contains a potpourri of sugars, gums, resins, proteins, fats, waxes, and lignin. This mixture plays an important role in improving the physical and chemical properties of soil.

Humus improves the physical and chemical attributes of soil in several ways, including the following:

- Humus improves soil structure by binding or “gluing” small mineral particles together into larger aggregates creating large soil pores for improved air and water infiltration and movement.
- Humus improves water retention and release to plants.
- Humus slowly releases nitrogen, phosphorus, and sulfur over time, which plants then use for growth and development.
- Because of its positive surface charge, humus improves soil fertility by retaining nutrients.
- Humus buffers the soil pH so it remains stable for plant roots.
- Humus can chelate or bind metals in soil, preventing metal toxicities.

As a point of clarification, garden stores sometime carry soil amendments labeled as *humus*. In reality these are generally “compost” and do not meet the soil scientist definition of humus as given here.

Soil Inoculation

Gardeners can purchase products at garden centers that are intended to introduce soil organisms to an existing soil. Adding decomposing bacteria from a purchased product is generally not necessary, because decomposing soil organisms are already present in the soil. Even if their populations are low due to unfavorable conditions, as soon as organic matter and water become available their populations rapidly increase. Thus, soil biologists encourage gardeners to nurture existing communities rather than introducing external organisms through purchased products.

In addition, inoculating with rhizobia is generally not needed, unless a vegetable gardener is planting a leguminous crop for the first time. In this case, the gardener should purchase the appropriate inoculant (bacteria) for the leguminous vegetable being planted. Inoculation in future years is not needed, because rhizobia produce survival structures to over-winter.

Myccorhizal products are considered highly experimental at this time, and are thus not recommended by CSU Extension for general use.

Soil Food Web

Within the soil, organisms function within an ecological food web (the smaller becoming the food for the larger) cycling nutrients through the soil biomass. This soil food web is the basis of healthy, living soil. Significant soil organisms involved in the soil food web include: 1) bacteria, 2) fungi, 3) protozoa, 4) nematodes, 5) arthropods, and 6) earthworms.

Bacteria

Bacteria are simple, single-celled microorganisms. Bacteria inhabit a wide variety of habitats, including soil. In fact, a teaspoon of productive soil can contain from 100 million to 1 billion bacteria. Soil-inhabiting bacteria can be grouped as decomposers, mutualists, pathogens, or chemoautotrophs. Bacteria that improve soil quality feed on soil organisms, decompose organic matter, help keep nutrients in the root zone, enhance soil structure, compete with disease-causing organisms, and filter and degrade pollutants in soil.

Fungi

Fungi are a diverse group of multi-cellular organisms. The best known fungi are mushrooms, molds, and yeast, but there are many others that go unnoticed, particularly those living in soil. Fungi grow as long strands called hyphae (up to several yards long), pushing their way between soil particles, rocks and roots. Fungi can be grouped as decomposers, mutualists, or pathogens. Fungi that improve soil quality decompose complex carbon compounds, improve accumulation of organic matter, retain nutrients in soil, bind soil particles into aggregates, compete with plant pathogens, and decompose certain types of pollution.

Protozoa

Protozoa are microscopic, single-celled microbes that primarily eat bacteria. The bacteria contain more nitrogen than the protozoa can utilize and some ammonium (NH_4) is released to plants. Protozoa also prevent some pathogens from establishing on plants and function as a food source for nematodes in the soil food web.

Nematodes

Nematodes are small, unsegmented round worms. Nematodes live in water films in the large pore spaces in soil. Most species are beneficial, feeding on bacteria, fungi, and other nematodes, but some cause harm by feeding on plant roots. Nematodes distribute bacteria and fungi through the soil as they move about. Predatory nematodes can consume root-feeding nematodes or prevent their access to roots.

Arthropods

Soil arthropods are small animals such as insects, spiders, and mites. They range in size from microscopic to several inches in length. Most live near the soil surface or in the upper three inches. Arthropods improve soil quality by creating structure through burrowing, depositing fecal pellets, controlling disease-causing organisms, stimulating microbial activity, enhancing decomposition via shredding organic matter and mixing soil, and regulating healthy soil food web populations.

Soil arthropods can be *shredders* (millipedes, sowbugs, etc.), *predators* (spiders, scorpions, pseudoscorpions, centipedes, and predatory mites, ants and beetles), *herbivores* (symphylans, root-maggots, etc.), or *fungal-feeders* (springtails and turtle mites). Most soil-dwelling arthropods eat fungi, worms, or other arthropods.

Earthworms

There are three types of earthworms, two of which that live in Colorado soils. Earthworms digest micro-organisms and organic matter. Refer to the *CMG GardenNotes* #218, **Earthworms** for more information**.**

Ways to Encourage Beneficial Soil Organisms

Creating a favorable environment for soil organisms improves plant growth and reduces garden maintenance. Encouraging their efforts is central to building a healthy fertile soil supportive to optimum plant growth.

- **Add organic matter to the soil**. Soil organisms require a food source from soil amendments (compost, crop residues) and/or mulch.

- **Use organic mulch**. It stabilizes soil moisture and temperature, and adds organic matter. Mulches may help prevent soil compaction and protect soil oxygen levels needed by soil organisms and roots.

  NOTE: The term ***mulch*** refers to material placed on the soil surface. A mulch controls weeds, conserves water, moderates soil temperature and has a direct impact on soil microorganism activity. ***Soil amendment*** refers to materials mixed into the soil.

- **Water effectively**. Soil organisms require an environment that is damp (like a wrung out sponge) but not soggy, between 50°F to 90°F. Soil organism activity may be reduced due to dry soil conditions that are common in the fall and winter. Avoid over-irrigation because water-logged soils will be harmful to beneficial soil organisms.

- **Avoid unnecessary roto-tilling**, as it will destroy the mycorrhizae and soil structure. Instead of tilling, mulch for weed control.

- **Avoid unwarranted pesticide applications**. Some fungicides, insecticides and herbicides are harmful to various types of soil organisms.

- **Avoid plastic sheets under rock mulch**. This practice discourages microorganism activity by reducing water and air movement and preventing the incorporation of organic matter.

Authors: Catherine Moravec (former CSU Extension Employee), David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired) and Jean Reeder, Ph.D., (USDA-ARS, retired). Artwork by David Whiting; used by permission. Revised by Susan Carter, (CSU Extension), 2015.

o Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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CMG GardenNotes #213

Managing Soil Tilth

Texture, Structure and Pore Space

Outline:

Soil Tilth

The term soil ***tilth*** refers to the soil's general suitability to support plant growth, or more specifically to support root growth. Tilth is technically defined as the physical condition of soil as related to its ease of tillage, fitness of seedbed, and impedance to seedling emergence and root penetration.

A soil with good tilth has large pore spaces for adequate air infiltration and water movement. (Roots only grow where the soil tilth allows for adequate levels of soil oxygen.) It also holds a reasonable supply of water and nutrients.

Soil tilth is a function of soil texture, structure, fertility, and the interplay with organic content and the living soil organisms that help make-up the soil ecosystem.

Gardening in Colorado can be a challenge due to poor soil tilth. Sandy soils hold little water and nutrients, while some Colorado soils are rocky and shallow.

Along Colorado's Front Range, many soils are clayey and compact readily. These soils may have poor drainage, which may lead to salt problems. Due to low soil oxygen levels, root systems are typically shallow, reducing the crop's tolerance to drought and hot windy weather.

Special attention to soil management is the primary key to gardening success. While gardeners often focus their attention on insect and disease problems, a large number of plant problems begin with soil conditions that reduce the plant's vigor.

Many gardeners give attention to the soil's nutrient content by applying fertilizers. However, fertilization is only one of the keys to a productive garden.

Texture

Texture refers to the size of the particles that make up the soil. The terms *sand*, *silt*, and *clay* refer to relative sizes of the individual soil particles. [Table 1 and Figure 1 and 2]

Table 1. The Size of Sand, Silt, and Clay

Name	Particle Diameter
Clay	below 0.002 mm
Silt	0.002 to 0.05 mm
Very fine sand	0.05 to 0.10 mm
Fine sand	0.10 to 0.25 mm
Medium sand	0.25 to 0.5 mm
Coarse sand	0.5 to 1.0 mm
Very coarse sand	1.0 to 2.0 mm
Gravel	2.0 to 75.0 mm
Rock	greater than 75.0 mm (~2 inches)

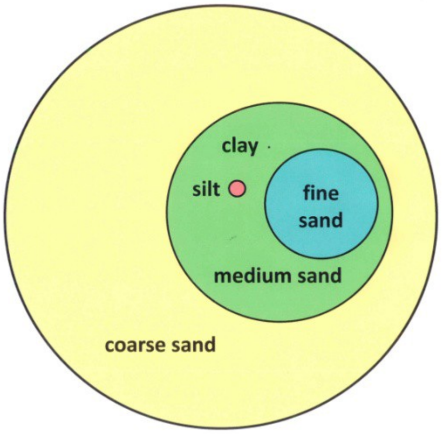


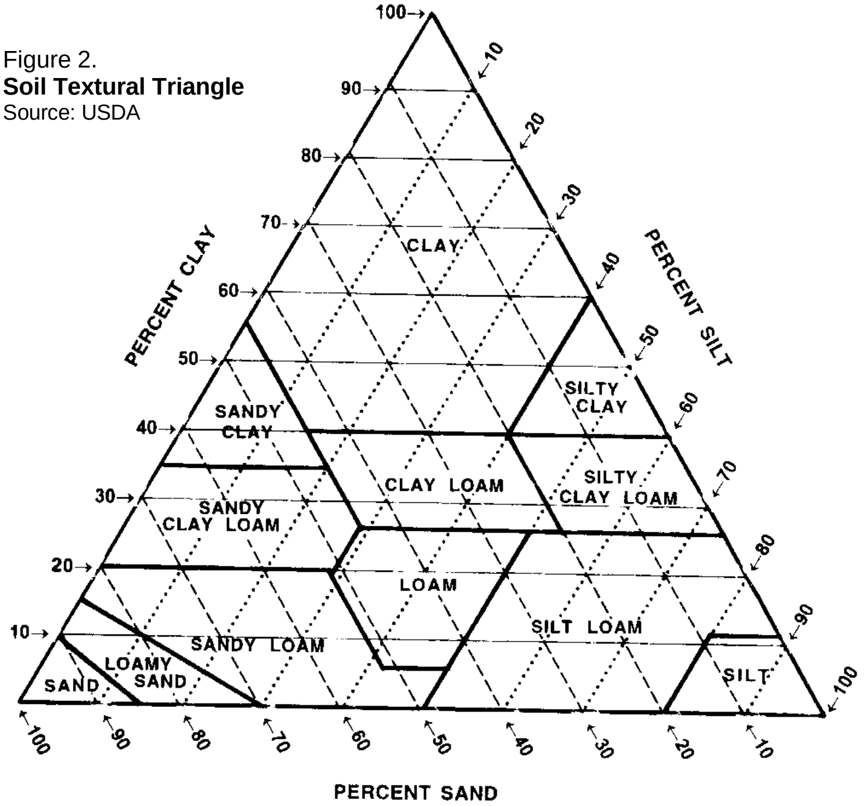
Figure 1. Comparative size of clay to coarse sand. Clay is actually less than 0.002 mm (0.00008 inch) with coarse sand up to 1.0 mm(0.04 inch).

Based on the ***Soil Textural Class Triangle***, (figure 2), the percentage of sand, silt and clay determine the *textural class.* (For example, a soil with 30% clay, 10% silt, and 60% sand is called a *sandy clay loam*. A soil with 20% clay, 40% silt and 40% sand is a *loam.*)

A ***fine-textured*** or ***clayey*** soil is one dominated by tiny clay particles. A ***coarse-textured*** or ***sandy*** soil is one comprised primarily of medium to large size sand particles. The term ***loamy*** soil refers to a soil with a combination of sand, silt, and clay sized particles.

Clay – Clay particles are flat, plate-like, negatively charged particles. They are so tiny in size that it takes 12,000 clay particles in a line to make one inch. Clay feels sticky to the touch. Soils with as little as 20% clay size particles behave like a sticky clayey soil. Soils with high clay content have good water and nutrient holding capacity, but the lack of large pore space restricts water and air movement. Clayey soils are also rather prone to compaction issues.

Figure 2.
Soil Textural Triangle
Source: USDA



Some types of clayey soils expand and contract with changes in soil moisture. These ***expansive*** soils create special issues around construction and landscaping. For homes on expansive clays, limit landscaping along the foundation to non-irrigated mulch areas and xeric plants that require little supplemental irrigation. Avoid planting trees next to the foundation and direct drainage from the roof away from the foundation.

Silt – Silt has a smooth or floury texture. Silt settles out in slow moving water and is common on the bottom of an irrigation ditch or lakeshore. Silt adds little to the characteristics of a soil. Its water holding capacity is similar to clay.

Sand – Sand, being the larger sized particles, feels gritty. There is a major difference in soil characteristics between fine sands and medium to coarse sands. Fine sands add little to the soil characteristic and do not significantly increase large pore space. An example of fine sand is the bagged sand sold for children's sandboxes.

For a soil to take on the characteristics of a sandy soil it needs greater than 50-60% medium to coarse size sand particles. Sandy soils have good drainage and aeration, but low water and nutrient holding capacity.

Gravel and rock – Some Colorado soils are dominated by gravel and rock, making them difficult for the gardener to work. Gravel and rock do not provide nutrients or water holding capacity for the soil. Rather they often drain readily, being a droughty soil with low nutrient holding capacity.

Texture directly affects plant growth and soil management as shown in Table 2. Properties of the clay trumps property of the sand in a soil with 20% clay and 80% sand, behaving as a clayey soil. [Table 2]

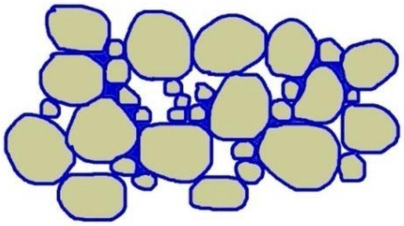
Table 2. Comparison of Fine-Textured (Clayey) Soil and Coarse-Textured (Sandy) Soil

	Clayey	**Sandy**
Water holding capacity	high	low
Nutrient holding capacity	high	low
Compaction potential	high	lower
Crusts	yes	no/sometimes
Drainage	slow	fast
Salinity build-up	yes	seldom
Warming in spring	slow	fast

Structure

Structure refers to how the various particles of sand, silt and clay fit together, creating ***pore spaces*** of various sizes. Sand, silt, and clay particles are "glued" together by chemical and biological processes creating ***aggregates*** (clusters of particles). Mycorrhizae, earthworms, soil microorganisms and plant roots are responsible for creating aggregates. [Figures 3 & 4]

Figure 3. The size of pore spaces between soil particles plays a key role in plant growth. Pore spaces are a function of soil texture and structure.



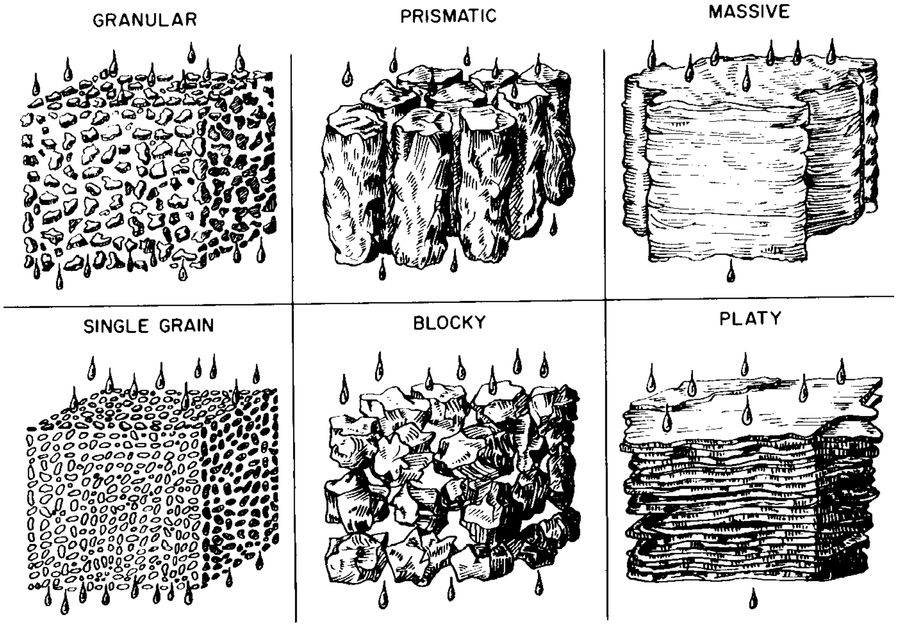


Figure 4. Examples of soil structure types. Line drawing by USDA

Undisturbed native soils often have a granular structure in the upper layer (with rapid drainage) and block structure (with rapid to moderate drainage) in the lower layers. A platy structure (with slow to no drainage) is common in soils high in clay.

Compacted, unamended landscape soils typically have a massive structure with no defined layers, little organic matter, low total pore space, and most significantly low large pore space.

The term ***peds*** describes the soil's individual aggregates or clods. Soils that create strong peds tolerate working and still maintain good structure. In some soils, the peds are extremely strong, making cultivation difficult except when the soil moisture is precisely right. Soils with soft peds may be easy to cultivate, but may readily pulverize destroying the soil's natural structure.

Primary factors influencing structure include the following:

- Texture
- Activity of soil mycorrhizae, earthworms and other soil organisms.
- Organic matter content
- Soil moisture (year round)
- The freeze/thaw cycle
- Cultivation – Tilling a soil has a direct impact on structure by breaking apart aggregates and collapsing pore spaces. Avoid tilling except to mix in organic matter, control weeds (limited use), or to prepare a seedbed.
- Soil compaction

.

To maintain good structure avoid over-working the soil. Acceptable ped size depends on the gardening activity. For planting vegetable or flower seeds, large peds interfere with seeding. In contrast, when planting trees peds up to the size of a fist are acceptable and pulverizing the soil would be undesirable.

Pore Space

Pore space is a function of soil texture, structure and the activity of beneficial soil organisms. Water coats the solid particles and fills the smaller pore spaces. Air fills the larger pore spaces. [Figure 5]

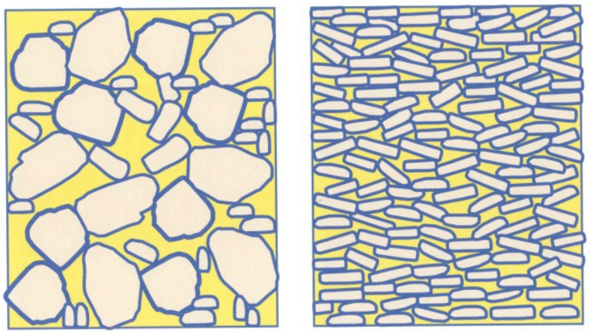


Figure 5. Comparative pore space. Left soil with large pore space. Right soil lacking large pore space.

To help understand pore space, visualize a bottle of golf balls and a bottle of table salt. The pore space between golf balls is large compared to the pore space between the salt grains.

The relative percent of clay size particles versus the percent of medium to coarse sand size particles influences the pore space of a soil. Silt and fine sand particles contribute little to pore space attributes. Note in Figure 6 how large pore space is non-existent to minimal until the sand strongly dominates the soil profile. Organic matter also plays a key role in creating large pore space.

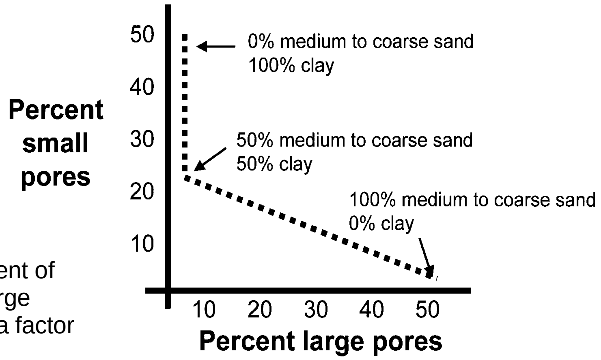


Figure 6. Percent of small versus large pore space as a factor of soil texture.

The quantities of large and small pore spaces directly affect plant growth. On fine-texture, clayey and/or compacted soils, a lack of large pore spaces restricts water and air infiltration and movement, thus limiting root growth and the activity of beneficial soil organisms. On sandy soils, the lack of small pore space limits the soil's ability to hold water and nutrients.

Water Movement

Soil water coats the mineral and organic particles and is held by the property of ***cohesion*** (the chemical process by which water molecules stick together) in the small pore spaces. Air fills the large pore spaces.

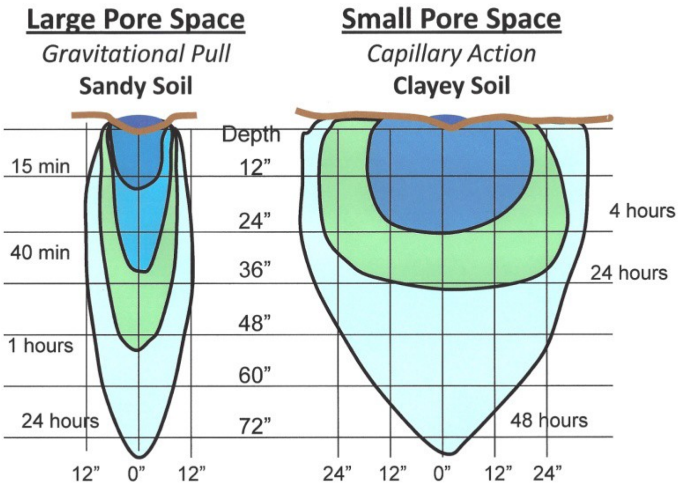


Figure 7. Comparative movement of water in sandy and clayey soils

Water movement is directly related to the size of pores in the soil. In the small pores of clayey soils, water slowly moves in all directions by ***capillary action***. The lack of large pore space leads to drainage problems and low soil oxygen levels. In sandy soils with large pores, water readily drains downwards by ***gravitational pull***. Excessive irrigation and/or precipitation can leach water-soluble nutrients, like nitrogen, out of the root zone and into ground water. [Figure 7]

Texture Interface

Within the soil profile, a ***texture interface*** (abrupt change in actual pore space) creates a boundary line that affects the movement of water, air infiltration, and root growth. Water and air are very slow to cross a texture interface.

When a clayey and/or compacted soil layer (primarily small pore space) is on top of a sandy soil layer (primarily large pore space) water accumulates just above the change. Water is slow to leave the small pore space of the clayey soil due to the water properties of *cohesion* (water molecules binding to water molecules).

Likewise, when water moving down through a sandy soil layer (primarily large pore space) hits a clayey and/or compacted soil layer (primarily small pore space) water accumulates in the soil just above the interface. This back up is due to the slow rate that water can move into the small pore space of the clayey soil. It is like a four-lane freeway suddenly changing into a country lane; traffic backs up on the freeway.

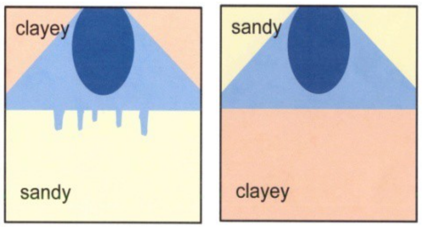


Figure 8. (left) With clayey soil over sandy soil, water is slow to leave to leave the small pore space of the clay. (right) With Sandy over clayey soil, water is slow to move into the small pore space of the clay.

Perched water table – This change in water movement creates a ***perched water table*** (overly wet layer of soil) generally 6 inches thick or greater just above the change line. When creating raised bed boxes, mix the added soil with the soil below to avoid creating a texture interface. In tree planting, to deal with the texture interface between the root ball soil and the backfill soil it is imperative that the root ball rises to the surface with no backfill soil over the root ball. In landscape soils that have a texture interface between soil layers, a perched water table may sit just above the interface line. In this situation, be cautious about frequent irrigation creating an oxygen deficiency in the roots below the perched water table. [Figures 9 & 10]

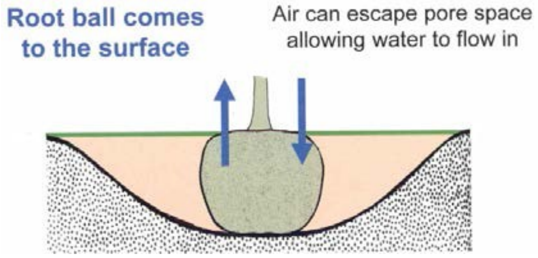
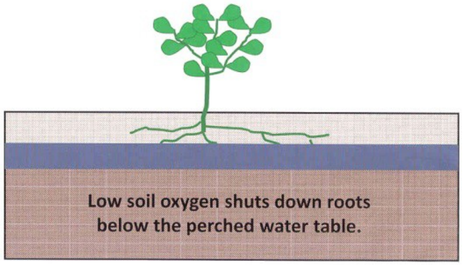


Figure 9. In tree planting, to deal with the texture interface between the root ball soil and the backfill soil it is imperative that the root ball comes to the surface with no backfill soil over top of the root ball.

Figure 10. On landscape soils with a texture interface in the soil profile, too frequent of irrigation creates a perched water table above the interface line. Roots below the perched water table have low soil oxygen levels.



Managing Soil Tilth

Gardening on Coarse-Textured, Sandy Soils

The major limitation of sandy soil is its low capacity to hold water and nutrients. Plants growing on sandy soils do not use more water; they just need to be irrigated more frequently but with smaller quantities. Heavy irrigation wastes water because it readily leaches below the root zone. Water-soluble nutrients, such as nitrogen, also leach below the rooting zone with excessive irrigation or rain.

The best management practice for sandy soils is routine applications of organic matter. Organic matter holds 10 times or more water and nutrients than sand. Sandy soils with high organic matter content (4-5%) make an ideal gardening soil.

Gardening on Fine-Textured, Clayey Soils

The limitations of clayey soils arise from a lack of large pores, thus restricting both water and air movement. Soils easily waterlog when water cannot move down through the soil profile. During irrigation or rain events, the limited large pore space in fine-textured soils quickly fills with water, reducing the roots' oxygen supply.

The best management practice for clayey soils is routine applications of organic matter and attention to fostering the activity of soil microorganisms and earthworms. As soil microorganisms decompose the organic matter, the tiny soil particles bind together into larger clumps or *aggregates*, increasing large pore space. This improvement takes place over a period of years. A single large application of organic matter does not do the trick.

A gardener may start seeing improvement in soil conditions in a couple of years as the organic content reaches 2-3%. As the organic content increases, earthworms and soil microorganisms become more active; this over time improves soil tilth. The ideal soil for most gardens has 4-5% organic matter, and at this level, additional fertilizer will not be needed. However, some native and xeric plants do not like this high organic content, having evolved for poor soils.

Take extra care to minimize soil compaction in clayey soils. Soil compaction reduces the large pore space, restricting air and water movement through the soil, thus limiting root growth. Soil compaction is the primary factor limiting plant growth in landscape soils. Soils generally become compacted during home construction.

Gardening on Gravelly and Decomposed Granite Soils

Soils in Colorado foothills and mountains change greatly with topography and precipitation. Soils may be well developed with organic matter on north and east facing slopes and in valley floors, but on dryer south and west facing slopes soils are often shallow and extremely low in organic matter.

Gardening in the gravelly and decomposed granite soils, common to many foothills and mountain areas, may be extremely challenging. Large rocks, erratic depths for bedrock, very little organic matter, pockets of clayey soil and rapid drainage with poor water holding capacity characterize these coarse textured soils. They erode readily once disturbed.

If the soil has been disturbed with the surface layer removed, decomposed granite soils will greatly benefit from organic matter. Add up to 25% by volume. For example, if tilling to a depth of eight inches, add two inches of compost or other organic materials. If only tillable to a depth of four inches, add one inch of compost. Use well decomposed materials. In some situations, mixing in the organic matter may be very labor intensive or impossible.

When Soil Amendment Is Not Practical Or Possible.

In real world settings, the ideal approach of improving soils by adding soil amendments may not be practical or possible. For example:

- In existing landscapes, it is easy to add amendments to annual flower beds and vegetable gardens, but amendments cannot be worked into the soil in the rooting zone of trees, shrubs, perennials and lawn.
- In working with new landscapes, the new home owner may not have the financial resources to purchase the amendments desired.
- The gardener may not have the physical ability for this intense labor.
- On slopes, removing the plant cover predisposes the soil to erosion.
- On rocky soils, it may be physically impractical or impossible to work in amendments.

Where amending is not practical or possible, gardeners need to consider alternatives. First and foremost, understand that without soil improvement the gardener may need to accept less than optimum plant growth and increased maintenance.

When amending is not practical or possible, consider the following options:

- Focus on selecting plants more tolerant of the soil conditions. This includes tolerance to low soil oxygen and reduced root spread (compaction issues), poor drainage (tolerance to wet soils), drought (tolerance to dry soils), and low fertility (fertilizer need). These are characteristics of some rock garden or alpine garden plants. However, be careful about assuming that these characteristics apply to native plants as it may or may not be the case.
- Space plants further apart to reduce competition for limited soil resources.
- Small transplants may adapt to poor soils better than either larger transplants or trying to grow plants from seed.

- Raised-bed gardening and container gardening may be a practical option when soils are poor.
- Pay attention to minimizing additional soil compaction with the use of organic mulches and management of foot traffic flow.
- Organic mulch (wood/bark chips) helps improve soil tilth over a period of time as the mulch decomposes and is worked into the soil by soil organisms. To allow this process to occur, do not put a weed fabric under the mulch and add material periodically.
- Established lawns, that have been in for more than some 20 years, come to equilibrium between root dieback and soil organic content.

Soil Practices to Avoid

The following is a summary of common practices that should be avoided in Western soils to maximize soil tilth and plant growth potential.

- **Avoid working the soil when wet –** Water lubricates soil particles, making the soil easier to compact.

- **Avoid excessive fertilization –** This has the potential for surface and ground water pollution and adds salts to the soil that can become toxic to plants. Heavy fertilization will not compensate for poor soil preparation. Many gardeners have over applied phosphate and potash.

- **Avoid adding too much organic matter** – This leads to salt build-up, large release of nitrogen, the build-up of excessive phosphorus, and an imbalance in potassium, calcium, magnesium, and iron. .

- **Avoid adding lime or wood ashes** – Being calcium sources, they are used to raise the soil pH. Most Colorado soils have a neutral to high pH. Lime or wood ashes would only be used on soils with a soil pH below 5.5.

- **Avoid adding gypsum (a calcium source)** – Gypsum is used to reclaim sodic soils by displacing the sodium with calcium.

- **Avoid creating texture interfaces** – For example, when making a raised bed, adding a different soil in the box creates an interface at the change line. Use similar soils and mix the soils.

- **Avoid trying to make dramatic changes in soil pH** – If the soil is high in *free lime* (calcium carbonate), lowering the pH is not effective.

Authors: David Whiting (CSU Extension, retired), with Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), Catherine Moravec (former CSU Extension Employee) and Jean Reeder, Ph.D., (USDA-ARS, retired). Reviewed by Eric Hammond (CSU Extension). Artwork by David Whiting unless otherwise noted; used by permission.

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MASTER GARDENER
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CMG GardenNotes #214

Estimating Soil Texture

Sandy, Loamy or Clayey?

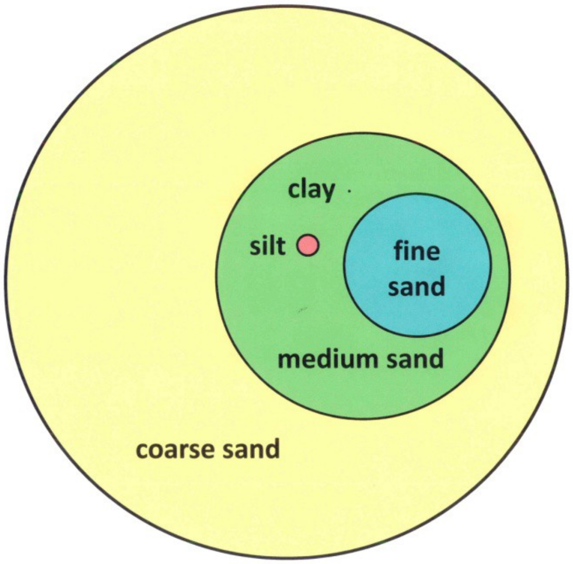
Sand, Silt and Clay

Texture refers to the size of the particles that make up the soil. The terms ***sand***, ***silt***, and ***clay*** refer to relative sizes of the soil particles. Sand, being the larger size of particles, feels gritty. Silt, being moderate in size, has a smooth or floury texture. Clay, being the smaller size of particles, feels sticky. [Table 1 and Figure 1]

Table 1. The Size of Sand, Silt and Clay

Name	particle diameter
Clay	below 0.002 mm
Silt	0.002 to 0.05 mm
Very fine sand	0.05 to 0.10 mm
Fine sand	0.10 to 0.25 mm
Medium sand	0.25 to 0.5 mm
Coarse sand	0.5 to 1.0 mm
Very coarse sand	1.0 to 2.0 mm
Gravel	2.0 to 75.0 mm
Rock	greater than 75.0 m (~2 inches)

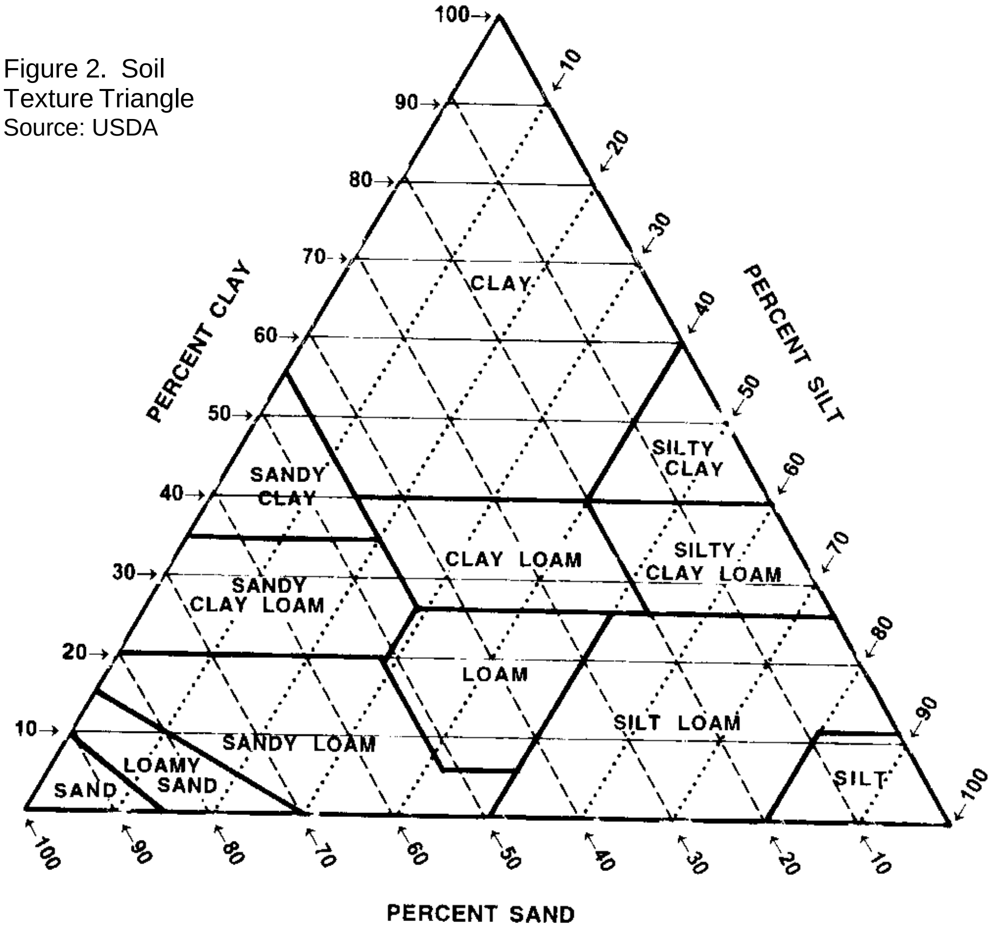
Figure 1. Comparative size of sands, silt and clay. If clay was the size of a dot on the page, silt and sands would be a comparative size.



Soil Texture Triangle

The ***soil texture triangle*** gives names associated with various combinations of sand, silt and clay. A *coarse-textured* or *sandy* soil is one comprised primarily of medium to coarse size sand particles. A *fine-textured* or *clayey* soil is one dominated by tiny clay particles. Due to the strong physical properties of clay, a soil with only 20% clay particles behaves as sticky, gummy clayey soil. The term *loam* refers to a soil with a combination of sand, silt, and clay sized particles. For example, a soil with 30% clay, 50% sand, and 20% silt is called a *sandy clay loam.* [Figure 2]

Figure 2. Soil Texture Triangle
Source: USDA



Identifying Soil Texture by Measurement

1. Spread soil on a newspaper to dry. Remove all rocks, trash, roots, etc. Crush lumps and clods.
2. Finely pulverize the soil.
3. Fill a tall, slender jar (like a quart jar) a one-quarter full of soil.
4. Add water until the jar is theee-quarters full.
5. Add a teaspoon of powdered, non-foaming dishwasher detergent.
6. Put on a tight fitting lid and shake hard for 10 to 15 minutes. This shaking breaks apart the soil aggregates and separates the soil into individual mineral particles.
7. Set the jar where it will not be disturbed for 2 to 3 days.

8. Soil particles will settle out according to size. **After 1 minute,** mark on the jar the depth of the sand.

9. **After 2 hours,** mark on the jar the depth of the silt.

10. **When the water clears** mark on the jar the clay level. This typically takes 1 to 3 days, but with some soils it may take weeks.

11. Measure the thickness of the sand, silt, and clay layers.
    a. Thickness of sand deposit ____
    b. Thickness of silt deposit ____
    c. Thickness of clay deposit ____
    d. Thickness of total deposit ____

12. Calculate the percentage of sand, silt, and clay.

[clay thickness]
-------------------- =____percent clay
[total thickness]

[silt thickness]
-------------------- =____percent silt
[total thickness]

[sand thickness]
-------------------- =____percent sand
[total thickness]

13. Turn to the soil texture triangle and look up the soil texture class.

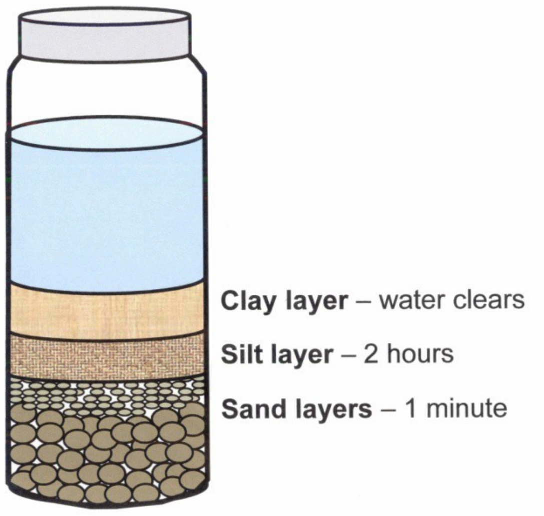


Figure 3. Measuring Soil Texture

Identifying Soil Texture by Feel [Figure 4]

Feel test – Rub some moist soil between fingers.

- Sand feels gritty.
- Silt feels smooth.
- Clays feel sticky.

Ball squeeze test – Squeeze a moistened ball of soil in the hand.

- Coarse texture soils (sand or loamy sands) break with slight pressure.
- Medium texture soils (sandy loams and silt loams) stay together but change shape easily.
- Fine textured soils (clayey or clayey loam) resist breaking.

Ribbon test – Squeeze a moistened ball of soil out between thumb and fingers.

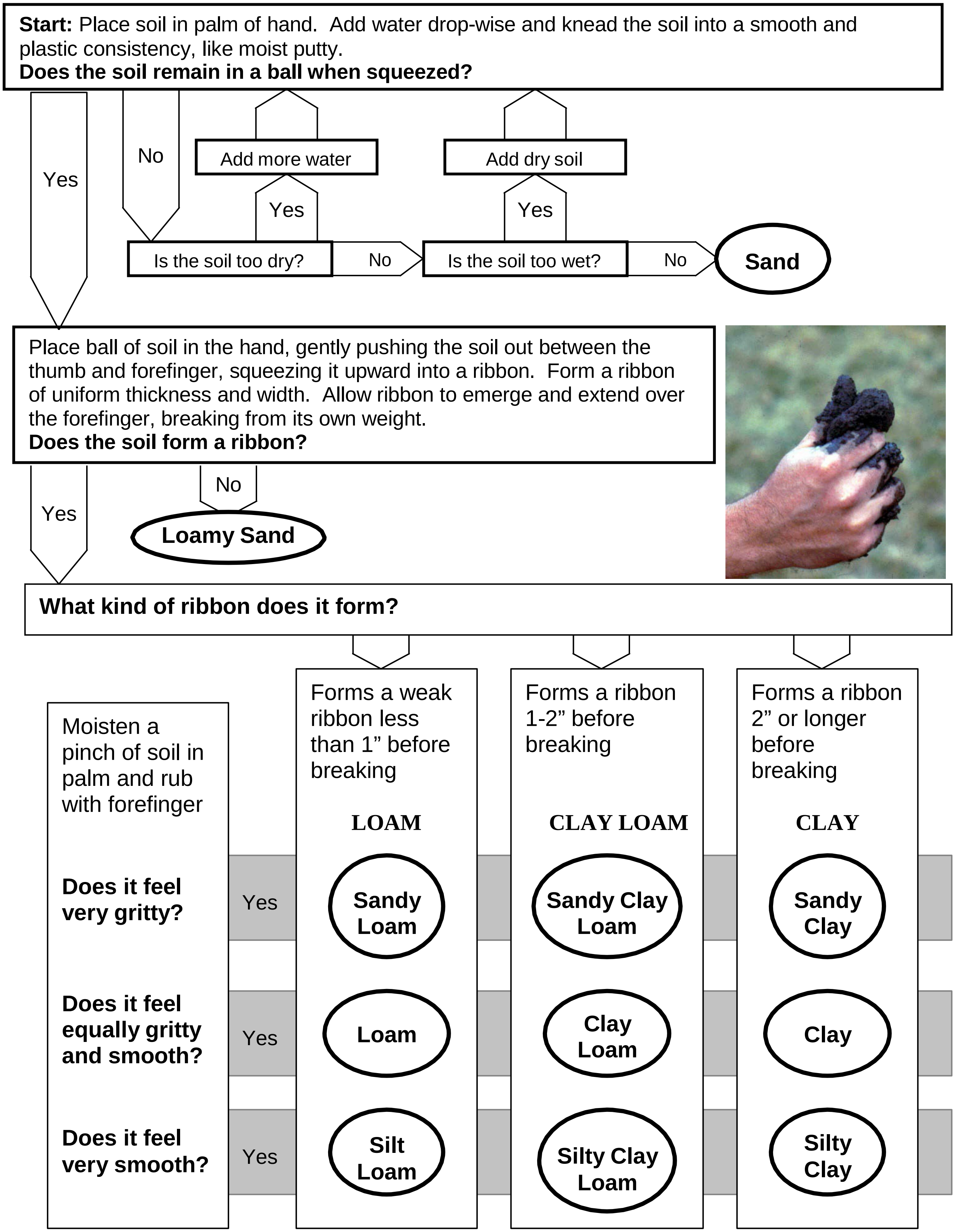
- Ribbons less than 1 inch
  - Feels gritty = coarse texture (sandy) soil
  - Not gritty feeling = medium texture soil high in silt
- Ribbons 1 to 2 nches
  - Feels gritty = medium texture soil
  - Not gritty feeling = fine texture soil
- Ribbons greater than 2 inches = fine texture (clayey) soil

Note: A soil with as little as 20% clay will behave as a clayey soil. A soil needs 45% to over 60% medium to coarse sand to behave as a sandy soil. In a soil with 20% clay and 80% sand, the soil will behave as a clayey soil.

Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired) and Jean Reeder, Ph.D., (USDA-ARS, retired). Reviewed by Eric Hammond (CSU Extension). Artwork by David Whiting; used by permission.

Revised 2014; reviewed December 2015

Figure 4. Soil Texture by Feel



Start: Place soil in palm of hand. Add water drop-wise and knead the soil into a smooth and plastic consistency, like moist putty.
Does the soil remain in a ball when squeezed?

Place ball of soil in the hand, gently pushing the soil out between the thumb and forefinger, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow ribbon to emerge and extend over the forefinger, breaking from its own weight.
Does the soil form a ribbon?

What kind of ribbon does it form?

Moisten a pinch of soil in palm and rub with forefinger		Forms a weak ribbon less than 1” before breaking LOAM	Forms a ribbon 1-2” before breaking CLAY LOAM	Forms a ribbon 2” or longer before breaking CLAY
Does it feel very gritty?	Yes	**Sandy Loam**	**Sandy Clay Loam**	**Sandy Clay**
Does it feel equally gritty and smooth?	Yes	**Loam**	**Clay Loam**	**Clay**
Does it feel very smooth?	Yes	**Silt Loam**	**Silty Clay Loam**	**Silty Clay**

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CMG GardenNotes #215

Soil Compaction

What Is Soil Compaction?

Soil compaction is the compression of soil particles. Compaction reduces total pore space of a soil. More importantly it significantly reduces the amount of large pore space, restricting air and water movement into and through the soil. *Low soil oxygen levels caused by soil compaction are the primary factor limiting plant growth in landscape soils.* Soil conditions, primarily soil compaction, contribute to a large portion of plant disorders in the landscape setting. Figure 1 illustrates comparison of large pore spaces in a non-compacted versus a compacted soil. Soil compaction can change a block or aggregate structure (with good infiltration and drainage) into a massive structure (with poor infiltration and drainage). [Figure 2]

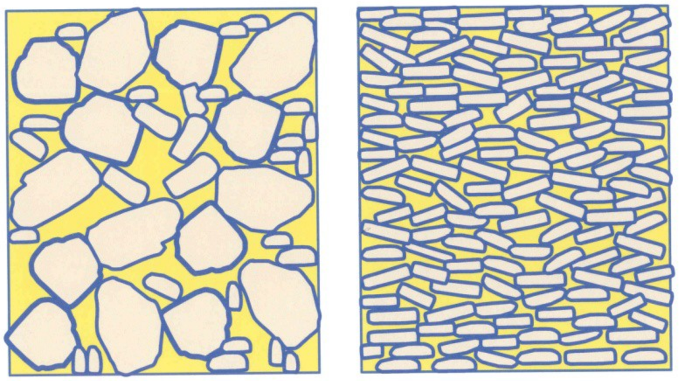

Figure 1. Comparison of large pore space in non-compacted soil (left) and compacted soil (right).

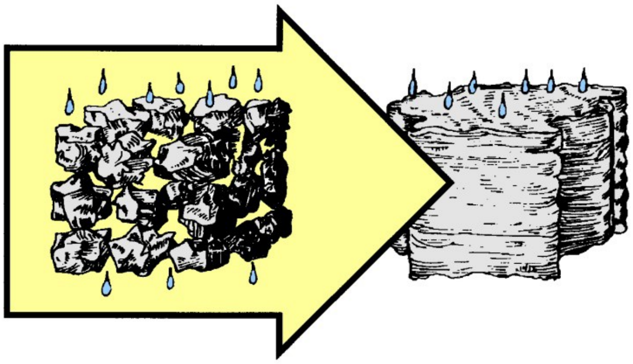

Figure 2. Soil compaction can change a blocky or granular soil structure (with good air infiltration and drainage) into a massive structure with poor air infiltration and drainage.
[Line drawing by USDA]

Soil compaction is difficult to correct, thus efforts should be directed at preventing compaction. Soils generally become compacted during home construction. Foot traffic on moist soils is another primary compaction force in the home landscape. The impact of falling raindrops and sprinkler irrigation also compacts the surface of fine-textured clayey soils. [Figure 3]

Figure 3. Foot traffic in the garden bed is a major source of compaction. The impact of raindrops and sprinkler irrigation also compacts fine-textured soils.

Techniques to Minimize Soil Compaction

Adding Organic Matter

To reduce soil compaction, cultivate organic soil amendments into the top six to eight inches of the soil. In compacted/clayey soils, anything less can lead to a shallow rooting system with reduced plant growth, lower vigor, and lower stress tolerance.

General application rates for organic soil amendments are based on the type of product and the salt content. Table 1 gives standard application rates for compost products. Compost made solely from plant residues (leaves and other yard wastes) is basically free of salt problems, so higher application rates are safe.

Compost that includes manure or biosolids as a component has a potential for high salts. Excessive salt levels are common in many commercially available products sold in Colorado. For compost made with manure or biosolids, the application rate is limited unless a soil test on that batch of product shows a low salt level. An amendment with up to 10 dS/m (10 mmhos/cm) total salt is acceptable if incorporated six to eight inches deep in a low-salt garden soil (less than 1 dS/m or 1 mmhos/cm). Any amendment with a salt level above 10 dS/m (10 mmhos/cm) is questionable.

Note: dS/m or mmhos/cm is the unit used to measure salt content. It measures the electrical conductivity of the soil.

Do not leave compost in chunks as this will interfere with root growth and soil water movement. As the soil organic content builds in a garden soil, the application rate should be reduced to prevent ground water contamination issues.

Table 1. Routine Application Rate for Compost

Site	**Incorporation Depth**[2]	**Depth of Compost Before Incorporation**[1]	
		Plant Based Compost and other compost known to be low in salts[3]	**Compost Made with Manure or Biosolids** for which the salt content is unknown[4]
One-time application—such as lawn area	6-8”	2-3”	1”
Annual application to vegetable and flower gardens – **first three years**	6-8”	2-3”	1”
Annual application to vegetable and flower gardens – **fourth year and beyond**	6-8”	1-2”	1”

1 Three cubic yards (67 bushels) covers 1,000 square feet approximately 1 inch deep.

2 Cultivate compost into the top 6-8 inches of the soil. On compacted/clayey soils, anything less may result in a shallow rooting depth predisposing plants to reduced growth, low vigor, and low stress tolerance. When depth of incorporation is different than 6-8 inches, adjust the application rate accordingly.

3 Plant based composts are derived solely from plant materials (leaves, grass clippings, wood chips and other yards wastes). Use this application rate also for other compost known, by soil test, to be low in salts.

4 Use this application rate for any compost made with manure or biosolids unless the salt content is known, by soil test, to be low. Excessive salts are common in many commercially available products sold in Colorado.

Manage Traffic Flow

Traffic over the soil is the major contributor to soil compaction. For example a moist soil could reach 75% maximum compaction the first time it is stepped on, and 90% by the fourth time it is stepped on.

Raised bed gardening techniques, with established walkways, eliminate compaction in the growing bed. In fine-textured clayey soils, limit routine traffic flow to selected paths.

Soils are more prone to compaction when wet. Soil water acts as a lubricant allowing the soil particles to readily slide together reducing large pore spaces.

Use Mulches

Some types of mulch effectively reduce the compaction forces of traffic. For example, three to four inches of wood or bark chips will minimize the effect of foot traffic.

Mulch minimizes the compaction forces of rainfall and sprinkler irrigation. In fine-textured clayey soil, keep garden beds mulched year round to minimize the compaction forces of summer and winter storms.
Organic mulches create an ideal home for beneficial earthworms and soil microorganisms, which play a key role in improving soil tilth.

Aerate Lawns and Around Trees

In a lawn or tree's rooting area, where organic matter cannot be cultivated into the soil, reduce compaction with soil aeration. Make enough passes with the aerator to have plugs at two-inch intervals. [Figure 4]

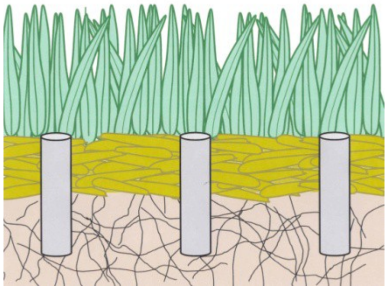

Figure 4. Lawn aeration helps manage the impact of soil compaction if enough passes are made with the aerator to have plugs at two-inch intervals.

Avoid Excessive Cultivation

Avoid cultivating fine-textured clayey soils except to incorporate organic matter and fertilizer, and to prepare a seedbed. Use mulches to help manage weeds.

Avoid Cultivating Overly Wet or Dry Soils

Never cultivate a clayey soil when wet as this will destroy soil structure; the clods created by tilling wet clay may last for years. To check dryness, take a handful of soil and gently squeeze it into a ball. If the soil is dry enough to crumble, it may be cultivated. If the ball only reshapes with pressure, it is too wet for cultivation. On some clayey soils, there may be only a few days (or even hours) between the time when the soil is too wet and too dry (too hard) to cultivate. In years when frequent spring rains prevent the soil from drying, planting will be significantly delayed.

Avoid Fill Over Compacted Soil

Adding a thin layer of topsoil over compacted soil is a common practice that leads to future landscape management problems. It is often justified as "a way to get plants established." However, root growth into the compacted layer will be restricted or even minimal.

Do not create a layer with added topsoil that is of a different texture than the soil below. This change in texture (actually pore space) interferes with water movement and root spread. Where additional fill is desirable, lightly mix the fill with the soil beneath.

Long-term landscape management will be much easier by breaking up surface compaction with tilling and organic matter amendments. Before planting a yard, enhance soil organic content to the extent feasible. A minimum of 3 to 4 cubic yards of organic matter per 1,000 square feet is recommended.

What About Adding Sand?

Some gardeners try to improve fine-textured soils by adding sand. The practice may help the gardeners feel that they have done something, but it will have a limited or even negative impact on the soil. Adding sand to a clayey soil may actually reduce large pore space until enough medium-to–coarse-size sand is added to reduce the clay content well below 20%. In clayey soils, this actually become a process of soil replacement rather than soil amendment. In some situations, adding sand to clayey soil can create concrete-like soil properties. To improve the soil, put efforts into adding organic matter, not sand.

What About Adding Gypsum?

Gypsum is a salt also known as calcium sulfate. When added to calcareous clayey soils (typical of Colorado), it simply increases the already high calcium content. Gypsum will not break up a compacted soil, but can increase the soil's salt levels.

Gypsum is useful when a soil has a high sodium problem. Sodium has a unique physical characteristic that brings soil particles closer together, reducing large pore space and "sealing" soils to water penetration. The calcium in gypsum replaces the sodium on the soil cation exchange site and the freed sodium is then leached out by heavy irrigation. Good quality (low salt) irrigation water must be available to successfully reclaim a high sodium soil.

The use of sulfur has also been incorrectly acclaimed to break up compacted soils. Over a period of time, sulfur may have an acidifying effect on a soil (if the soil is not high in lime). Adding sulfur to a calcareous soil only creates gypsum (calcium sulfate).

Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired) and Jean Reeder, Ph.D., (USDA-ARS, retired). Reviewed by Eric Hammond (CSU Extension). Artwork by David Whiting (unless otherwise noted); used by permission.

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CMG GardenNotes #218

Earthworms

<u>Outline:</u>

Regarded by Aristotle as the "intestines of the earth", earthworms aid in soil fertility and structure, and contribute to overall plant health.

Earthworm Types

There are three types of earthworms: (see Figure 1.)

Anecic (Greek for "up from the earth" or "out of the earth")

- Capable of burrowing to depths of 6'
- Build permanent burrows into the deep mineral layers of the soil
- Drag organic matter from the soil surface into their burrows for food
- Include the familiar bait worm, the nightcrawler or dew worm (*Lumbricus terrestris)*

Endogeic (Greek for "within the earth")

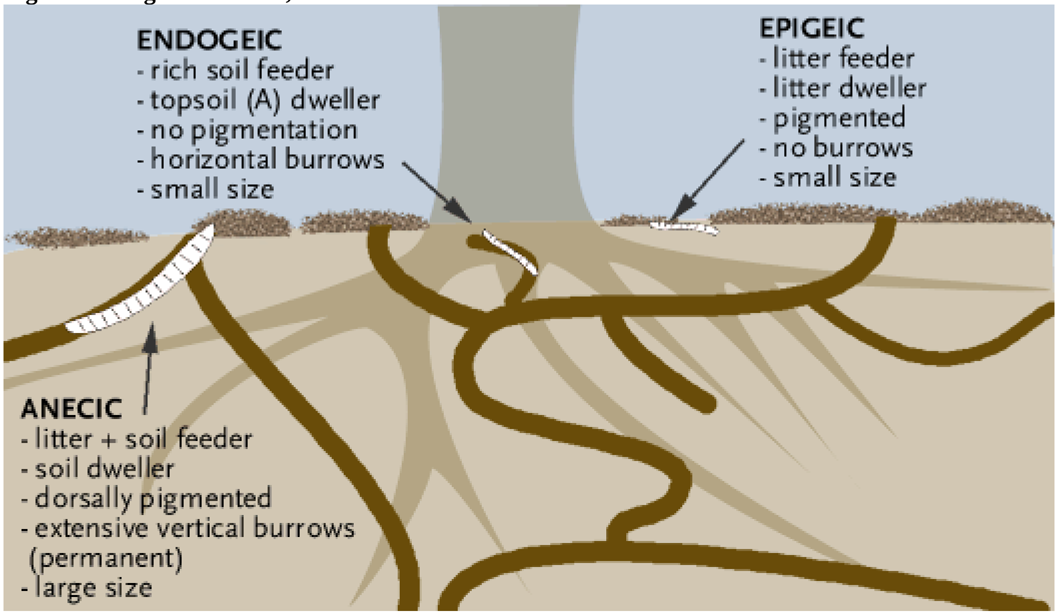
- Build extensive non-permanent burrows in the upper mineral layer of soil
- Feed on the organic matter in the soil
- Live exclusively in soil and usually are not noticed, except after a heavy rain when they come to the surface

Epigeic (Greek for "upon the earth")

- Live on the soil surface
- Form no permanent burrows
- Feed on decaying organic matter
- Common names: red worm, manure worm, brandling worm, red wiggler and compost worm

The anecic (an – ess – ik) and endogeic (in – dough – gee – ik) are the types most often noticed in Colorado soils. Because the upper foot of soil freezes here during the winter, the epigeic worms are usually killed. In addition, the low organic matter content of Colorado soils will likely not support the food needs of epigeic earthworms. Anecic are larger than the endogeic.

Figure 1: Image from UNM, Natural Resources Research Institute



Biology of Earthworms

Earthworms breathe through their skin and must be in an environment that has at least 40% moisture (at least as damp as a wrung out sponge). If their skin dries out, they cannot breathe and will die.

Earthworms prefer a near-neutral soil pH.

Instead of teeth, earthworms have a gizzard like a chicken that grinds the soil and organic matter that they consume. They eat the soil microorganisms that live in and on the soil and organic matter.

Worm excrement is commonly called worm casts or castings. These soil clusters are glued together when excreted by the earthworm and are quite resistant to erosive forces. Their castings contain many more microorganisms than their food sources because their intestines inoculate the casts with microorganisms.

Earthworms become sexually mature when the familiar band (the clitellum) appears around their body, closer to their mouth. Each worm with a clitellum is capable of mating with other worms and producing cocoons that contain baby worms. Cocoons are lemon shaped and slightly smaller than a pencil eraser.

Benefits of Earthworms

Charles Darwin, known for his work with evolution of species wrote a paper on earthworms during his final years. In it he surmised that most all of the fertile soil on earth must have passed through the gut of an earthworm. While not entirely accurate, earthworms do play an important role in soil and plant health.

Soil Fertility

Earthworms are part of a host of organisms that decompose organic matter in the soil. As earthworms digest the microorganisms and organic matter in soil, the form of nutrients is changed as materials pass through the earthworm's gut. Thus, worm casts are richer than the surrounding soil, containing nutrients changed into forms that are more available to plants. For example, one study found that in a sample of soil with 4% organic matter, worm casts contained 246 pounds of nitrogen per 1000 square feet while the surrounding soil contained 161 pounds of nitrogen per 1000 square feet (Source: ATTRA, Sustainable Soil Systems).

Soil Structure

The deep burrows of anecic earthworms create passages for air, water and roots. Burrows provide easy avenues for the exchange of soil gases with the atmosphere. Clay soils with extensive earthworm burrows will allow water to infiltrate and percolate more readily than those without. Plants have the capacity to root deeper and the lower layers of soil can recharge with air more quickly. Air is an essential component of root development.

Anecic worms mix the soil as they create their burrows and build soil organic matter and humus as they drag litter into their burrows and excrete castings in the soil.

Endogeic worms burrows contribute to soil tilth, tying together many of the large pore spaces in the soil and increasing soil porosity.

The mucus from the skin of earthworms aids in the formation of soil aggregates, which are integral components of the crumb of soil structure. Aggregates are also formed in castings.

Water-Holding Capacity

By increasing the organic matter content, soil porosity and aggregation, earthworms can greatly increase the water-holding capacity of soils.

How to Encourage Earthworm Activity

Earthworms will not go where it is too hot/cold or too dry/wet. Soil temperatures above 70ºF or below 40ºF will discourage earthworm activity. While soil temperature is hard to alter, moisture can be managed. When soil becomes water logged, oxygen is driven out of the large pore spaces. Without this free oxygen, earthworms cannot breath. Conversely, when soil dries beyond half of field capacity, earthworm skin dries in the soil. Maintaining moisture levels that are ideal for optimum plant growth in a landscape or garden will also be ideal for earthworm activity.

Providing a food source in the form of organic matter is also important. Mulching grass clippings into the lawn, putting down a layer of organic mulch in beds, amending the soil with compost, and turning under a green manure are all excellent ways to feed earthworm populations.

Practices Detrimental to Earthworm Activity

- High rates of ammonium nitrate are harmful to earthworms
- Tillage destroys permanent burrows and can cut and kill worms. Fall tillage can be especially destructive to earthworm populations. Deep and frequent tillage can reduce earthworm populations by as much as 90%.
- Earthworms are also hindered by salty conditions in the soil.
- Some chemicals have toxic effects on earthworm populations. [Table 1]

Table 1. Earthworm Population Reduction by Pesticides

Pesticide	Toxicity to Earthworms	Reduction
Sevin (carbaryl) insecticide	Severe	76-100%
Diazinon insecticide	Moderate	26-50%
2,4-D herbicide	Low	0-25%

*Study from University of Kentucky Department. of Entomology

Transplanting Earthworms

To create worm populations in a soil without worms simply dig a large spade-full of soil from an area with visible worm numbers and bury this soil in the area where worms are needed.

Author: Adrian Card, Colorado State University Extension, Boulder County, Revised by Susan Carter, CSU Ext, Tri River Area

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CMG GardenNotes #219

Soil Drainage

Outline:

Pore Space Controls Soil Drainage Characteristics

Pore space controls soil drainage characteristics. In other words, drainage problems often arise from lack of large-sized pores.

In soils dominated by large pores (i.e., sandy soils), water moves rapidly. Soils that allow rapid ***leaching*** (water movement down through the soil profile) also pose environmental hazards because rain or irrigation water moving through the soil profile takes water-soluble pollutants with it. Ground water pollution is a sensitive issue on coarse-textured sandy soils.

In comparison~~, in~~ soils dominated by small-sized pores (i.e., compacted soils and soils with greater than 20% clay content), water is slow to move or may not move at all. Soils easily waterlog.

Roots must have oxygen to survive and root activity shuts down in waterlogged soils. Plants growing on wet soils are typically shallow rooted. Many plants are prone to root rot in wet soils. Prolonged periods of waterlogged soil conditions lead to the decline or even death of most plants.

When water does not leach through the soil profile, salts left behind by surface evaporation accumulate and create a white crust on the soil. This is frequently observed as a white deposit on low spots of pastures and fields. High soil salt content limits plant growth in some areas of Colorado.

Poor drainage is a common problem in many Colorado soils. In some areas, the surface soil allows water infiltration only to have the water stopped as it reaches a less permeable subsurface soil layer.

A simple test to evaluate soil drainage is to dig a hole 12 inches deep and fill it with water. If the water fails to drain in 30 minutes, the soil has a drainage problem. If the hole fails to drain in 24 hours, waterlogged soils may affect plant growth.

Correcting Drainage Problems

Managing Soil Tilth

Attention to managing soil tilth plays a key role in soil drainage. On coarse- textured sandy soils, routine applications of organic matter increase the water holding capacity. On compacted and fine-textured clayey soils, attention to organic matter and the “living soil” helps create large pores, improving drainage.

French Drains

In some situations, a ***French drain*** facilitates water drainage. A French drain is a lined ditch-like trench that is filled with rock or gravel, typically with a pipe in the bottom. It catches water runoff and directs it away from structures that can be damaged. The rock should meet grade to prevent soil from covering the drain. The trench must slope at least 1-3% and flow to an outlet. [Figure 1]

Figure 1. A French drain is a ditch-like trench filled with rock. Water must flow downhill to an outlet.

Surface Drainage and Runoff

To minimize surface runoff and soil erosion, sloping areas should be planted with perennial ground covers or turf. Mowed lawns or un-mowed naturalized grass areas make the best ground cover for slowing runoff. Some landscapes may be terraced to control runoff.

To improve surface drainage problems, first identify, and then correct, the contributing factors.

Irrigation – Many surface drainage problems arise from over-irrigation (too much and/or too often).

Compaction – Compaction is difficult to deal with; so prevention is the key. Soils around new homes are typically compacted from construction traffic. Break up the compacted layer by tilling, adding organic matter, using cover crops and encouraging earthworms and soil organisms.

Organic mulches, like wood/bark chips, help manage compaction around trees and shrubs, perennials, small fruits, and garden paths.

Thatch in lawn – A heavy thatch layer in a lawn slows water infiltration. Improve by aerating the lawn (making enough passes that plugs are at 2-inch intervals). (See lawn care information for additional details.) [Figure 2]

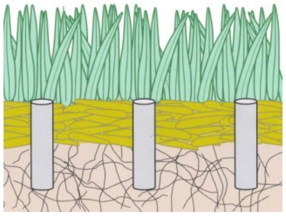

Figure 2. A heavy thatch layer slows water infiltration. Routine aeration maybe needed on compacted clayey soil to help reduce thatch and open the soil to air and water.

Grading – Sometimes the grade may be deceiving. Make sure areas are properly graded so there are not low spots and all drainage heads in the right direction.

Standing water – It is common to find standing water in low spots. Look at the irrigation schedule; is the area being over-watered or is irrigation running off instead of soaking in (aerate and use multiple shorter irrigation cycles). Fill in the low spot, or install a French or underground drain with a gravity-flow outlet.

High water table – Some areas of Colorado have high water tables. The only solution may be to raise the soil level (raised bed or berm gardening).

Impervious subsoil – In Colorado, we find many soil profiles with an impervious soil layer under the surface. This can be caused by many years of tillage at the same depth. Refer to the subsequent discussion on subsurface drainage.

Subsurface Drainage

Subsurface drainage problems are generally correctable only to the extent that large soil pore spaces can be increased to allow for better water movement. Use of soil drainage tiles are only effective to the extent that the soil will allow water to flow through it to the drain tile, and water in the drain tile can flow downhill to an outlet.

To improve subsurface drainage problems, first identify, and then correct, the contributing factors.

Impervious subsoil layer underlain with permeable soil

- If less than 2 feet thick, rip or double-dig when soil is dry. Irrigate to settle, and do final grade when soil re-dries.
- If greater than 2 feet thick, bore holes through layer
- Holes are typically 4-6 inches in diameter, at 6 foot intervals. Fill with coarse sand or fine gravel.

Impermeable subsoil

- Increase soil depth
- Select shallow-rooted and water-tolerant plants
- These soils may have a salt problem.

Change in soil texture – A change in soil texture creates water movement problems. This is a common problem when soils are added to a raised-bed box or applied as a top dressing.

- Cultivate to mix layers

Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired) and Jean Reeder, Ph.D., (USDA-ARS, retired). Artwork by David Whiting, used by permission. Revised by Susan Carter, CSU Extension.

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CMG GardenNotes #221

Soil Tests

Outline:

Value of a Soil Test

In agronomic crops, greenhouse crops and turf, an extensive research base for interpretation of soil test results makes soil testing a key tool in crop management for commercial producers.

In the home garden setting, soil testing is valuable to establish a base line on soil limitations related to pH, salt levels, and the need for phosphate and potash fertilizers. A special lead test would be of concern to homeowners with lead-based paints on older homes.

In some gardening situations, soil testing has limited value. For example, soil testing for nitrogen has limited use for the home gardener because the nitrogen level constantly changes in response to soil organic matter additions, soil microorganism activity, and temperature, moisture levels, leaching and nitrogen consumption by plants and other soil life.

The research base for interpreting results is also lacking for landscape plants. For example, a test for a maple tree, native plants, or a gardener’s favorite peony would be difficult to interpret based on standards used for general agronomic crops.

Finally, a standard soil test will not identify common garden problems related to over-watering, under-watering, poor soil drainage, soil compaction, diseases, insects, weed competition, environmental disorders, too much shade, poor varieties, or simple neglect.

Typical Test

A standard soil test typically includes the following:

- Texture (estimated by the hand-feel method)
- Organic matter (reported as a percent of the total soil)

    - About two-thirds of a pound of nitrogen per 1,000 square feet will be released (mineralized to nitrate) during the growing season for each one percent organic matter present.
- pH
- Lime ($CaCO_3$ reported by percent)
- In soils with "free lime", sulfur will not effectively lower the pH
- Soluble salts (reported in mmhos/cm or dS/m)
- Nutrients (reported in parts per million)
    - Nitrate nitrogen
    - Phosphorus
    - Potassium
    - Micronutrients such as copper, iron, manganese and zinc

Additional tests could be run for special needs like lead content or sodium problems. For additional details on soil testing, refer to CSU Extension fact sheet #0.502, *Soil Test Explanation*.

Frequency

For a gardener a soil test gives a useful base line on soil salts, phosphorus, potassium, pH and *free lime* content (or buffer index if acid).

In the neutral and alkaline soils of Colorado, repeat the test when dramatic changes are made to the soil (such as addition of larger quantities of manure, biosolids, or compost that may be high in salts) or approximately every 4-8 years to reestablish the base line.

In other parts of the country where lime is routinely added to raise the pH on acid soils, a soil test may be needed annually.

Taking a Soil Sample

A soil sample may be taken at any time of year, although spring or fall sampling is usually the most convenient.

The results of a test are no better than the quality of the sample sent to the laboratory. The sample must be representative of the yard or garden being considered. Gardeners who try to shortcut the sampling procedure will not receive a reliable result.

Submit a sample for each area that receives different fertilizer and soil management treatments. For example, if the front and back lawn are fertilized the same, the sample should include subsamples taken from each and mixed together. Because garden areas are managed differently from lawns, the garden should be sampled separate from the lawn. Sample various garden beds that receive differing amounts of fertilizers and soil amendments separately.

Samples are most easily collected using a soil tube or soil auger. A garden trowel, spade, bulb planter, or large knife also works. Discard any sod, surface vegetation or litter. Sampling depth is critical and varies for the type of test taken and for various labs. Follow sampling depth directions given by the laboratory. [Table 1]

Table 1. Example of Sampling Depth for Soil Tests

Crop	Sampling Depth
Garden (vegetable and flower)	0 through 6 inches
Lawns, new (prior to planting)	0 through 6 inches
Lawns, established	0 through 3 inches
Lead test	0 through ¾ inch

Each sample should be a composite of subsamples collected from randomly selected spots within the chosen area. Take five or more subsamples from a relatively small area in the home lawn, flower border or vegetable garden. Take 10-15 subsamples for larger areas.

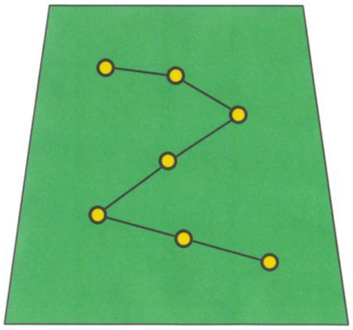

Figure 1. A proper soil sample is a composite of five to fifteen sub samples.

Collect the subsamples in a clean plastic pail, thoroughly mixing the subsamples together. Remove plant debris and break up clods. If possible, air-dry the soil by spreading it out on paper towel. (Do not oven-dry the sample.)

Place about two cups of the soil mix into the sample bag or box. Label the sample container (e.g., front lawn, vegetable garden, or flowerbed) and keep a record of the area represented by each sample taken. Send the samples to the soil-testing laboratory.

Climate and soil vary considerably in different parts of the country so it's important to select a local laboratory that processes for the alkaline calcareous soils of the mountain west. Future testing should be done with the same laboratory to make comparisons.

Soil tests are available from many local providers. For a list of laboratories, refer to CSU Extension fact sheet #0.520, *Selecting an Analytical Lab* available online at www.cmg.colostate.edu.

Soil Test Recommendations

In production agriculture, it is not uncommon for a grower or fertilizer dealer to split a sample and send it to different laboratories. Because individual laboratories do not necessarily use the same soil test procedures, their ***availability indexes*** (the reported available nutrients) can, and frequently do, differ.

Laboratories can also differ in the objectives behind their recommendations. For example, are maximum yields the primary objective? In this scenario, fertilizer application will be highest, with increased costs, and higher potential for leaching of fertilizers into ground water. In another scenario, the crop's net return may be the primary objective, reducing production (fertilizer) costs, or minimizing potential for ground water pollution.

Fertilizer practices may also impact recommendations. For example, is the phosphate fertilizer recommendation based on an annual application or a single application to last several years? For new turf, it is a standard practice to bring the phosphorus to a higher level when the fertilizer can be cultivated through the soil profile before the sod is laid.

The recommendations resulting from a soil test need to be made by the laboratory doing the work, based on cropping information provided by the grower/gardener.

Home Soil Test Kits

Home soil test kits have questionable value. The actual process used in some procedures is based on soil pH. Most home test kits were designed for acid soils, and have questionable accuracy on the alkaline soils of the west.

The accuracy in home soil test procedures may, at best, give a ballpark reading but not precise accuracy. For example, the calibration on a home soil pH kit will tell the gardener that the soil has a pH level between 7 and 8. How close to 7 or 8 makes a huge difference for the growth of some plants. More precise measurement requires more expensive equipment.

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CMG GardenNotes #222

Soil pH

Soil pH

Soil pH is a measurement of the acidity or alkalinity of a soil. On the pH scale, 7.0 is neutral. Below 7.0 is acidic, and above 7.0 is basic or alkaline. A pH range of 6.8 to 7.2 is termed ***near neutral***. A soil's pH is a product of the factors which formed it. Primarily, it is a result of the parent material of the soil and climate. The quality of irrigation water used can also have an effect on soil pH. Areas of the world with limited rainfall typically have alkaline soils while areas with higher rainfall typically have acid soils.

Soil pH is important to gardeners because it can affect the availability of plant nutrients as well as the soil ecology. In very acid or alkaline soils some plant nutrients convert to forms that are more difficult for plants to absorb. This can result in nutrient deficiencies. Plants which have evolved under such soil conditions often have developed mechanisms to deal with this issue.

In Colorado, many of our soils are alkaline with a pH of 7.0 to 8.3. Soils with a pH of 7.5 to 8.3 generally have a high calcium carbonate content (known as ***free lime***). This is important because it is impractical to lower a soil's pH if it contains free lime. Free lime buffers the soil against pH change by neutralizing acids which are added to the soil. Soils with a pH of 8.3 or higher normally have a very high sodium content (such soils are referred to as sodic). In some mountain soils and older gardens that have been irrigated and cultivated for many years the pH may be in the neutral range (6.8 to 7.2). When possible, select plants which are adapted to your soil pH.

Many gardening books list the preferred pH for common plants (generally 6.0 to 7.2). **Most common landscape plants can tolerate a wider range.** The exception is acid-loving plants, like blueberries, azaleas, and rhododendrons that need acid soil. Blue hydrangeas also require a pH lower than 5.0 to induce the blue flower color. [Figure 1]

Figure 1. Soil pH and Plant Growth

Soil Reaction	pH	Plant Growth
	>8.3	Too alkaline and sodic for most plants
	7.5	Iron availability becomes a problem on alkaline soils.
Alkaline soil	**7.2**	6.8 to 7.2 – “near neutral” 6.0 to 7.5 – acceptable for most plants
Neutral soil	**7.0**	
Acid soil	**6.8**	
	6.0	
	5.5	Reduced soil microbial activity esp. bacteria
	<4.6	Too acid for most plants

Managing Alkaline Soils

Manage Colorado soils with moderate to high alkalinity (pH above 7.5) by increasing soil organic matter content and managing soil moisture through organic mulches and proper irrigation. Overly wet or dry soils may amplify the issues created by high soil alkalinity.

In Colorado, a major problem with high pH is iron chlorosis.

Soils with a pH above 7.3 and/or with *free lime* cannot be adequately amended for acid-loving plants like blueberries, azaleas, and rhododendrons.

Gardeners may find a slight decrease in soil pH over many decades. This occurs as irrigation leaches out elements (calcium and magnesium) which contribute to the higher pH. Many fertilizers also add acidity to soil and plant roots secrete weak acids into the soil which may also contribute to a gradual pH change. The presence of free lime in a soil slows this gradual acidification.

Lowering the pH

Applications of elemental sulfur are often recommended to lower a soil’s pH. This is effective in many parts of the country**. However it is not effective in many Colorado soils due to high levels of free lime.** In alkaline soils which contain free lime, drastically modifying the pH of the soil is impractical.

To test for ***free lime***, place a heaping tablespoon of crumbled dry soil in a cup. Moisten it with vinegar. If the soil-vinegar mix bubbles, the soil has free lime. **In soils with *free lime*, a gardener will not effectively lower the pH.**

On soils without free lime, the following products may help lower the pH.

Elemental sulfur **is one chemical that can be used to lower soil pH. The soil type, existing pH, and the desired pH are used to determine the amount of elemental sulfur needed (see Table 1). Incorporate sulfur to a depth of six inches. It may take several months to over a year to react with the soil, lowering the pH. Test soil pH again 3 to 4 months after initial application. If the soil pH is not in the desired range, reapply.**

Table 1. Pounds of Sulfur Needed to Lower Soil pH[1]

Material	pH Change	Pounds per 100 Square Feet[2]
Sulfur	7.5 to 6.5	1.5
	8.0 to 6.5	3.5
	8.3 to 6.5	4.0

1 Effective only on soils without free lime, do the vinegar test.
2 Higher rates will be required on fine-textured, clayey soils and soils with a pH 7.3 and above.

Aluminum sulfate will also lower pH, but it is not recommended as a soil acidifying amendment because of the potential of aluminum toxicity to plant roots.

Acid sphagnum peat incorporated into the soil prior to planting will help provide a favorable rooting environment for the establishment of acid-loving plants in near neutral soils. Incorporate peat at the rate of one to two cubic feet per plant. The positive effects of acid peat will last a few years, but unless other measures are used, the pH of the soil will eventually increase. The pH will be driven up with the high calcium in our irrigation water. Soil with a pH above 7.3 and/or with *free lime* cannot be adequately amended for acid-loving plants.

Fertilizers – Use of **ammonium sulfate, ammonium nitrate** or **urea** as nitrogen fertilizer sources will also have a small effect on lowering soil pH in soils without free lime. However, do not use these fertilizers at rates greater than those required to meet the nitrogen needs of the plants. For example, ammonium sulfate fertilizer, 21-0-0, at ten pounds per 1000 square feet (maximum rate for crop application) may lower the pH from 7.3 to 7.2.

Raising the pH in Acid Soil

On acid soils, the pH can be raised by adding lime (calcium carbonate). The amount to add depends on the cation exchange capacity (nutrient-holding capacity) of the soil, which is based on the soil's clay content. Soil higher in clay will have a higher cation exchange capacity and will require more materials to raise the pH.

A laboratory test called **buffer index** measures the responsiveness of the soil to lime applications. The soil test will give recommendations on application rates based on the buffer index rather than just the pH. Table 3 gives an estimated amount of lime to apply to raise a soil's pH.

3. Limestone Application Rates to Raise Soil pH to Approximately 7.0 for Turf

	Lime Application Rate (pound per 1,000 square feet)		
Existing Soil pH	Sandy	Loamy	Clayey
5.5–6.0	20	25	35
5.0–5.5	30	40	50
3.4–5.0	40	55	80
3.5–4.5	50	70	80

- Lime application rates shown in this table are for dolomite, ground, and pelletized limestone and assume a soil organic matter level of approximately 2% or less. In soils with 4 to 5% organic matter, increase limestone application rates by 20%.
- Individual applications to turf should not exceed 50 pounds of limestone per 1,000 square feet.
- Avoid the use of hydrated or burned lime because it is hazardous to both humans and turf (can seriously burn skin and leaves). If hydrated lime is used, crease application rates in the above table by 50% and apply no more than 10 pounds of hydrated or burned line per 1000 square feet of turf.

Lime is commonly sold as ground agricultural limestone. It varies in how finely it has been ground. The finer the grind, the more rapidly it becomes effective in raising pH. **Calcitic lime** mostly contains calcium carbonate ($CaC0_3$). **Dolomitic lime** contains both calcium carbonate and dolomite [$MgCa(CO_3)_2$]. On most soils, both are generally satisfactory. However, on sandy soils low in organic matter, dolomitic lime may supplement low magnesium levels. Low soil magnesium levels should be verified with a soil test prior to applying dolomitic lime as excess levels of magnesium can lead to calcium deficiencies in some vegetables.

Home pH test kits

In alkaline soils, home pH kits have questionable value. Inexpensive kits do not calibrate closely enough on alkaline soils to be meaningful and small changes in techniques, such as how much water and the pH of the water used in the sample, can change results. Most home soil test kits are designed for acid soils.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #223

Iron Chlorosis of Woody Plants

Symptoms

The term ***chlorosis*** means a general yellowing of the leaves. Many factors contribute to chlorosis.

Iron chlorosis refers to a yellowing caused by an iron deficiency in the leaf tissues. The primary symptoms of iron deficiency include ***interveinal chlorosis***, i.e., a general yellowing of leaves with veins remaining green. In severe cases, leaves may become pale yellow or whitish, but veins retain a greenish cast. Angular shaped brown spots may develop between veins and leaf margins may scorch (brown along the edge). [Figure 1]

Figure 1. Symptoms of iron chlorosis include yellowing of the leaf with veins remaining green.

Iron is necessary for the formation of chlorophyll, which is responsible for the green color in plants and necessary for photosynthesis (sugar production in plants). Any reduction in chlorophyll during the growing season reduces plant growth, vigor, and tolerance to stress conditions. Plants with reduced vigor from iron chlorosis are more prone to winter injury and winter injury may aggravate an iron chlorosis problem. Weakened plants also are more susceptible to other diseases and insect infestations

Iron is not very mobile within plants. Plants use their stores of iron in new leaves as they create them so iron chlorosis shows first and more severely on the newer growth at branch tips. Leaves may be smaller than normal. Leaves may eventually curl, dry up, and fall. Fruits may be small with a bitter flavor. Mildly affected plants become unsightly and grow poorly. In severe cases individual limbs or the entire plant may die.

It is common for iron chlorosis to show on a single branch or on one side of a tree. This is particularly common for plant species with marginal winter hardiness following winter injury. Plant species and varieties vary greatly in their susceptibility to iron deficiency.

Chlorosis usually develops as an overall yellowing of needles on junipers, pines, and other evergreens.

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Similar Symptoms

Iron chlorosis symptoms can be confused with other problems. In the high pH soils of Colorado, an iron chlorosis problem may actually be a combination of iron and manganese deficiencies. It is common for chlorotic trees to show a response to both iron and manganese treatments.

Zinc and manganese deficiencies result in similar leaf symptoms. Iron chlorosis appears first on the younger or terminal leaves. Under severe conditions, it may progress into older and lower leaves. By comparison, zinc and manganese deficiencies typically appear first on older, interior leaves.

Nitrogen deficiency shows as a uniform yellowing of the entire leaf (including the veins). Nitrogen deficiency shows first in the older leaves, while iron chlorosis shows first in the newer growth.

Damage from soil sterilants (i.e., Pramitol, Atrazine, Simazine, Ureabor, and Diuron) used to prevent weeds result in similar symptoms. With these weed killers, the leaf tissue along the vein remains green. With iron chlorosis, just the vein itself remains green.

Natural aging of tissues may create similar symptoms in some plants. Root and trunk damage and some virus, phytoplasmas, and vascular wilt diseases may cause similar leaf symptoms.

Causes and Complicating Factors

The factors leading to iron chlorosis are complex and not fully understood. A number of chemical reactions govern iron availability and contribute to the complexity of iron chemistry in soils.

Many environmental factors also create or contribute to iron deficiency. These factors need to be evaluated and alleviated to the extent possible. In many situations, attention to watering and soil conditions will satisfactorily correct minor iron chlorosis problems**.**

Calcareous Soils

Many Colorado soils are naturally high in lime (calcium carbonate and other calcium compounds) which raise the soil pH above 7.5. In these *calcareous* soils, iron chlorosis is common on susceptible plants.

Colorado soils are abundant in iron, as evidenced by the common "red rock" formations. In alkaline soils (pH above 7.0), iron is rapidly fixed through a chemical reaction into insoluble, solid forms that cannot be absorbed by plant roots. Such iron will be tied up indefinitely unless soil pH changes. Soil applications of iron alone are ineffective, as the applied iron will quickly be converted to these unavailable solid forms.

Over-Watering

Iron chlorosis is a common generic symptom of over-watering.

Overly wet or dry soils predispose plants to iron chlorosis. Iron chlorosis is more prevalent following wet springs, and where gardeners over-water in the spring. In western calcareous soils, iron chlorosis can be moderated by eliminating springtime over-watering. Dry soils can also lead to nutrient deficiencies as nutrients are absorbed in solution with water. Severe cases of iron chlorosis involving "acid-loving" loving plants may not be corrected through improved irrigation practices.

It is common for gardeners to allow sprinkler control settings to remain unchanged from the high summer water needs to the lower water needs of spring and fall. In this situation, the yard receives as much as 40% more water than is needed in the spring and fall. Such over watering can contribute to iron chlorosis.. For details, refer to *CMG GardenNotes* on irrigation management.

Soil Compaction

Soil compaction and other conditions that limit soil air infiltration (like surface crusting and use of plastic mulch) predispose plants to iron chlorosis by limiting effective rooting area and soil oxygen levels. Plants that have smaller root systems have less chance of "finding" available iron. These are key contributing factors in clayey soils. Using organic mulch (like wood or bark chips) helps prevent and reduce soil compaction. Avoid the use of plastic under rock mulch around landscape plants. For details on mulching and soil compaction, refer to *CMG GardenNotes* #215, **Soil Compaction**, and #245, **Mulching with Wood/Bark Chips, Grass Clippings, and Rock**.

Trunk-Girdling Roots

Iron chlorosis is a common early symptom of trunk girdling roots in trees. The primary cause of trunk girdling roots is planting trees too deep. Trunk girdling roots can lead to decline and death some 20 years after planting.

In tree planting standards, the top of the root ball should rise slightly above grade (i.e., 1-2 inches above grade) for newly planted trees. At least two structural roots should be located in the top 1-3 inches of the root ball. For additional information on tree planting, refer to *CMG GardenNotes* #633, **The Science of Planting Trees**.

On established trees, the trunk-to-root flare should be noticeable. If the trunk goes straight into the ground, suspect planting problems and possible development of trunk girdling roots over time. To check, perform a root collar excavation (carefully removing the soil around the base of tree) and examine the trunk/root flare.

Other Contributing Factors

Plant competition – In susceptible plants, competition from adjacent lawns or flowers may aggravate iron chlorosis. Replace the grass under the tree canopy with wood/bark chip mulch.

Winter injury – Trees with cankers and other winter injuries are prone to iron deficiency. (Winter bark injury on tree trunks is caused by winter drought.)

Soil organic matter – Organic matter is a key to successfully gardening in Colorado's soils. Ideally, the soil's organic content should be increased to 5%. However, excessive amounts may aggravate iron problems.

Excessive salt levels – High soil salt levels adversely affect uptake of water and nutrients, including iron. For details, refer to *CMG GardenNotes* #224, **Saline Soils**.

Soil temperature and light intensity – Extreme soil temperatures and high light intensity may increase iron chlorosis problems. Use an organic mulch to moderate soil temperature. Shading may help some crops.

Acid-loving plants – Acid loving plants are highly susceptible to iron chlorosis and not suited to Colorado's soil conditions. These include blueberries, azaleas, rhododendron, flowering dogwood, and heather.

Nutrients – Excessive levels (from over-application) of phosphate, manganese, copper, or zinc may aggravate iron chlorosis.

Plant Selection – Right Plant, Right Place

In Colorado's high pH soils, the best method to prevent iron chlorosis is to select plant species tolerant of high soil pH and less affected by low iron availability. Avoid planting the more susceptible species (Table 1) on soils prone to iron chlorosis problems (pH above 7.5, compacted, clayey, or wet soils).

Table 1. Examples of Plants with High Susceptibility to Iron Chlorosis

Amur maple
Apple
Arborvitae
Aspen
Azalea
Beech
Birch
Boxelder
Bumald spiraea
Cherry
Cotoneaster
Crabapple
Dawn redwood
Douglas-fir
Elm
Flowering dogwoods
Grape
Honeylocust
Horse chestnut
Juniper
Linden
London plane tree (sycamore)
Magnolia
Mountain-ash
Northern red oak
Peach
Pear
Pin oak
Pine
Raspberry
Red maple
Rhododendron
Silver maple
Spruce

Iron Additives

Unfortunately, there is no easy, inexpensive, or long-term correction for iron chlorosis. Treatments may be rather expensive and give disappointing results.Plant and soil conditions vary greatly so there is no single approach that is consistently best. Focusing on reducing springtime over-watering, soil compaction and other contributing factors is can be effective in mitigating iron chlorosis in some situations.

The first step in using iron additives is to know the soil *pH* and *free-lime* (calcium carbonate) content. These soil factors directly affect the success of any approach. Determine soil pH by soil test. When the pH is above 7.5, effective approaches are limited.

To check for ***free-lime***, place a rounded tablespoon of dry crumbled soil in a small cup. Moisten the soil with vinegar. (The soil needs to be thoroughly moistened, but not swimming in vinegar.) If the soil-vinegar mix fizzes or bubbles, it has free-lime. High lime content is typical of soils with a pH above 7.5. A standard approach in treating iron chlorosis is to lower the soil's pH. **Lowering the pH is impractical to impossible if the soil contains *free-lime*.**

There are four general approaches to iron treatments: 1) lowering the soil's pH, 2) soil iron treatments, 3) foliar sprays, and 4) tree injections. Each has advantages and disadvantages. Each procedure gives variable results depending on plant species and soil conditions.

The two principal types of iron-containing products used for iron application include iron chelates and inorganic iron compounds (such as iron sulfate, ferrous sulfate). Several types of iron chelates are marketed under a variety of trade names. Soil pH dictates the type of chelate to use. Treatment of any iron product made mid-season may not produce satisfactory results.

Lowering Soil pH with Sulfur Products

A standard approach used in many products is to lower the soil pH. This approach merits consideration only if the soil does NOT have "free-lime" (high calcium carbonate), and may show effectiveness over a period of years.

Due to the high pH and lime content of many Colorado soils, this approach seldom merits consideration. If irrigation water is hard, the calcium carbonate (lime) in the water will counter any acidifying effect. (As a side note, it has been observed that in some older gardens the pH has dropped below natural levels as the lime content is slowly leached out with decades of irrigation.)

The pH is lowered by soil applications of sulfur products. See the product labels for specific application rate. (Use of aluminum sulfate to lower soil pH is not recommended due to a potential for aluminum toxicity.) For details on lowering pH, refer to the *CMG GardenNotes* #222, **Soil pH**.

Soil Applications of Iron Sulfate Plus Sulfur

A simple approach is to apply a mixture of equal amounts of iron (ferrous) sulfate and sulfur to the soil. Examples of products include Copperas, Jirdon Super Iron Green, HiYield Soil Acidifier Plus Micros, and Fertilome Soil Acidifier Plus Iron. Over a period of months to years, an improvement may be noticed. When it is effective, treatments may last up to three or four years, depending on soil conditions.

This approach merits consideration only on soils without "free-lime".

For trees, apply the mixture in holes around the drip-line of the tree, as described for chelates (see below). Over time, the sulfur reacts to lower soil pH in a localized area. Broadcast applications, that dilute the material over a larger area, are less likely to give satisfactory results. Treat rows of berries or small shrubs by placing the mix in a furrow four inches deep and 12-24 inches away from the plant. See specific label directions for application rates. For best results, treat the soil in spring.

Soil Applications of Iron Chelates

Soil application of iron chelates may give a rapid response if the correct chelate is used and other contributing factors are minimal. Applications after May 1st are less likely to show results. Treatments may last less than a season to a couple of years.

Treat trees by placing the iron product in rings of holes in the ground beneath the dripline (outer reaches of the branches). Make holes 1½ to 2 inches in diameter, 6 inches deep and 12 inches apart in rings 2 feet apart. For smaller trees, make 2 to 3 rings of holes. For large trees, create four to five or more rings of holes, and rings may need to extend beyond the drip line. No holes should be made within 2½ to 4 feet of the tree trunk on established trees. [Figure 2]

Drill holes in the soil with a power or hand auger, bulb planter, or small trowel, removing the soil core. Using a punch bar that makes holes by compacting the surrounding soil may be less effective. To avoid damage to shallow utility lines, have the area utility-staked before starting. [Figure 2]

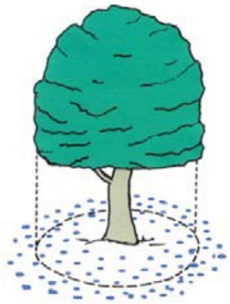

Figure 2. Place soil additive in a ring of holes around the drip line of the tree.

In soils with a pH above 7.5, only special chelates formulated for a high pH are effective. Examples include EDDHMA (Miller's Ferriplus) or EDDHA (Fe Sequestrene 138). Due to its higher cost, these products have limited availability. See product label for specific application rates.

In acid to slightly alkaline soils, try other chelates like EDTA (Fe Sequestrene 330, Fertilome Liquid Iron) and DTPA (Miller's Iron Chelate DP). They lose effectiveness quickly as the pH rises above 7.2 to 7.5. See product label for specific application rates.

Soil Applications of Iron Sucrate

Iron sucrate, a relatively new iron source, is manufactured from iron oxide and molasses to form an iron-containing organic complex with limited water solubility. It is less prone to staining due to its very low solubility.

Iron sucrate merits consideration in high pH soils, and additional scientific evaluation is warranted for Colorado soils. It is marketed as Lilly Miller Iron Safe.

Foliar Sprays

Foliar sprays of iron sulfate or iron chelates may provide quick response, often in a matter of days. However, the treatment is often spotty and only temporary. Multiple applications per season may be needed. Effects will not carry over into subsequent years.

Both types of products are equally effective, but iron chelates are more expensive. See product labels for specific application rates and instructions. With foliar applications, spray in the evening or on cloudy days when drying time is slower. A few drops of liquid dishwashing soap or commercial wetting agent will enhance sticking properties.

Foliar applications are generally not recommended due to application limitations. Complete coverage of all leaves is essential. Individual leaves not treated may remain chlorotic. Coverage on large trees is impractical to impossible.

There is a small margin between an iron concentration that will green up the leaves and a concentration that will cause leaf burn. Leaf tissues are rather prone to turn black from an iron burn. Following an iron sulfate foliar treatment, it is common to see leaves that remain chlorotic, leaves that green up, and leaves with black burn spots on the same plant. Spray hitting the sidewalk, house, and other objects may leave a permanent rusty discoloration. Chelated iron sprays are inactivated by sunlight.

Trunk Injections

Professional arborists have trunk implant or injection methods available for treating iron chlorosis on large trees. Trunk injections may last from one to five years. Refer to product information for application details. Injections may create pathways for decay organisms to enter a tree.

Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., (USDA-ARS, retired). Artwork by David Whiting; used by permission.

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CMG GardenNotes #224

Saline Soils

Soluble Salts

The term ***soluble salts*** refers to the salts (ions) dissolved in the soil's water. Some salts such as gypsum (calcium sulfate) are less soluble. Limestone (calcium carbonate) dissolves only in acidic water. Others like sodium chloride (table salt0 dissolves very easily and bonds with water molecules making it hard for plants to absorb the water. Salts are another soil factor limiting crop growth in some areas of Colorado, especially in the Western Colorado Valleys. The salty layer of the Grand Valley is Mancos shale that can have a depth up to 4150'. Some salts such as Boron, chloride and sodium can be toxic to plants.

Impact of High Salt on Plant Growth

High salt levels can reduce water uptake by plants, restrict root growth, cause marginal burning of the foliage, inhibit flowering, limit seed germination, and reduce fruit and vegetable yields. Irregular bare spots in gardens and uneven crop growth suggest salinity problems. Crop yields may be reduced as much as 25% without any damage being apparent. Salt injury generally is more severe during periods of hot dry weather, when water use is high.

Sensitivity to soluble salts differs among plant species/cultivars and is dependent on their state of growth. Seed germination and seedling growth are more sensitive to salt stress than mature plants. [Table 1]

Salt burn on bean leaf from high salts in compost

Table 1. Relative Salt Tolerance of Cultivated Plants

Non-tolerant 0-2 dS/m	**Slightly Tolerant** 2-4 dS/m	**Moderately Tolerant** 4-8 dS/m	**Tolerant** 8-16 dS/m
begonia	apple	beet	arborvitae
carrot	cabbage	black locust	asparagus
cotoneaster	celery	boxwood	juniper
green bean	cucumber	broccoli	Russian olive
onion	grape	chrysanthemum	Swiss chard
pea	forsythia	creeping bentgrass	
radish	Kentucky bluegrass	geranium	
raspberry	lettuce	marigold	
red pine	linden	muskmelon	
rose	Norway maple	perennial ryegrass	
strawberry	pepper	red oak	
sugar maple	potato	spinach	
viburnum	red fescue	squash	
white pine	red maple	tomato	
	snapdragon	white ash	
	sweet corn	white oak	
		zinnia	

Note: dS/m is the unit used to measure salt content. It measures the electrical conductivity of the soil. dS/m = mmhos/cm

Factors Contributing to Salt Problems

Drainage

A common sign of salt problems is the accumulation of salts at the soil surface due to limited percolation in compacted and/or clayey soils. Soluble salts move with the soil water. Deep percolation of water down through the soil profile moves salt out of the rooting zone. Surface evaporation concentrates the salts at the soil surface. Salt deposits may or may not be seen as a white crust on the soil surface. As you drive around Colorado, it is common to see these soils with the white salt accumulation in low spots of fields and natural areas.

In some areas, salt naturally accumulates due to limited rainfall to leach the salt out. Salt levels drop when the soil undergoes irrigation. In other areas, salts may build-up when poor soil drainage prevents precipitation and irrigation water from leaching the salt down through the soil profile. In this case, corrective measures are limited to improvements in soil drainage.

Soil Amendments

Manure, biosolids, and compost made with manure or biosolids may be high in salt. When using manure or compost made with manure, routinely monitor salt levels. For more information, see the section on Soil Amendments.

Excessive/Unnecessary Fertilizer Applications

Unwarranted application of fertilizers (such as phosphate or potash) increases the salt level. On soils marginally high in salts, potash fertilizers should be avoided unless a potassium deficiency is identified by soil tests. Over- fertilization also has other environmental impacts.

Placing fertilizer and salty soil amendments too close to seeds or plant roots creates a salt burn of the tender roots. Germination failure or seedling injury can result.

De-Icing Salts

The use of **de-icing salts** on streets and sidewalks frequently results in high salt levels in adjacent soils. Along roads, salt injury has become a major concern. Highway salts may reach plants in two ways: movement to soil and uptake by plant roots, or movement onto plant stems and foliage through the air as vehicle "splash-back". Salts deposited on both soil and foliage have high potential to cause plant injury. Highway salts in road-melt runoff is another concern for plants and the wider environment.

Pet Urine

Damage by **pet urine** is also a salt problem containing alkaline salts and nitrogen. Water moves by osmotic pressure from the roots to the high salt concentration in the soil, dehydrating and killing roots. Train your pet to eliminate in a plant free zone or follow other salt management methods below.

Measuring Soil Salt Levels

Bean plants are rather salt sensitive and can be used to help assess salt problems. In a garden, if beans are doing well, soluble salts are not a problem. If the beans are doing poorly, consider salts as a possibility. Beans, tomatoes and other easily germinated seeds can be used in a "pot test" on a windowsill to live assay the salt content of a soil. Assess plants' performance in light of Table 1.

The amount of salt in a soil can be quantified only by a soil test. A soil test for soluble salts can be useful when investigating the cause of poor plant growth, determining the suitability of a new planting site, or monitoring the quality of fill soil or soil amendments for use on a landscape area.

Soil tests for soluble salts are based on electrical conductivity. Pure water is a very poor conductor of electric current, whereas water containing dissolved salts conducts current approximately in proportion to the amount of salt present. Thus, measurement of the electrical conductivity, ***ECe***, of a soil extract gives an indication of the total soluble salt concentration in the soil. The ECe is measured in decisiemens per meter (dS/m) or millimhos per centimeter (mmhos/cm). 1 dS/m = 1 mmhos/cm. [Table 2]

Table 2. Soluble Salt Test Values and Relative Sensitivity Levels of Plants

Electrical Conductivity[1] (dS/m)	Salinity Level	Effect on Plant Growth
0 to 2	non-saline	none
2.1 to 4	very slight salinity	sensitive plants are inhibited
4.1 to 8	moderate~~ly~~ salinity	many plants are inhibited
8.1 to 16	strong~~ly~~ salinity	most cultivated plants are inhibited
over 16	very strong~~ly~~ salinity	few plants are tolerant

[1] Saturated paste extract

Managing Soil Salts

Leaching Salts

Leaching is the only practical way of removing excess salts. This is effective only to the extent that water moves down through the soil profile and beneath the root zone (drainage must be good). The amount of salts removed depends on the quantity and quality of water leached through the soil profile <u>during a single irrigation period</u>. Water should be low in salts (high quality) and must not run off the surface. It should be applied slowly so amounts do not exceed the ability of the soil to take in water (infiltration rate). If you see pets urinate on a plant, rinse and flush with water within 8 hours.

The following amounts of water applied in a single, continuous irrigation will dissolve and decrease soil salts by these fractional amounts:

- 6 inches of water will leach about ½ the salt
- 12 inches of water will leach about 4/5 of the salt.
- 24 inches of water will leach about 9/10 of the salt.

Salty soils are not reclaimable when the soil's clay content, compaction, or hardpan prevents leaching.

Adding Soil Amendments

Because manure, biosolids, and compost made from manure or biosolids may be high in salts, do not add more than 1 inch per season without a soil test to evaluate salt levels. An amendment with up to 10 dS/m total salts is acceptable if mixed through the upper six to eight inches of a low-salt soil (less than 1 dS/m). Amendments with a salt content greater than 10 dS/m are questionable. Avoid these soil amendments in soils that are already high in salts (above 3 dS/m) when growing the salt sensitive plants.

Note: Because soil amendments are not regulated in Colorado, do not assume that products sold in bags or by bulk are necessarily low in salt content and good for the garden's soil. Many commercially available sources of manure, biosolids, and compost made with manure or biosolids have excessively high levels of salt. Some companies do test, so ask if they have recent salt levels of the amendment.

On marginally salty soils, concentrate on gradually improving the soil organic content and activity of soil microorganisms and earthworms. Do not exceed recommended rates per application as large quantities of organic matter can hold salts next to plant roots and cause injury. Organic amendments applied over time improve soil tilth, which then will improve the potential for effective leaching as well as plant growth.

Other Management Techniques

Plants grown on salty soils are less tolerant of dry soil conditions. Plants will require more frequent irrigation, with reduced amounts of water.

Within pedestrian and vehicle safety limits, avoid the use of de-icing salts. Consider the use of sand or other abrasive materials for use on slick sidewalks and pavement. Where de-icing salts are routinely used, expect to find salt problems in adjacent soils and drainage swales where the snowmelt runs. Because soil salt levels from de-icing salts easily rise above the tolerance of even the most salt-tolerant plants, a rock mulch area without plants may be a better landscape design solution in salt use areas.

For additional details on soil salt issues, refer to the following CSU Extension fact sheets #7.227, *Growing Turf on Salt-Affected Sites.*

Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., USDA-ARS (retired). Artwork by David Whiting; used by permission. Revised by Susan Carter, (CSU Extension)

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MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #231

Plant Nutrition

Outline:

Fertility and Fertilization

Many people confuse plant nutrition with plant fertilization. ***Plant nutrition*** refers to the need for basic chemical elements for plant growth.

The term ***fertilization*** refers to the application of plant nutrients to supplement the nutrients naturally occurring in the soil. Nutrients may be applied as commercially manufactured fertilizers, organic fertilizers and/or other soil amendments. Organic fertilizers and soil amendments are typically low in plant-available nutrient content.

Adequate soil fertility is only one of the many soil-related growth factors. Fertilizers will increase desirable plant growth only if the plant is deficient in the nutrient applied and other growth factors are not also significantly limiting plant growth. Fertilization will not compensate for poor soil preparation, the lack of water, weed competition and other non-nutrient growth limiting factors! Fertilization will not enhance desired growth if the nutrients applied are not deficient.

From a nutritional perspective, a plant cannot tell if applied nutrients come from a manufactured fertilizer or a natural source. Plants use nutrients in ionic forms. Soil microorganisms must break down organic soil amendments, organic fertilizers and many manufactured fertilizers before the nutrients become usable by plants.

From a nutritional perspective, the primary difference between manufactured and organic soil amendments/organic fertilizers is the speed at which nutrients become available for plant use. Manufactured fertilizers release rates are typically, but not always, a few days to weeks. Some are specially formulated as “controlled release”, “slow release” or “time release” products release over a period of months, but some organic fertilizers are quickly available. With natural-organic fertilizer, nutrients typically become available over a period of months or years. However, there are exceptions to this general rule. High salt contents of *some* manufactured fertilizers and *some* organic soil amendments can slow the activity of beneficial soil microorganisms and subsequent nutrient release.

Benefits of organic fertilizers and soil amendments include improvements in soil tilth (suitability of the soil to support plant growth). This should not be confused with “fertilization”, a distinctly different soil management objective.

Remember that fertility is only part of the soil’s role in supporting plant growth. The organic content of the soil also directly affects plant growth due to its influence on soil tilth and the activity of beneficial soil microorganisms. Relying solely on manufactured fertilizers is not recommended as this does not support good soil tilth.

Plant Nutrients

Plants need 17 elements for normal growth. Carbon, hydrogen, and oxygen come from the air and water. Soil is the principle source of other nutrients. ***Primary nutrients*** (nitrogen, phosphorus, and potassium) are used in relatively large amounts by plants, and often are supplemented as fertilizers. [Table 1]

Secondary nutrients (calcium, magnesium, and sulfur) are also used in large amounts but are typically readily available and in adequate supply. M***icronutrients*** or trace elements are needed only in small amounts. These include iron, zinc, molybdenum, manganese, boron, copper, cobalt, and chlorine. [Table 1]

Table 1. Essential Plant Nutrients

Nutrient	Ions Absorbed by Plants
Structural elements	
Carbon, C	CO_2
Hydrogen, H	H_2O
Oxygen, O	O_2
Primary nutrients	
Nitrogen, N	NO_3^-, NH_4^+
Phosphorus, P	$H_2PO_4^-$, HPO_4^{-2}
Potassium, K	K^+
Secondary nutrients	
Calcium, Ca	Ca^{+2}
Magnesium, MG	Mg^{+2}
Sulfur, S	SO_4^{-2}
Micronutrients	
Boron, B	$H_2BO_3^-$
Chlorine, Cl	Cl^-
Cobalt, Co	Co^{+2}
Copper, Cu	Cu^{+2}
Iron, Fe	Fe^{+2}, Fe^{+3}
Manganese, Mn	Mn^{+2}
Molybdenum, MO	MoO_4^{-2}
Zinc, Zn	Zn^{+2}

Roots take up nutrients primarily as ***ions*** dissolved in the soil's water. The ions may be positively charged (***cations***) or negatively charged (***anions***). The nutrient ion soup in the soil's water is in a constant state of flux as the variety of ions dissolve in and precipitate out of solution.

Clay particles and organic matter in the soil are negatively charged, attracting the positively charged cations (like ammonium, $NH_4^{+,}$ and potassium, K^+) and making the cations resistant to leaching. Negatively charged anions (like nitrate, $N0_3^-$) are prone to leaching and can become a water pollution problem. Both ammonium and nitrate are important plant nitrogen sources and are commonly found in salt forms in fertilizers.

The ***Cation Exchange Capacity, CEC,*** is a measurement of the soil's capacity to hold cation nutrients. More precisely, it is a measurement of the capacity of the negatively charged clay and organic matter to attract and hold positively charged cations. CEC is useful in comparing the potential for different soils to hold and supply nutrients for plant growth.

Colorado Soils and Plant Nutritional Needs

Nitrogen

Nitrogen is the one nutrient most often limiting plant growth. The need for nitrogen varies from plant to plant. For example, tomatoes and vine crops (cucumbers, squash, and melons) develop excessive vine growth at the expense of fruiting with excess nitrogen. Potatoes, corn and cole crops (cabbage, broccoli, and cauliflower) are heavy feeders and benefit from high soil nitrogen levels. Bluegrass turf and many annuals also benefit from routine nitrogen applications. Trees and shrubs have a low relative need for soil nitrogen. Colorado soils benefit from nitrogen fertilization of the right amount and frequency to meet plant needs. General symptoms of nitrogen deficiency are shown in Table 2 and Figure 1.

Table 2 and Figure 1. Symptoms of Nitrogen Deficiency

Leaves
- **Uniform yellowish-green**
- **More pronounced in older leaves**
- Small, thin leaves
- Fewer leaflets
- High fall color
- Early leaf drop

Shoots
- Short, small diameter
- May be reddish or reddish brown

Soil tests have limited value in indicating nitrogen needs for a home garden or lawn because the value is constantly changing due to organic content, microorganism activity, and changes in temperature and water.

Nitrogen is useable by plants in two forms, **ammonium** (NH_4+), and **nitrate** (NO_3^-). Ammonium, being positively charged, is attracted to the negatively charged soil particles and thus is resistant to leaching (movement down through the soil profile). Soil microorganisms convert ammonium to nitrate. Nitrate, being negatively charged, readily leaches below the root zone with excess rain/irrigation in sandy soils. Prevent water pollution by avoiding over-fertilization of nitrogen, particularly on sandy soils.

Soil microorganisms release nitrogen tied-up in organic matter over a period of time. Release rates from compost are very slow (i.e., over a period of years). The need for nitrogen fertilizer is based on the organic content of the soils. [Table 3]

Table 3.
Need for Nitrogen Fertilizer Based on Soil Organic Content

Soil Organic Content	Routine Application Rate For Gardens
1%	2 pounds actual N / 1000 square feet
2-3%	1 pound actual N / 1000 square feet
4-5%	0

Iron

Iron chlorosis refers to a yellowing of leaves caused by an iron deficiency in the leaf tissues. Primary symptoms include interveinal chlorosis (i.e., a general yellowing of leaves with veins remaining green). Symptoms appear first and are more pronounced on younger leaves and on new growth. In severe cases, leaves may become pale yellow or whitish, but veins retain a greenish tint. Angular shaped brown spots may develop between veins and leave margins may scorch (brown along the edge). Symptoms may show on a single branch or on the entire tree. General symptoms of iron chlorosis are shown in Table 3 and Figure 2.

Table 3 and Figure 2. Symptoms of Iron Chlorosis

Leaves
- **General yellowing of leaf with veins remaining green**
- **More pronounced in younger leaves and new growth**
- Angular brown spots and marginal scorch
- Smaller
- Curl, dry up and fall early

Branches
- May show on a single branch or the entire plant

In western, high pH soils, iron is not deficient; but rather unavailable for plant uptake due to the soil's high lime (calcium carbonate) content. In western soils, <u>iron chlorosis is a general symptom of other problems</u>, including the following:

- **Springtime over-watering** is the primary cause of iron chlorosis in western soils! Attention to irrigation management, with seasonal changes of the irrigation controller will generally correct iron chlorosis.
- **Soil compaction** and low soil oxygen contributes to iron chlorosis.
- Iron chlorosis is an early symptom of **trunk girdling roots.**
- Iron chlorosis appears as a complication of **winter trunk/bark injury**.

Attention to these contributing factors is much more effective than adding iron products.

Phosphorus

Note: ***Phosphorus*, P**, is a primary nutrient in plant growth. The word ***phosphate*, P_2O_5 ,** refers to the ionic compound containing two atoms of phosphorus and five atoms of oxygen. The *phosphorus* content of fertilizer is measured in percent *phosphate*.

Phosphorus may be present in high concentrations, however it may not be in a plant available form. Deficiencies are most likely to occur in new gardens where the organic matter content is low and the soil has a high pH (7.8 to 8.3). A soil test is the best method to determine the need for phosphorus fertilizers.

Phosphorus is also *less available* to plants when soil temperatures are cool. In the spring, the use of starter fertilizers with phosphorus may be beneficial to herbaceous flowers and vegetable transplants.

Phosphorus deficiency is difficult to diagnose, because other growth factors will give similar symptoms. General symptoms include sparse, green to dark green leaves. Veins, petioles, and lower leaf surface may be reddish, dull bronze, or purple, especially when young. Phosphorus deficiency may be observed on roses in the early spring when soils are cold, but the condition corrects itself as soils warm.

Excessive phosphorus fertilizer can aggravate iron and zinc deficiencies and increase the soil salt content. Many home gardener soils are significantly over fertilized with phosphates, aggravating soil salts and iron chlorosis. Typically the over fertilization results from over application of composts.

Potassium

Note: ***Potassium***, K, is a primary nutrient in plant growth. The word ***potash***, K_2O, refers to the ionic compound containing two atoms of potassium and one atom of oxygen. The potassium content of fertilizer is measured in percent potash.

Potassium levels are naturally adequate and even high in most Colorado soils. Deficiencies occasionally occur in new gardens low in organic matter and in sandy soils low in organic matter. A soil test is the best method to determine the need for potassium fertilizers.

Potassium deficiency is very difficult to diagnose, because other growth factors will give similar symptoms. General symptoms include a marginal and interveinal chlorosis (yellowing), followed by scorching that moves inward. Older leaves are affected first. Leaves may crinkle and roll upward. Shoots may show short, bushy, zigzag growth, with dieback late in season.

Excessive potash fertilizer can aggravate soil salt levels. Many home garden soils are over fertilized with potash, leading to salt problems.

Zinc

Zinc deficiency occasionally occurs in sandy soils containing excessive lime and in soils low in organic matter (typical of new yards where the topsoil has been removed). Excessive phosphate fertilization may aggravate a zinc problem. It will be seen more in years with cold wet springs.

Sweet corn, beans, and potatoes are the most likely vegetables to be affected. Symptoms include a general stunting of the plant due to shortening of internodes (stem length between leaves). Leaves on beans typically have a crinkled appearance and may become yellow or brown. On young corn, symptoms include a broad band of white–to-translucent tissue on both sides of the leaf midrib starting near the base of the leaf, but generally not extending to the tip.

Occasional manure applications will supply the zinc needs. If a soil test indicates zinc deficiency (less than 1 ppm), apply a zinc-containing fertilizer according to label directions.

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- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
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CMG GardenNotes #232

Understanding Fertilizers

Fertility is only part of the soil management process. Colorado soils are naturally low in organic matter. To maximize productivity, our soils also need routine applications of organic matter to improve soil tilth. For flower and vegetable gardens, it is desirable to raise the soil organic content, over time, to 4-5%.

Manufactured fertilizers are popular with gardeners because they are readily available, inexpensive, easy to apply, and generally provide a quick release of nutrients for plant growth. Application rates depend on the nutrient need of the soil and the percent of nutrients in the specific fertilizer. **In products containing multiple nutrients, the application rate is always based on the nitrogen content.**

Fertilizer or Soil Amendment?

By legal definition, the term ***fertilizer*** refers to a soil amendment that guarantees the minimum percentages of nutrients (at least the minimum percentage of nitrogen, phosphate, and potash).

An ***organic fertilizer*** refers to a soil amendment derived from natural sources that guarantees, at least, the minimum percentages of nitrogen, phosphate, and potash. Examples include plant and animal by-products, rock powders, seaweed, inoculants, and conditioners. These are often available at garden centers and through horticultural supply companies.

These should not be confused with substances approved for use with the ***USDA National Organic Program (NOP)***. The USDA NOP, with its "USDA Organic" label, allows for the use of only certain substances. The Organic Materials Review Institute (www.omri.org) and the Washington Department of Agriculture (WSDA) (http://agr.wa.gov/) review and approve brand name products made with ingredients from the “national list” for use in certified organic production. If a fertilizer is not OMRI or WSDA approved, it may still be allowed for organic production but has not been reviewed and deemed suitable for use in certified production. To learn more about which inputs are allowed and which are prohibited refer to http://www.ams.usda.gov/about-ams/programs-offices/national-organic-program

Many of the organic fertilizers listed here will meet NOP standards (based on the National List). Growers participating in the NOP should consult with their certifier to ensure compliance for organic certification.

The term ***soil amendment*** refers to any material mixed into a soil. ***Mulch*** refers to a material placed on the soil surface. In Colorado, soil amendments contain no legal claims about nutrient content or other helpful (or harmful) effects they will have on the soil and plant growth. In Colorado, the term ***compost*** is also unregulated, and could refer to any soil amendment regardless of active microorganism activity.

Many gardeners apply *organic soil amendments*, such as compost or manure, which most often do not meet the legal requirements as a “fertilizer” but add small amounts of nutrients.

What is in a Fertilizer?

Analysis or Grade

By law, all products *sold as fertilizer* require uniform labeling guaranteeing the minimum percentage of nutrients. The three-number combination (fertilizer ***grade*** or ***analysis***) on the product identifies percentages of nitrogen (N), phosphate (P_2O_5), and potash (K_2O), respectively. For example, a 20-10-5 fertilizer contains 20% nitrogen, 10% phosphate, and 5% potash.

> Note: ***Phosphorus, P***, is a primary nutrient in plant growth. The word ***phosphate, P_2O_5***, refers to the ionic compound containing two atoms of phosphorus with five atoms of oxygen. The *phosphorus* content of fertilizers is measured in percent *phosphate*.
>
> Note: ***Potassium, K,*** is a primary nutrient in plant growth. The word ***potash, K_2O,*** refers to the ionic compound containing two atoms of potassium with one atom of oxygen. The *potassium* content of fertilizers is measured in percent *potash*.

The product may also identify other nutrients, such as sulfur, iron, and zinc, if the manufacturer wants to guarantee the amount. This may be done by placing a fourth number on the product label and identifying what nutrient was added in the ingredients.

Ratio

Fertilizer ***ratio*** indicates a comparative proportion of nitrogen to phosphate to potash. For example, a 15-10-5 fertilizer has a ratio of 3-2-1, and an 8-12-4 fertilizer has a ratio of 2-3-1. **Fertilizer recommendations from a soil test are given in ratios.**

When shopping for a fertilizer, select a product with a ratio somewhat similar to that desired. For example, if a soil test recommended a 2-1-0 ratio, the ideal fertilizer would be something like 8-4-0, 10-5-0 or 20-10-0. However, if you cannot find that exact fertilizer, an 8-4-2 would be similar. If a garden soil test calls for a 1-0-0 ratio, a 21-0-0 or 24-2-2 fertilizer would be similar.

Formulation

The ***formulation*** tells what specific kinds of fertilizer are in the product. Table 1 gives examples of manufactured fertilizers that could be mixed to derive any specific analysis, ratio, or brand name.

Table 1. Examples of Manufactured Fertilizers

Product	N%	P_2O_5%	K_2O%
Ammonium nitrate	34	0	0
Ammonium sulfate	21	0	0
Urea	48	0	0
Ammoniated super-phosphate	3-6	48-53	0
Di-ammonium phosphate	11	48	0
Mono-ammonium phosphate	11	48	0
Super-phosphate	0	18-50	0
Triple super phosphate	0	46	0
Potassium chloride	0	0	60
Potassium nitrate	13	0	44
Potassium sulfate	0	0	50
Potassium-magnesium sulfate	0	0	22

What else is in the fertilizer? In a manufactured fertilizer, the grade does not add up to 100% because the fertilizer also contains other elements like carbon, hydrogen, oxygen, sulfur, iron, zinc, etc. For example, ammonium nitrate (NH_4^+ NO_3^-) has a grade of 34-0-0 with 34% of the content from nitrogen and 66% from hydrogen and oxygen. Ammonium sulfate (NH_4^+ SO_2^- has a grade of 21-0-0 with 21% from the nitrogen and 79% from the hydrogen, sulfur and oxygen.

Time release or ***slow release*** fertilizers contain coatings or are otherwise formulated to release the nutrients over a period of time as water, heat, and/or microorganisms break down the material. [Table 2]

Table 2. Examples of Quickly and Slowly Available Nitrogen

Quickly available nitrogen	Ammonium sulfate
o Lasts 4-6 weeks	Ammonium nitrate
	Calcium nitrate
	Potassium nitrate
	Urea
Slowly available nitrogen	Resin-coated urea
o Available over weeks to months	Sulfur-coated urea
	Isobutylidene diurea (IBDU)
o Regulated by solubility or microorganism activity	Methylene urea
	Urea formaldehyde
	Manure
	Poultry wastes
	Blood meal

In an “organic” type fertilizer, the base is decomposed or processed plant and/or animal by-products. For example, fish emulsion is ground and processed non-edible fish or fish scraps. Its nutrient content would be around 8-4-2, with 8% from nitrogen, 4% from phosphate, and 2% from potash.

Some manufactured and “organic” fertilizers contain fillers, which are used to prevent caking, control dust, derive the desired grade, or to facilitate ease of application.

Complete fertilizer is a term used to identify fertilizers that contains nitrogen, phosphorus, and potassium. In the national home garden trade, most fertilizers are complete. However, in Colorado many gardens do not need phosphorus or potassium. It is advisable to avoid heavy applications of phosphate and potash when unneeded as they contribute to soil salts.

Nitrogen Applications

Nitrogen is the nutrient needed in largest quantities as a fertilizer**.** Nitrogen is annually applied by manufactured fertilizer, organic fertilizers, and/or organic soil amendments. **Application rates are critical, because too much or too little directly affect crop growth**.

Application rate is based on the soil organic content. As the organic content increases, nitrogen will be slowly *mineralized* (released) by the activity of soil microorganisms. Standard application rates for gardens are given in Table 3.

Nitrogen fertilizer can be broadcast and watered in, or broadcast and tilled into the top few inches of soil. It can be banded 3-4 inches to the side of the seed row. Do not place the fertilizer in the seed row or root injury may occur.

For additional information on fertilizers refer to the *CMG GardenNotes* #234, Organic Fertilizers, and #711, Vegetable Garden: Soil Management and Fertilization.

Table 3. Nitrogen Fertilizer Application Rates for Home Gardens

	Soil Organic Content		
	Typical garden soil low in organic matter (0-1% organic matter)	Moderate level of organic matter (2-3% organic matter)	High level of organic matter (4-5% organic matter)
Nitrogen needed	**0.2 lb. actual N per 100 square feet**	**0.1 lb actual N per 100 square feet**	**0**
<u>Fertilizer to apply</u>			
Ammonium sulfate 21-0-0	1 lb. fertilizer per 100 square feet (approximately. 2 cups)	0.5 lb. fertilizer per 100 square feet (approximately. 1 cup)	0
OR			
Ammonium nitrate 34-0-0	0.6 lb. fertilizer per 100 sq. ft. (approximately 1 1/3 cups)	0.3 lb. fertilizer per 100 sq. ft (approximately 2/3 cup)	0
OR			
Urea, 45-0-0	0.4 lb. fertilizer per 100 sq. ft. (approximately. 1 cup)	0.2 lb. fertilizer per 100 sq. ft (approximately ½ cup)	0

Phosphate and Potash Applications

A soil test is the best method to determine the need for phosphate and potash. When a fertilizer contains a combination of nitrogen with phosphate and/or potash, the application rate is always based on the nitrogen percentage, because nitrogen levels are most critical to plant growth. Phosphate and potash fertilizers are best applied in the spring or fall when they can be tilled into the soil.

<u>Phosphorus</u>

Phosphorus may be present in high concentrations, however, it may not be in a plant available form. With annual applications of compost or manure, phosphorus levels will likely be adequate. Deficiencies are most likely to occur in new gardens where the organic matter content is low and in soils with a high pH (7.8 to 8.3).

Excessive phosphorus fertilizer can aggravate iron and zinc deficiencies and increase soil salt content.

Where phosphate levels are believed to be low, the standard application rate without a soil test is ¼ to 1 pound triple super phosphate (0-46-0) or ammonium phosphate (18-46-0) per 100 square feet.

When a phosphate fertilizer is applied to a soil, the phosphorus is quickly immobilized in the soil profile. It typically moves only about an inch. Therefore, it needs be tilled into the rooting zone to be most effective.

Phosphorus and Water Quality

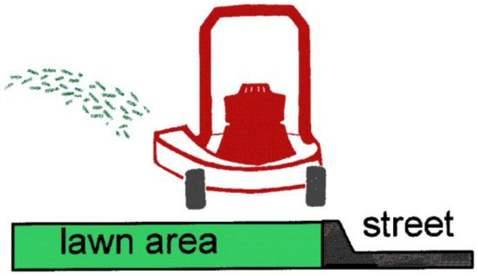
In surface water, low phosphorus levels limit the growth of algae and water weeds. However, when the phosphorus content of surface water increases, algae and water weeds often grow unchecked, a process called *eutrophication*. This significant decrease in water quality is a major problem related to manure management in production agriculture and the handling of yard wastes from the landscape environment.

Popular press articles often incorrectly point to phosphorus-containing lawn and garden fertilizers as the major source of phosphate water pollution. Actually, phosphate fertilizers are rather immobile when applied at correct rates to lawn and garden soils.

However, high rates of manure applied year after year will build soil phosphorus content where leaching becomes a water quality problem. In sandy soils coupled with high rainfall/irrigation, excessive application rates of organic or manufactured fertilizers may also lead to water quality concerns.

The primary source of water polluting phosphorus in the landscape environment is the mowing, sweeping or blowing of lawn clipping and leaves onto the gutter and street. When mowing, mow in a direction to blow the clippings onto the lawn rather than onto the sidewalk or street. Also sweep any grass on the sidewalk/driveway onto the grass. Avoid blowing autumn leaves into the street! [Figure 1]

Figure 1. Grass clippings and leaves mowed or blown into the street are the major source of phosphate pollution from the landscape environment. Mow in a direction to discharge clippings back onto the lawn and not into the street.



Phosphate in fertilizer is immobilized upon contact with soil and is not a source of phosphate pollution when applied to a lawn (or garden) soil. However, fertilizer over-spread onto the sidewalk, driveway, and street moves with surface runoff into local lakes, streams and ponds. Exercise caution when fertilizing to keep the phosphate out of the street.

It is also important to leave an unmowed buffer strip edging all lakes, streams, ponds and wetlands rather than mowing plant residues into the water.

Second to yard waste management, over-spreading fertilizers onto hard surface (sidewalks, driveways and streets) adds to surface water pollution. When applying fertilizer, avoid spreading the fertilizer onto hard surfaces where it will wash into local surface water through the storm sewer system. Sweep any fertilizer that landed on the sidewalk/driveway onto the lawn area.

Another very important source of phosphorus pollution in the landscape setting is soil erosion from new construction sites, unplanted slopes and poorly maintained landscapes. When the soil moves, it takes the soil bound phosphorus with it. For good water quality, sloping ground needs to be planted with year-round plant cover to prevent soil erosion.

Potassium

Potassium levels are naturally adequate to high in most Colorado soils. With annual applications of compost or manure, potassium levels will likely be adequate. Deficiencies occasionally occur in new gardens low in organic matter and in sandy soils low in organic matter. A soil test is the best method to determine the need for potassium.

Excessive potash fertilizer can increase soil salt content.

Where potash levels are believed to be low, the standard application rate without a soil test is ¼ to ½ pound potassium chloride (0-0-60) or potassium sulfate (0-0-50) per 100 square feet.

Movement of potassium in soils is dependent on soil texture. As the clay content increases, movement decreases. For most soils, it is important that applied potash be tilled into the root zone. In sandy soils, potassium could leach down past the root zone.

Specialty fertilizers

Specialty fertilizers may be preferred for specific purposes. For example, slow release fertilizers are recommended for lawns (see lawn care information for details). ***Slow release*** or ***time release*** fertilizers give out small quantities of nutrients over a time period. The release may be controlled by water, temperature, or microbial activity. For trees and shrubs, use only slow release products.

For planters and hanging baskets, two popular specialty fertilizers include time release products (e.g., Osmocote) and water solubles (e.g., MiracleGro, Peters, etc.).

Time release fertilizers such as Osmocote are designed for indoor and outdoor potted plants. Each time the soil is watered, a small amount of nutrients are released. Depending on the specific formulation, it would be applied to the soil once every 3 to 9 months. In outdoor pots watered daily, it releases faster, having about half the life span of the product used on indoor plants. Gardeners sometimes see the Osmocote pellets in potted plants and mistake them for insect eggs.

Numerous brands of ***water solubles*** are popular in the home garden trade, (e.g., MiracleGro, Peters, Schultz Plant Food, Fertilome Root Stimulator, etc.). Water soluble fertilizers are mixed with the irrigation water, typically giving a blue or green color. This can be done in a bucket or hose-on fertilizer applicator. It is important to water the soil with the fertilizer water, not just wet the leaves. (Note: Hose-on fertilizer applicators and hose-on pesticide sprayers are not the same thing. Fertilizer applicators apply a higher volume as the purpose is to water the soil. Pesticide applicators release a lower volume, as wetting the leaf is the objective.) Water solubles are the standard in greenhouse production where the fertilizer is injected into the irrigation water.

For herbaceous transplants (flowers and vegetables), water soluble fertilizers are recommended at planting and possibly two and four weeks after planting (depending on soil organic matter content). These are often marketed as *root stimulators*. It is the nitrogen content that promotes growth rather than any hormones or vitamins in the product. In cool springtime soils, the readily available phosphate may also be helpful. Woody plants (trees and shrubs) do not respond to water soluble fertilizer at planting. Always read the label directions to avoid over-fertilization.

Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., (USDA-ARS, retired). Revised by Dan Goldhamer (CSU Extension)

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CMG GardenNotes #233

Calculating Fertilizer Application Rates

Outline: Steps to calculating fertilizer application rate, page 1
Fertilizer application rate table, page 3

Steps to Calculating Fertilizer Application Rate

Example is for a 40-foot by 100-foot lawn area, using a 20-10-0 fertilizer

1. Calculating size of area to be fertilized

__ ft. long X ft. wide = ____square feet

Example:

40 feet X **100** feet = **4000** square feet

2. Calculating fertilizer application rate

__ lb. nutrient per_____sq. ft.
-------------------------------------- = pounds fertilizer /________sq. ft.
__ % nutrient in fertilizer

Example:

1 lb. nutrient per **1000** sq. ft.
-------------------------------------- **=** **5** pounds. fertilizer / **1000** sq. ft.
20% nutrient in fertilizer
(.20)

3.**Calculating pounds of fertilizer to apply**

lawn or garden area	X	application rate	=	pound of fertilizer per garden or lawn

____sq. ft.		___pounds fertilizer		__ pounds fertilizer
-------------------	X	----------------------	=	---------------------
garden or lawn		___sq. ft.		garden or lawn

Example:

4000 sq. ft.		**5** pounds fertilizer		**20** pounds fertilizer
-------------------	X	-----------------	=	--------------------
lawn		**1000** sq. ft.		lawn

Authors: David Whiting (CSU Extension, retired), Adrian Card (CSU Extension) and Carl Wilson (CSU Extension, retired) Reviewed by Eric Hammond (CSU Extension)

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- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.
- Extension programs are available to all without discrimination.
- No endorsement of products mentioned is intended nor is criticism implied of products not mentioned.
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Reviewed October 2015

Table 1. Fertilizer Application Rate Table

Because soil test recommendations for any given soil do not exactly match a fertilizer, select a fertilizer that gives comparative amounts of nitrogen, phosphorus and potassium as recommended by the soil test. In fertilizer application, it is most important to match the nitrogen requirement and compromise some for the phosphorus and potassium. The amount of fertilizer to apply that will give the recommended amount of nitrogen can be obtained from the following table:

Amount of Fertilizer to Apply Based on Actual Nitrogen Recommendations

Nitrogen Rate:		**0.1 pound nitrogen Per 100 square feet**	**0.2 pound nitrogen. per 100 square feet**	**1 pound nitrogen per 1,000 square feet**
Fertilizer Grade		pounds fertilizer to apply per 100 square feet	pounds fertilizer to apply per 100 square feet	pounds. fertilizer to apply per 1 000 square feet
45-0-0 (urea)		0.2	0.4	2.2
37-3-3		0.3	0.5	2.7
36-6-6		0.3	0.6	2.8
33-0-0		0.3	0.6	3.0
32-4-4	32-3-10	0.3	0.6	3.1
30-4-4	30-0-10	0.3	0.7	3.3
28-3-3	28-4-6	0.4	0.7	3.6
27-7-7	27-3-3	0.4	0.7	3.7
25-5-5	25-3-12	0.4	0.8	4.0
24-8-16	24-0-15	0.4	0.8	4.2
22-4-4	22-6-3	0.5	0.9	4.5
21-0-0	21-3-12	0.5	1.0	4.8
20-20-20	20-4-8	0.5	1.0	5.0
19-19-19	19-11-12	0.5	1.0	5.3
18-6-12	18-3-6	**0.6**	1.1	5.6
16-8-8	16-4-8	0.6	1.3	6.3
15-15-15	15-5-5	0.7	1.3	6.7
13-3-9	13-25-12	0.8	1.5	7.7
12-12-12	12-4-4	0.8	1.7	8.3
10-10-10	10-20-10	1.0	2.0	10.0
10-5-5	10-10-20	1.0	2.0	10.0
6-12-12	6-2-0	1.7	3.3	16.7
5-10-10	5-10-5	2.0	4.0	20.0

Example: If the N (nitrogen) recommendation is for 0.1 lb. N/100 sq. ft. and the fertilizer grade selected has a ratio of 18-6-12 (column 1), apply 0.6 lb. of this fertilizer per 100 sq. ft.

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CMG GardenNotes #234

Organic Fertilizers

Outline:

Terms

By legal definition, the term ***fertilizer*** refers to a soil amendment that guarantees the minimum percentages of nutrients (at least the minimum percentage of nitrogen, phosphate, and potash).

An ***organic fertilizer*** refers to a soil amendment derived from natural sources that guarantees, at least, the minimum percentages of nitrogen, phosphate, and potash. Examples include plant and animal by-products, rock powders, seaweed, inoculants, and conditioners. These are often available at garden centers and through horticultural supply companies.

These should not be confused with substances approved for use with the ***USDA National Organic Program (NOP)***. The USDA NOP, with its "USDA Organic" label, allows for the use of only certain substances. The Organic Materials Review Institute (www.omri.org) and the Washington Department of Agriculture (WSDA) (http://agr.wa.gov/) review and approve brand name products made with ingredients from the "national list" for use in certified organic production. If a fertilizer is not OMRI or WSDA approved, it may still be allowed for organic production but has not been reviewed and deemed suitable for use in certified production. To learn more about which inputs are allowed and which are prohibited refer to http://www.ams.usda.gov/about-ams/programs-offices/national-organic-program. Many of the organic fertilizers listed here will meet NOP standards (based on the National List). Growers participating in the NOP should consult with their certifier to ensure compliance for organic certification.

The term ***soil amendment*** refers to any material mixed into a soil. ***Mulch*** refers to a material placed on the soil surface. In Colorado, soil amendments have no legal claims about nutrient content or other helpful (or harmful) effects it will have on the soil and plant growth. In Colorado, the term ***compost*** is also unregulated, and could refer to any soil amendment regardless of active microorganism activity.

Many gardeners apply *organic soil amendments*, such as compost or manure, which most often do not meet the legal requirements as a "fertilizer" but add small amounts of nutrients.

Release Time – Organic products require the activity of soil microorganisms before nutrients are available for plant uptake. Microorganism activity is generally dependent on soil temperatures greater than 50ºF in the presence of sufficient soil moisture. Dry and/or cold soil conditions will delay the release of nutrients from these organic sources. This period refers to how long these products are available if applied to the soil. Use this information to time the application of the product.

Application – Products may be applied in various ways. Some may be tilled in (worked into the soil with a machine or hand tool), others may be applied as a foliar spray (mixed with a surfactant and sprayed in a fine mist on the leaf surface while temperatures are below 80ºF), and some may be injected into a drip or overhead irrigation system (fertigation with a siphon mixer). Application rates in this fact sheet are generalized and based on some manufacturers' recommendations. Over- or under-fertilization may occur using these recommendations.

Plant By-Products

Alfalfa Meal or Pellets

Alfalfa meal or pellets are often used as animal feed. They are used primarily to increase organic matter in the soil but do offer nutrients and a high availability of trace minerals. They contain trianconatol, a natural fatty-acid growth stimulant.

Alfalfa Meal or Pellets

Typical NPK analysis	2-1-2
Release time	1-4 months
Pros	Available at feed stores
Cons	May contain seeds
Application	Till in 2-5 pounds per 100 square feet

Corn Gluten Meal

Corn gluten meal has a high percentage of nitrogen. Products carry a warning to allow 1 to 4 months of decomposition in the soil prior to seeding. Allelopathic properties will inhibit the germination of seeds. However, there is no danger to established or transplanted plants. This product is also marketed as a pre-emergent weed control for annual grasses in bluegrass lawns.

Corn Gluten Meal

Typical NPK analysis	9-0-0
Release time	1-4 months
Pros	Very high nitrogen
Cons	Germination inhibitor, some are GMOs
Application	Till in 20-40 pounds per 1000 square feet

Cottonseed Meal

Cottonseed meal is a rich source of nitrogen. Buyers should be aware that many pesticides are applied to cotton crops and residues tend to remain in the seeds. Pesticide-free cottonseed meal is available.

Cottonseed Meal

Typical NPK analysis	6-0.4-1.5
Release time	1-4 months
Pros	High nitrogen
Cons	Pesticide residues, most are GMOs
Application	Till in 10 pounds per 100 square feet

Soybean Meal

Used primarily as an animal feed product. Available bagged at many feed stores.

Soybean Meal

Typical NPK analysis	7-2-1
Release time	1-4 months
Pros	High nitrogen, available at feed stores
Cons	Almost half of the conventionally grown soy is GMO
Application	8 pounds per 100 square feet

Animal By-Products

Bat Guano – High N

Bat guano (feces) harvested from caves is powdered. It can be applied directly to the soil or made into a tea and applied as a foliar spray or injected into an irrigation system.

Bat Guano – High N

Typical NPK analysis	10-3-1
Release time	4+ months
Pros	Stimulates soil microbes
Cons	Cost
Application	Till in 5 pounds per 100 square feet or as a tea at 3 teaspoons per gallon of water

Bat Guano – High P

Bat guano (feces) harvested from caves is powdered. It can be applied directly to the soil or made into a tea and applied as a foliar spray or injected into an irrigation system. Difference is that it is processed for high phosphorus content.

Bat Guano – High P

Typical NPK analysis	3-10-1
Release time	4+ months
Pros	Stimulates soil microbes
Cons	Cost
Application	Till in 5 pounds per 100 square feet or as tea at 3 teaspoons per gallon of water

Blood Meal

Blood meal, made from dried slaughterhouse waste, is one of the highest non-synthetic sources of nitrogen. If over-applied it can burn plants with excessive ammonia.

Blood Meal

Typical NPK analysis	12-0-0
Release time	1–4 months
Pros	Available at feed stores
Cons	Can burn. Expensive at garden centers
Application	Till in 5–10 pounds per 100 square feet

Bone Meal

A well-known source of phosphorus, bone meal is steam processed and widely available at feed stores and in garden centers. If purchased at feed stores, phosphorus is expressed on the label as elemental phosphorus and is 2.3 times higher than numbers shown on garden center labels for phosphate (i.e. – 12% phosphate is the same as 27% phosphorus). **However, recent CSU research has shown that phosphorus from bone meal is only available to plants in soils that have a pH below 7.0.**

Bone Meal

Typical NPK analysis	3-15-0
Release time	1–4 months
Pros	Highly plant available form of phosphorus
Cons	Cost
Application	Till in 10 pounds per 100 square feet

Feather Meal

Sourced from poultry slaughter, feather meal has fairly high nitrogen levels but is slow to release the nitrogen.

Feather Meal

Typical NPK analysis	N varies 7 – 12% on process
Release time	4+ months
Pros	Long term fertilizer
Cons	Cost versus speed of nitrogen release
Application	Till in 2.5-5 pounds per 100 square feet

Fish Emulsion

Infamous for its foul smell, emulsions are soluble, liquid fertilizers that have been heat and acid processed from fish waste.

Fish Emulsion

Typical NPK analysis	5-2-2
Release time	1 – 4 months
Pros	Adds needed micronutrients
Cons	Some have foul smell
Application	Mix 6 tablespoons per gallon of water

Enzymatically Digested Hydrolyzed Liquid Fish

Enzymatically digested hydrolyzed liquid fish products use enzymes to digest the nutrients from fish wastes instead of using heat and acids. This retains more of the proteins, enzymes, vitamins and micronutrients than emulsions.

Enzymatically Digested Hydrolyzed Liquid Fish

Typical NPK analysis	4-2-2
Release time	1 – 4 months
Pros	More nutrients than emulsions
Cons	More expensive than emulsions
Application	Mix 5 tablespoons per gallon of water

Fish Meal

Fish meal is ground and heat dried fish waste.

Fish Meal

Typical NPK analysis	10-6-2
Release time	1 – 4 months
Pros	N and P source
Cons	Heat processed
Application	Till in 5-10 pounds per 100 square feet

Fish Powder

Fish power is dried with heat and turned into water-soluble powder. It is a high source of nitrogen. Many can be mixed into solution and injected into an irrigation system.

Fish Powder

Typical NPK analysis	12-0.25-1
Release time	Immediate to 1 month
Pros	Adds micro-nutrients
Cons	Heat processed
Application	Till in 1-2 ounces per 100 square feet OR mix at 1 tablespoon per gallon of water

Rock Powders

Rock powders relevant for use in Colorado soils are those that supply phosphorus. Those that serve as a potassium source (greensand, feldspar, potassium sulfate, biotite, etc.) are not necessary as Colorado soils are naturally high in potassium. Similarly, it is not necessary to add calcium (gypsum, lime, etc.) due to naturally high calcium levels in Colorado soils and arid conditions.

If you are making annual applications of manure and/or compost to your garden to add nitrogen, you should have sufficient levels of phosphorus in your soil.

Generally, plant or animal sources are the best value for phosphorus in the home garden. **Recent CSU research results concluded that no rock P (regardless of mesh size) is available for plant use unless the soil pH is below 7.0.**

Colloidal Phosphate – a.k.a. Soft Rock Phosphate

This product is made by surrounding clay particles with natural phosphate. Total phosphate is about 20% while available phosphate is about 2-3%. You can apply large amounts of colloidal phosphate, as it will release slowly over the years (usually more available the second year than the first). For home gardeners the cost/return is adequate to apply colloidal phosphate at rates to supply phosphorus for this season’s crops. This product also adds micronutrients to soil.

Micronized (passing through 1000 mesh screen [1000 wires per square inch]) sources may be more available than regular soft rock grinds in soils with a pH below 7.0.

Seaweed

Kelp is the most common form and is valued not for its macronutrient (nitrogen, phosphorus and potassium) contributions but for micronutrients.

Kelp is often mixed with fish products to enhance growth.

Three processes are available: extracts (as kelp meal or powder), cold-processed (usually liquid) and enzymatically digested (liquid). Ranked in quality of content and plant availability they are (highest to lowest) 1) enzymatically digested, 2) cold-processed and 3) extracts.

Kelp Meal

Kelp meal, a product of the ocean, is used primarily as a trace mineral source. It is often combined with fish meal to add nitrogen, phosphorus and potassium.

Kelp Meal

Typical NPK analysis	negligible
Release time	4+ months
Pros	Adds micronutrients
Cons	Insignificant nitrogen, phosphorus and potassium
Application	Till in 1 pound per 100 square feet

Kelp Powder

Kelp powder is similar to kelp meal but ground fine enough to put into solution and applied as a foliar spray or injected into an irrigation system.

Kelp Powder

Typical NPK analysis	1-0-4
Release time	Immediate – 1 month
Pros	Adds micronutrients
Cons	Insignificant nitrogen, phosphorus and potassium
Application	Mix ¼ to ½ teaspoon/gallon of water

Liquid Kelp

Usually cold processed, liquid kelp will have higher levels of growth hormones than extracts. Some may also be enzymatically digested, making the growth hormones even more available to the plants.

Liquid Kelp

Typical NPK analysis	Negligible
Release time	Immediate – 1 month
Pros	Adds micronutrients plus helps plant with stress
Cons	Insignificant nitrogen, phosphorus and potassium
Application	Mix 1-2 tablespoons per gallon of water

Authors: Adrian Card (CSU Extension), with David Whiting (CSU Extension, retired), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., (USDA-ARS, retired) Revised Dan Goldhamer (CSU Extension)

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CMG GardenNotes #241

Soil Amendments

Terms

The term ***soil amendment*** refers to any material mixed into a soil. ***Mulch*** refers to a material placed on the soil surface. By legal definition, soil amendments make no legal claims about nutrient content or other helpful (or harmful) effects that it will have on the soil and plant growth. In Colorado, the term ***compost*** is also unregulated, and could refer to any soil amendment regardless of microorganism activity.

By legal definition, the term ***fertilizer*** refers to soil amendments that guarantee the minimum percentages of nutrients (at least the minimum percentage of nitrogen, phosphate, and potash).

An ***organic fertilizer*** refers to a soil amendment derived from natural sources that guarantees, at least, the minimum percentages of nitrogen, phosphate, and potash. Examples include plant and animal by-products, rock powders, seaweed, inoculants, and conditioners. These are often available at garden centers and through horticultural supply companies.

These should not be confused with substances approved for use with the ***USDA National Organic Program (NOP)***. The USDA NOP, with its "USDA Organic" label, allows for the use of only certain substances. The Organic Materials Review Institute (www.omri.org) and the Washington Department of Agriculture (WSDA) (http://agr.wa.gov/) review and approve brand name products made with ingredients from the "national list" for use in certified organic production. If a fertilizer is not OMRI or WSDA approved, it may still be allowed for organic production but has not been reviewed and deemed suitable for use in certified production. To learn more about which inputs are allowed and which are prohibited refer to http://www.ams.usda.gov/about-ams/programs-offices/national-organic-program Many of the organic fertilizers listed here will meet NOP standards (based on the National List). Growers participating in the NOP should consult with their certifier to ensure compliance for organic certification.

Many gardeners apply *organic soil amendments*, such as compost or manure, which most often do not meet the legal requirements as a “fertilizer” and generally add only small quantities of plant nutrients.

Managing Soil Texture and Structure

Routine applications of organic matter should be considered an essential component of gardening and soil management. Organic matter improves the water and nutrient holding capacity of coarse-textured sandy soil. In a fine-textured clayey soil, the organic matter glues the tiny clay particles into larger chunks or *aggregates* creating large pore space. This improves water infiltration and drainage, air infiltration (often the most limiting aspect of plant growth), and allows for deeper rooting depths (allowing the plant to tap a larger supply of water and nutrients). For additional discussion, refer to the *CMG GardenNotes* #213, **Managing Soil Tilth**.

Using ***organic soil amendments*** is a great way to turn otherwise useless products, like fall leaves and livestock manure, into compost for improving soil tilth.

When using organic soil amendments, it is important to understand that only a portion of the nutrients in the product are available to plants in any one growing season. Soil microorganisms must process the organic compounds into chemical ions (NO_3^-, NH_4^+, HPO_4^{-2}, $H_2PO_4^-$, K^+) before plants can use them.

Cultivate or hand-turn the organic matter thoroughly into the soil. Never leave it in chunks as this will interfere with root growth and water movement.

Selecting Soil Amendments

Desired results – In selecting soil amendments, first consider the desired results. To improve the water and nutrient holding capacity on sandy, gravelly, and decomposed granite soils, select well decomposed materials like finished compost, aged manure, and peat. To improve aeration and infiltration (improve structure on clayey soils) select fibrous materials like composted wood chips, peat and straw.

Potential for routine applications – Another important consideration is the potential for routine applications to improve the soil over time, as in a vegetable garden or annual flowerbed. In many landscape settings, the amendment is a one-time application added before planting lawns, perennials, trees and shrubs.

Longevity of the product merits consideration. Produces that decompose rapidly (like grass clippings and manure) give quick results, while products that decompose slowly (like wood chips, bark chips and peat) provide longer lasting results. For quick improvement that last, use a combination of materials.

Salts are a primary consideration. Products made with manure and/or biosolids are often very high in salts. Salt levels may actually increase in the composting process, although water moving through the compost pile leaches out the salts. Use with caution! Plant-based products are naturally low in salts.

Routine application rates depend on the salt potential of the material and the depth to which it will be cultivated into the soil. Table 1 gives standard rates.

Table 1. Routine Application Rate for Soil Amendments

Site	**Incorporation Depth**[2]	**Depth of Compost Before Incorporation**[1]	
		Plant-Based Compost and other compost known to be low in salts[3]	**Compost Made with Manure or Biosolids** for which the salt content is unknown[4]
One-time application— such as lawn area	6-8 inches	2-3 inches	1 inch
Annual application to vegetable and flower gardens – **first three years**	6-8 inches	2-3 inches	1 inch
Annual application to vegetable and flower gardens – **fourth year and beyond**	6-8 inches	1-2 inches	1 inch

1 Three cubic yards (67 bushels) covers 1,000 square feet approximately 1 inch deep.

2 Cultivate compost into the top 6-8 inches of the soil. On compacted/clayey soils, anything less may result in a shallow rooting depth predisposing plants to reduced growth, low vigor and low stress tolerance. If the actual incorporation depth is different, adjust the rate accordingly.

3 Plant-based composts are derived solely from plant materials (leaves, grass clippings, wood chips and other wards wastes). Use this application rate also for other compost known, by soil test, to be low in salts.

4 Use this application rate for any compost made with manure or biosolids unless the salt content is known, by soil test, to be low. Excessive salts are common in many commercially available products sold in Colorado. For a few products in the market with extremely high salt levels, even this low rate may be too high.

When purchasing products, gardeners need to understand that there are no regulations about the quality of the product, salt content or other beneficial or harmful qualities of bagged products. Voluntary standards for bulk products may help in product evaluation. Use with caution! Many of the soil amendments sold in Colorado are high in salts!

Need for nitrogen fertilizer – Soil microorganisms release nitrogen tied-up in organic matter over a period of time. Release rates from compost are very slow, over a period of years. The need for nitrogen fertilizer is based on the soil organic content. As the soil organic content increases, the need for fertilizer decreases. [Table 2]

Table 2.
Need for Nitrogen Fertilizer Based on Soil Organic Content

Soil Organic Content	Routine Application Rate For Gardens
1%	2 pounds actual N / 1,000 square feet
2-3%	1 pound actual N / 1,000 square feet
4-5%	0

Over Amending

Over-amending is a common problem. Some gardeners try to fix their soil limitations by adding large quantities of amendment in a single season. This can result in following problems:

- High salts
- High nitrogen
- Low nitrogen (from the tie-up of nitrogen due to a carbon to nitrogen ratio imbalance)
- Holding too much water
- High ammonia (burns roots and leaves)

Problems may also arise, over time, from the continual application of high rates. This can result in the following problems:

- High salts
- Excessive nitrogen, phosphorus, and potassium
- Ground water contamination
- Micronutrient imbalance

Evaluating the Quality of Organic Amendments

The quality of organic amendments can be determined by both visual evaluation and laboratory testing.

Visual Evaluation

Color – Dark brown to black
Odor – Earthy, no ammonia smell
Texture – Less than ½ inch particle size; lawn top dressing less than ¼ inch
Foreign materials – Less than 1% and smaller than ½ inch size
Uniformity Within the batch
Consistency Between different batches
Raw materials – Concern of heavy metals (biosolids), human pathogens (manure), and salts (manure and biosolids)
Weed seeds – Test by germinating some material

Laboratory Testing

C:N ratio – Less than 20 to 1 acceptable; 10-12 to 1 is better

Ash content – (This measurement of the mineral portion after the organic matter is burned off will determine if soil was a primary part of the mix.)

- 20-30% common
- Keep below 50%
- If greater than 50-60% it probably contains a lot of soil

Bulk density – Less than 1.0 gm/cc

pH – 6.0 to 7.8

- May be higher in manure
- Near neutral (6.8 to 7.2) is best

Salts – Acceptable levels depend on use

- Potting grade: < 2.5 mmhos/cm
- Potting media amendment: < 6 mmhos/cm
- Top dressing: < 5 mmhos/cm
- Soil amendment in a low salt soil: <10 mmhos/cm

Sodium – Sodium adsorption ratio less than 13%

Ammonium – Less than 1/3 of total nitrogen. If higher, it may not be finished composting.

Heavy metals – A concern with biosolids but regulated by application permits.

Pesticide residues – Generally not a problem as they breakdown in composting.

Pathogens – *E-coli* and other human pathogens are a potential in manure.

Nutrient content varies greatly from product to product.

Germination test – Seeds are started to check potential of toxic chemicals.

Stability (respiration rate) vs. maturity – Relative measurement of the completeness of microbial activity. If microorganisms are highly active, they may consume oxygen in the root zone causing root problems.

Bacterial and fungal diversity – Some compost has been found to suppress plant diseases. This is a high-tech field with commercial applications.

Examples of Soil Amendments

There are two broad categories of soil amendments: organic and inorganic. Organic amendments come from something that is or was alive. Inorganic amendments, on the other hand, are either mined or man-made. Organic amendments include sphagnum peat, wood chips, grass clippings, straw, compost, manure, biosolids, sawdust, and wood ash. Inorganic amendments include vermiculite, perlite, tire chunks, pea gravel, and sand.

Peat

Sphagnum peat is a good soil amendment, especially for sandy soils, which will retain more water after sphagnum peat application. Sphagnum peat is generally acidic (i.e., low pH) and may help gardeners grow plants that require a more acidic soil. Sphagnum peat is harvested from bogs in Canada and the northern United States. The bogs can be revegetated after harvest and grow back relatively quickly in this moist environment. In recent years however, harvest rates have become so high that it is raising questions on renewability.

Colorado mountain peat is not an acceptable soil amendment. It often is too fine in texture and generally has a higher pH. Mountain peat is mined from high-altitude wetlands that will take hundreds of years to rejuvenate, if ever. This mining is extremely disruptive to hydrologic cycles and mountain ecosystems.

Biosolids

Biosolids (sewage sludge) add slow release nutrients and organic matter to soil. They are available from some communities or sewer treatment districts in bulk and from garden stores in bags.

Some biosolids are extremely high in salts. For example, tests on MetroGro report a salt content of 38.3 dS/m (38.3 mmhos/cm), which is considerably above acceptable tolerances for soil amendments. (A soil amendment above 10 dS/m is considered questionable.) For details on salty soil amendments, refer to *CMG GardenNotes* #224, **Saline Soils**.

Biosolids typically have 5-6% nitrogen content. Annual applications should be made only when the biosolids and garden soil are routinely tested for salt content.

Worm Castings

Versatile worm castings can be used in potted plants, soil mixes, and in garden beds. Worm castings pose no threat of burning potted plants. Worms should have digested the batch of vermicompost for 4 months to ensure that microbial oxygen consumption has diminished sufficiently.

Red worm castings are the feces from compost worms. It has a slow release performance due to a mucus covering which is slowly degraded with microorganism activity. It contains highly available forms of plant nutrients that are water-soluble, has a neutral pH, and contains trace elements, enzymes, and beneficial microorganisms. The release time for nutrients is around 4 months. For continual release of nutrients, repeat applications at 4-month intervals.

Some batches made from livestock manure may have high salts depending on whether the animals producing the manure had access to a salt lick and if the vermicompost maker leached them out or not.

Castings can be applied as a top dressing, 1/4 inch deep, to potted plants, as 25% of a soil mix (1 to 4 mix) or tilled into a garden at 1 gallon per 13 square feet or 7.5 gallons (1 cubic foot) per 100 square feet. Due to the high cost in Colorado, they are generally used in small gardens or potting mixes.

Perlite and Vermiculite

Perlite and vermiculite are common inorganic amendments used in potting soils and planter mixes.

Vermiculite is made from heat expanded silica. It helps increase pore space and has a high water holding capacity. Perlite is made from heat expanded volcanic rock. It is used to increase pore space and has a low water holding capacity.

Summary: Considerations in Selecting Soil Amendments

There is really not a best amendment to use in each situation. What is practical and available varies from place to place. The important points are that 1) soils are routinely amended to improve soil tilth and 2) the gardener follows the limitations for the specific product used. The following summarizes selection considerations:

- Cost
  - Local availability
  - Cost of product
  - Size of area to be treated (quantity needed)
  - Depth of incorporation (application rate / quantity needed)
  - Transportation costs

- Need for fertilizer after amending
  - Soil organic content

- Precautions with specific products
  - Salts (manure and biosolids)
  - Weed seeds (manure and compost)
  - Plant pathogens (compost)
  - Human pathogens (manure)

- Alternatives to amending
  - Potential to incorporate amendments
  - Accepting a reduction in plant growth and vigor
  - Accepting increased maintenance requirements
  - Selecting plants more tolerant of poor soils
  - Avoid crowding plants competing for limited soil resources
  - Mulching with organic mulch to slowly improve soil over time
  - Container and raised-bed gardening
  - Preventing compaction forces

Authors: David Whiting (CSU Extension, retired), with Adrian Card (CSU Extension), Catherine Moravec, Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., USDA-ARS (retired). Revised by Dan Goldhamer (CSU Extension)

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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CMG GardenNotes #242

Using Manure in the Home Garden

Outline:	*E coli*, a health issue, page 1 Nitrogen release rate is slow, page 1 Salts, page 3 Other disadvantages of farm manure, page 3 Composted manure, page 4

For some gardeners in Colorado, manure is readily available as a source of organic matter to build soils and add small amounts of nutrients. However, follow precautions with manure applications or they could become more detrimental than beneficial.

E. coli, a Health Issue

Due to the potential of transmitting human pathogens, such as *E. coli*, fresh manure should only be used on fruits and vegetables when specific precautions are taken. Apply non composted (fresh) manures in the fall and mix it into the soil. Do not leave it on the soil surface. Wait 120 days from manure application to harvest. Never apply it to growing good crops.

Nitrogen Release Rate is Slow

Manure contains small amounts of plant nutrients and micronutrients. The nutrient composition of farm manure varies widely depending on bedding material, moisture content, exposure, and aging, even for the same species of animal. Where manure is routinely added, garden soils will likely have adequate phosphorus and potassium. Manure is a great source of micronutrients like zinc. Table 1 gives approximate amounts of nitrogen, phosphate, and potash. [Table 1]

Table 1. Approximate nutrient content of manure*

Type		N	P_2O_5	K_2O
Beef	with bedding	1.1%	0.9%	1.3%
	without bedding	1.1%	0.7%	1.2%
Dairy cattle	with bedding	0.5%	0.2%	0.5%
	without bedding	0.5%	0.2%	0.5%
Horse	with bedding	0.7%	0.2%	0.7%
Poultry	with litter	2.8%	2.3%	1.7%
	without litter	1.7%	2.4%	1.7%
Rabbit		2.0%	1.3%	1.2%
Sheep	with bedding	0.7%	0.5%	1.3%
	without bedding	0.9%	0.6%	1.3%
Swine	with bedding	0.4%	0.4%	0.4%
	without bedding	0.5%	0.5%	0.4%
Turkey	with litter	1.0%	0.8%	0.7%
	without litter	1.4%	1.0%	0.9%

*At time of land application
Sources: CSU Extension Bulletin 552A, *Utilization of Animal Manure as Fertilizer* except for rabbits from *Western Fertilizer Handbook* of the California Fertilizer Association.

The nitrogen in manure is not all available to growing plants the first year as much of it may be tied up in organic forms. Organic nitrogen becomes available to plants when soil microorganisms decompose organic compounds, such as proteins, and then convert the released N to NH_4. This process, known as ***mineralization***, begins almost immediately, but fully occurs over a period of years. [Table 2]

Table 2. Approximate percentage of organic N mineralized in the first year after application

Manure Source	Percent of organic N mineralized
Beef	35%
Dairy	35%
Horse	20%
Poultry	35%
Sheep	25%
Swine	50%

Source: Nebraska Cooperative Extension Bulletin EC89-117, *Fertilizing Crops with Animal Manures*

The amount mineralized in the first year depends upon the manure source, soil temperature, moisture, and handling. **In general, about 30% to 50% of the organic nitrogen becomes available the first year. Thereafter, the amount**

gradually decreases. A general estimate is 50% the first year, 25% the second year, 12.5% the third year, and so forth.

In gardens low in organic matter, it is common to find nitrogen deficiencies when the gardener relies solely on manure and/or compost due to the slow release rates. The gardener may need to supplement with a high nitrogen organic or manufactured fertilizer. As the soil builds in organic matter over the years, the problems with low nitrogen levels will improve.

Salts

Salt content may be high in fresh manure and decreases with exposure to rains and irrigation as salts are leached out. **Continual and/or heavy applications of manure can lead to a salt build-up.**

To avoid salt problems associated with the use of manure or compost made with manure, limit applications to one inch per year (when cultivated six to eight inches deep) and thoroughly cultivate the manure or compost into the soil. When cultivation is less than six to eight inches deep, adjust the application rate accordingly. Have a soil test for salt content before adding large amounts.

Manure or compost made with manure containing up to 10 dS/m (10 mmhos/cm) total salt is acceptable if cultivated six to eight inches deep into a low-salt garden soil (less than 1 dS/m or 1 mmhos/cm). Manure with a salt content greater than 10 dS/m (10 mmhos/cm) is questionable. Avoid use of manure on soils that are already high in salts (above 3 dS/m (3 mmhos/cm).

> Note: dS/m or mmhos/cm are the units used to measure salt content. It measures the electrical conductivity of the soil.

Other Disadvantages of Farm Manure

Other disadvantages of farm manure include the following:

- Potential burning of roots and foliage from high ammonia.
- High potential for weed seeds.
- Labor and transportation necessary to apply the manure to the garden.

Horse manure is legendary in its potential to introduce a major weed seed problem into a garden. Composting the manure before application may kill the weed seeds if the pile heats to above 145ºF and the pile is turned to heat process the entire product.

Feedlot manure is often high in salts if a salt additive is used in the livestock diet.

Poultry manure is particularly high in ammonia and readily burns if over-applied. The ammonia content will be higher in fresh manure compared to aged manure. Laying hen manure can raise soil pH due to the calcium supplements in their diet. Occasionally, gardeners may want to “fix” their soil by adding large quantities of organic matter at one time. Excessive applications of manure can lead to a reduction of plant growth due to excessive levels of nitrogen, ammonia burn, and salt damage to the roots.

Composted Manure

A growing trend in the use of manure is to compost it before application. Bagged composted manure is readily available in garden stores and nurseries. Composted manure has fewer odors. It is easier to haul and store than fresh manure because of the reduction in the weight of water and a decrease in overall volume by four to six fold. The composting process may kill weed seeds and pathogens if the pile heats above 145ºF and the pile was turned to heat-process the entire product. Salts can be concentrated during composting as moisture is lost and volume is reduced. Many bagged manure products sold in Colorado are high in salts.

In composted dairy manure, only 5-20% of the nitrogen will be available the first year. In soils low in organic content, this can lead to a nitrogen deficiency unless an additional quick release nitrogen source is supplemented. This could be supplied with blood meal (approximately 1 to 2 pounds per 100 square feet) or with a manufactured fertilizer like ammonium nitrate (2/3 cup per 100 sq. ft) or ammonium sulfate (1 cup per 100 sq. ft.). The ammonia content drops due to volatilization during composting, thereby reducing the burn potential.

Fresh manure without bedding materials is somewhat difficult to compost, because of the high ammonia and moisture content. To speed decomposition and minimize foul odors from anaerobic decay, add some high carbon material, such as sawdust, straw, dried leaves or wood chips. Depending on climatic conditions, on-farm manure composting takes six to ten or more weeks if turned weekly.

Authors: David Whiting (CSU Extension, retired) with Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., (USDA-ARS, retired) Revised by Dan Goldhamer (CSU Extension)

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #243

Using Compost in the Home Garden

For information on home composting see Colorado State University Extension fact sheet #7.212, *Composting Yard Waste.*

Compost Products

Home made or commercial compost is a good source of organic matter for the garden. Compost provides a food source for beneficial soil organisms, enhancing the soil food web and releasing nutrients over the long term.

A home compost bin is an environmentally sound method to convert yard wastes into a valuable soil-building resource. Using compost has also been found to suppress some soil borne plant disease pathogens in certain situations.

Home compost has the advantage that the gardener controls what goes into the compost pile and can avoid weed seeds, diseased plants and salt problems.

There are many bagged compost based products available in the retail trade. They can be any combination of plant residues, manure, and/or biosolids. Some products also have added rock minerals or animal by-products. These bagged products are usually more expensive than manure and compost supplies available in bulk. They provide a long-term release of nutrients and add organic matter to soils, improving soil physical properties.

In Colorado, compost is unregulated. Materials sold as “compost” could be anything (plant materials, manure, biosolids, animal by-products, etc.) and could be at any stage of decomposition. Not all “composts” are good for the soil.

Application Rates and Salt Problems

General application rates for compost are based on the salt content of the compost and soil and on the depth to which it is cultivated into the soil. Ideally, cultivate the compost into the top six to eight inches of the soil. In compacted/clayey soils, anything less can lead to a shallow rooting system with reduced plant growth, lower vigor, and lower stress tolerance.

Table 1 gives standard application rates for compost. Compost made solely from plant residues (leaves and other yard wastes) is basically free of salt problems and higher application rates are safe.

Table 1. Routine Application Rate for Soil Amendments

Site	**Incorporation Depth**[2]	**Depth of Compost Before Incorporation**[1]	
		Plant-Based Compost and other compost known to be low in salts[3]	**Compost Made with Manure or Biosolids** for which the salt content is unknown[4]
One-time application—such as lawn area	6-8 inches	2-3 inches	1 inch
Annual application to vegetable and flower gardens – **first three years**	6-8 inches	2-3 inches	1 inch
Annual application to vegetable and flower gardens – **fourth year and beyond**	6-8 inches	1-2 inches	1 inch

1 Three cubic yards (67 bushels) covers 1,000 square feet approximately 1 inch deep.

2 Cultivate compost into the top 6-8 inches of the soil. In compacted/clayey soils, anything less may result in a shallow rooting depth predisposing plants to reduced growth, low vigor and low stress tolerance.

3 Plant-based composts are derived solely from plant materials (leaves, grass clippings, wood chips and other wards wastes). Use this application rate also for other compost known, by soil test, to be low in salts.

4 Use this application rate for any compost made with manure or biosolids unless the salt content is known, by soil test, to be low. Excessive salts are common in many commercially available products sold in Colorado. For a few products in the market with extremely high salt levels, even this low rate may be too high.

Compost that includes manure or biosolids as a component has a potential for high salts. Excessive salt levels are common in many commercially available products sold in Colorado. For compost made with manure or biosolids the application rate is limited unless a soil test on that batch of product shows a low salt level. An amendment with up to 10 dS/m (10 mmhos/cm) total salt is acceptable if incorporated six to eight inches deep in a low-salt garden soil (less than 1 dS/m or 1 mmhos/cm). Any amendment with a salt level above 10 dS/m (10 mmhos/cm) is questionable.

Note: dS/m or mmhos/cm is the unit used to measure salt content. It measures the electrical conductivity of the soil.

Compost needs to be thoroughly mixed into the upper six to eight inches of the soil profile. Do not leave compost in chunks, as this will interfere with root growth and soil water movement.

As the soil organic content builds in a garden soil, the application rate should be reduced to prevent ground water contamination issues. A soil test is suggested every four to six years to establish a base line on soil organic matter content.

Nitrogen Release is Slow

Typical nutrient content includes 1.5% to 3.5% nitrogen, 0.5% to 1% phosphate, and 1% to 2% potash, plus micronutrients. Thus compost is more of a soil conditioner than a fertilizer. In gardens where compost is routinely added, phosphorus and potassium levels are likely to be adequate.

As in other organic soil amendments, the nitrogen release rate from compost will be very slow, (i.e., over a period of years). When the organic content is below 4-5%, additional supplemental organic or manufactured nitrogen fertilizer may be needed.

> **4-5% Organic Matter** – Soils with 4-5% organic matter from compost will *mineralize* (release to plants) about 0.2 pound of nitrogen per 100 square feet per year. This should be sufficient for plant nitrogen needs.
> **2-3% Organic Matter** – Soils with 2-3% organic matter from compost will *mineralize* about 0.1 pound of nitrogen per 100 square feet per year. Additional nitrogen fertilizer will be needed for high nitrogen crops like broccoli, cauliflower, cabbage, potatoes, and corn.
> **<2% Organic Matter** – In soils with less than 2% organic matter, the release rate for nitrogen will be too low to adequately provide the nitrogen needed for crop growth. A supplemental organic or manufactured nitrogen fertilizer may be needed.

Beware of Unfinished Compost

Finished compost is dark and crumbly, does not resemble the original contents and has an earthy smell. Compost that has not thoroughly processed could be "hot" with high ammonia content. This could burn plant roots (when applied to the soil) or plant leaves (when applied as a mulch). If the compost smells like ammonia, it should be processed longer or be worked into the soil at least one month prior to seeding or transplanting in the area.

Compost maturity can be assessed in a laboratory by measuring the carbon dioxide (CO_2) production by the microorganisms living in the material. Lower levels of CO_2 indicate more mature compost (i.e. microbial activity is low because they have used the available nitrogen to decompose the carbon in the compost). Conversely, if microbes are producing CO_2, they are consuming oxygen (O_2). Unfinished compost can consume all of the O_2 from the root zone and greatly inhibit root growth. Finished compost should smell earthy, like healthy soil, not like ammonia.
When making compost at home, it is advisable to turn the pile when the compost pile temperatures drop below 120ºF and before the compost pile temperatures

exceed 160ºF. To encourage active microorganism processing, moisten the pile so that it feels like a wrung-out sponge. When temperatures do not rise above 120ºF after turning to reheat, compost has entered its curing stage. It should cure for 45 days before being considered finished. This curing period allows nitrogen and other chemical constituents to stabilize into forms suitable for placement around plants.

Weed Seeds and Diseased Plants

It is advisable not to compost diseased plants or weeds loaded with seeds. If the compost pile did not heat adequately or was not turned, the compost could be a source of weed seeds or plant disease pathogens. All parts of the compost should reach 145ºF to kill weed seeds and plant disease pathogens. Because only the inner layers of the pile will reach this temperature, it is important that the outer layers are folded into the inner layers and the pile is allowed to reheat to 145ºF. These temperatures must be maintained for at least 3 days. Temperatures of 130ºF will somewhat minimize weed seeds and pathogens.

Livestock manure (horse, sheep, cow, swine, etc.) can also be a source of weed seeds in compost if the animals were fed hay with weed seeds or if seeds blew into a pile of manure.

Pet Manure

Do not add companion animal (cat, dog, etc.) feces to compost as this increases the incidence of nuisance animals rummaging through the compost pile and disease transmission to humans.

Authors: David Whiting (CSU Extension, retired), with Adrian Card (CSU Extension), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., (USDA-ARS, retired) Reviewed by Dan Goldhamer (CSU Extension)

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #244

Cover Crops and Green Manure Crops

Terms: Green Manure and Cover Crop

A ***cover crop*** is simply high numbers of plants, usually specific annual, biennial, or perennial grasses and/or legumes, growing and covering the soil surface which improves the soil. When the cover crop is tilled into the soil it is referred to as a ***green manure*** crop. These two terms are often used interchangeably.

Why is Cover Cropping Beneficial?

Cover crops can protect the soil from wind and water erosion, suppress weeds, fix atmospheric nitrogen, build soil structure, and reduce insect pests.

Erosion protection – The primary erosive force for Colorado is wind. Winter winds are especially destructive, carrying away small particles of topsoil from the soil surface. A thick stand of a cover crop protects the soil surface from wind erosion and as the cover crop's roots hold soil in place against water erosion during heavy downpours.

Weed suppression – Cover crops left in place for part or all of a growing season can suppress annual and some perennial weeds. Among the grasses, annual rye has alleopathic properties that prevent weed seeds from germinating and suppress weed seedlings around the root zone of the rye.

Nitrogen fixation – Legumes, inoculated with their specific *Rhizobium* bacteria, will take nitrogen out of the air (present in the soil) and store it in their plant tissues via nodules on the roots of the legume. This is a symbiotic relationship, as the bacteria uses the plants sugar in return for the nitrogen. Some of this nitrogen is available as roots die, but the majority becomes available when the legume is tilled under (green manure). Alfalfa is a legume with alleopathic properties towards plants of the same species.

Soil structure creation – Plant roots exude a sticky substance then glues soil particles together, creating structure. Grasses are exceptional in their ability to do this.

Insect rests reduction – Cover crops encourage beneficial insect populations, often minimizing or eliminating the need for other insect control measures.

Why is Green Manuring Beneficial?

Green manuring enhances soil fertility and soil structure by feeding soil organisms and gluing together soil particles into aggregates.

Soil fertility – When fresh plant material decomposes in the soil, its carbon-to-nitrogen ratio becomes low, allowing the nitrogen to be easily released into the soil chemistry by bacteria. Nitrogen accumulation is greater with legumes, which have nitrogen-fixing *Rhizobium* bacteria growing in nodules on the legume roots [Table 1]. Notice the lower figure for rye.

Table 1. Nitrogen Accruement of Selected Cover Crops

Cover Crop	Nitrogen Accruement*
Hairy vetch	3.2 lbs/1000 ft^2
Crimson clover	2.6 lbs/1000 ft^2
Austrian winter pea	3.3 lbs/1000 ft^2
Winter (annual) rye	2.0 lbs/1000 ft^2

* Nitrogen accumulated in growing crop prior to tilling under
Source: ATTRA: Overview of Cover Crops and Green Manures

Table 2 shows values of nitrogen fixation for legumes. Rates vary due to variations in the activity level of rhizobium.

Table 2. Potential Nitrogen Fixation Rates of Selected Legumes for Colorado

Legume Crop	Pounds N per 1000 ft^2
Crimson clover	1.6-3.0
Field peas	2.0-3.4
Hairy vetch	2.0-4.6
Medics	1.1-2.8
Red clover	1.6-3.4
Sweet clover	2.0-3.9
White clover	1.8-4.6

Source: *Managing Cover Crops Profitability*, Sustainable Agriculture Network

Soil structure – Microorganisms decomposing plant material and the plant material itself produce substances that glue soil particles together. These substances include slime, mucus and fungal mycelia, which contain gums, waxes, and resins. These aggregate soil particles, thereby enhancing the tilth, porosity, and water holding capabilities of soil.

Basic Recipes for Cover Crops and Green Manure Crops in a Garden

Spring-Planted

Most gardeners do not have enough space to forfeit to a cover crop for an entire growing season. However, if you do, a spring seeded clover would give your soil a great boost. Some seed companies will "rhizo-coat" seed with the specific *Rhizobium* bacteria or apply *Rhizobium* as specified on the bag. *Rhizobium* comes in a black powder specific to the species of clover. It also has a definite shelf life, so check the expiration date. Broadcast the seed/*Rhizobium* mix at a specified rate after the last frost with a hand held broadcaster (often used with pelleted fertilizer) into a loose seedbed and incorporate shallowly and water until germinated. Monitor water as you would in a lawn.

Till under at least two weeks prior to planting. Decomposing plant material consumes soil oxygen and can create plant health problems if not tilled in ahead of time. More than one tilling may be necessary to get an acceptable kill of the clover.

Fall-Planted for Spring Till

Most will opt for a fall cover crop tilled under as a spring green manure. Seeding dates should be done by mid-October at the latest. Mid-September is ideal on the Colorado Front Range and the western valleys. In mountain elevations, plant in August or earlier. A rye/Austrian winter pea or rye/hairy vetch mixture will overwinter in Colorado. Hairy vetch is hardier than winter pea. Rye is extremely winter hardy. Newer winter cover crops include Daikon radish, tillage radish, and turnips. There are many mixes available as well, usually referred to by the number or species per mix (for example, a 3 way mix). Prepare as above and broadcast at the rates in Table 3.

Table 3. Seeding Rates for Selected Winter Cover Crops

Cover Crop	Ounces per 100 Square Feet	Pounds per 1000 Square Feet
Winter rye	4 – 6	2.5 – 3.75
Austrian Winter pea	4 – 6	2 – 4
Hairy vetch	2 – 3	1 – 2
Radish, Daikon		*8-12 lbs./acre

Source: *Managing Cover Crops Profitability,* Sustainable Agriculture Network

Over-wintered cover crops become a veritable salad-bar to geese and deer. A cover crop that is well established prior to winter temperature extremes should rebound from wildlife grazing in late winter/early spring.

Till the cover crop in mechanically or turn it under with a spade a month before you plan to plant/seed into that area. Decomposing plant material consumes soil oxygen and can create plant health problems if not tilled in ahead of time.

Landscape Uses

Bare soil presents erosion and aesthetic issues for homeowners. During droughty periods, watering restrictions and the lack of natural precipitation may make turf establishment difficult or impossible. A temporary cover crop or long-term xeric grass may be the answer.

In this scenario, the homeowner has to understand that a cover crop will not look or feel like a healthy Kentucky bluegrass lawn, but should satisfy the need to cover the soil.

Annual Species Options

These are cool season grains that should be broadcast at 2-3 pounds per 1000 square feet in February or March and later for higher elevations. Natural precipitation may be sufficient to get them established. They are suited for non-traffic areas, as they will grow to 2 feet tall and brown-out in the heat of summer. The Sterile Triticale will not produce viable seeds so may be a good idea for areas that will eventually be put into turf or garden space. Winter rye seeds can be a weed problem in seeded turf grass and gardens. [Table 4]

Table 4. Annual Species

Name	Bunch or Sod	Cool or Warm Season	Annual or Perennial	Turf?	Reseed?
Winter rye	Bunch	Cool	Annual	No	Yes
Pioneer sterile triticale	Bunch	Cool	Annual	No	No

Perennial Species Options

These are non-native grasses often used on roadsides for stabilization and cover. They are perennial and will be persistent (i.e., – difficult to kill) once they are established. Water requirements for both are 9-10 inches of precipitation per year. Streambank wheatgrass has a slightly higher water requirement but is tolerant of very clayey soils, unlike Crested wheatgrass. Broadcast in February or March at 3-5 pounds per 1000 square feet. [Table 5]

Table 5. Perennial Species

Name	Bunch or Sod	Cool or Warm Season	Annual or Perennial	Turf?	Reseed?
Streambank wheatgrass	Sod	Cool	Perennial	Yes	Some
Crested wheatgrass	Bunch	Cool	Perennial	Yes	Some

Native Species Options

These have the lowest water requirements at 8 inches of precipitation per year and should be considered for areas of a landscape that are being converted to xeric management. This is a long-term management decision as the price of these seeds is more than the other options. These grasses will not feel like Kentucky blue grass and will brown out like other cool season grasses. Seed as per perennial species options specifications. Seed for native species will be available from local seed sources. [Table 6]

Table 6. Native Species

Name	Bunch or Sod	Cool or Warm Season	Annual or Perennial	Turf?	Reseed?
Indian ricegrass	Bunch	Cool	Perennial	No	Some
Squirreltail bottlebrush	Bunch	Cool	Perennial	No	Some

Establishment and Care

Before seeding – Prepare a seedbed for fine grass seed, ideally amending the soil with compost and tilling as deeply as possible. If possible, fence off the area from traffic.

Seeding – Water area prior to seeding if possible to establish ample soil moisture levels.

Broadcast the correct amount of seed per area onto a loosely tilled, fine (no soil pieces bigger than 1/4 inch) seedbed. Shallowly incorporate seed with garden rake (not a leaf rake) to a depth of 1/4 to 3/4 inch deep.

For larger areas consider hydromulching the seed. This will save time and increase germination of seeds.

After seeding – Consider laying a thin layer (<1” deep) of seed-free straw to hold in moisture and increase germination and survival of grass seedlings. Bird netting over the straw fastened to the ground with landscape fabric staples will keep the straw from blowing away.

Check moisture levels in the upper inch of soil at least every other day (soil should feel as moist as a wrung out sponge) and water if necessary (and if possible).

Mowing – If necessary, mow as high as possible or use a weed eater to reduce the height or seed heads.

Removing cover crops – For winter rye, either till under, mow and mulch heavily, or spray herbicide before it goes to seed. A seed bank can be sodded over or watered, germinated and killed. Perennial grasses can be either mowed and mulched heavily prior to sodding, or sprayed with herbicide and sodded, or sprayed with herbicide, tilled and seeded.

Authors: Adrian Card (CSU Extension) with David Whiting (CSU Extension, retired), Carl Wilson (CSU Extension, retired), and Jean Reeder, Ph.D., USDA-ARS (retired), revision by Susan Carter (CSU Extension)

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MASTER GARDENER
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CMG GardenNotes #251

Asking Effective Questions About Soils

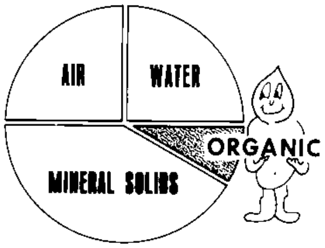
Outline:

Communications

Education, the product of Colorado State University Extension, is about communication. Are there ways we can make our communications with clients more effective? One way is to improve our questioning technique. Another is to focus on soil conditions, which contribute to a large percentage of landscape plant disorders. If we don't know how to ask our clients effective questions about their soils, we will have difficulty diagnosing their plant problems

Many of the questions asked should be about physical soil properties, not chemical ones. Poor physical soil conditions for plant growth make up the bulk of soil concerns. Soil tests tell us about texture but little else relating to soil physical conditions. A routine soil test is often a poor tool for figuring out a plant growth problem. Compaction, poor drainage and low oxygen levels are the most frequent causes of poor root growth, but not assessed by a soil test.

Soil physical properties include texture (mineral solids), soil structure, and pore space of a soil.



Ask Open Ended Questions

Ask questions that require long answers. While occasional yes-no answers may help, be sure to stay on track with questions requiring more detailed answers. Do this by using the **what, how, when, where** and perhaps **why** leads:

- Tell me about your soil.
- Describe your soil for me.
- Is the soil part of your landscape or one that you brought in?
- What is your soil like to water?

- How do you care for your soil?
- When did you amend your soil?
- How often do you till your soil?
- What do you add to the soil?
- What worms or other living things do you see in the soil?

Be careful with "why" questions. They can sound accusatory and get in the way of gathering information.

"Piggy Back" Questions

Remember to "piggy back" your new questions on top of the answers already obtained. Example – "O.K., let's talk about your soil in a little more detail. Is it a clayey or a sandy soil?" Avoid negative presuppositions. For example, ask "Have you amended your soil? What amendment did you use?" Do not accusingly ask, "You didn't amend your soil with fresh manure did you?" Other questions to consider are:

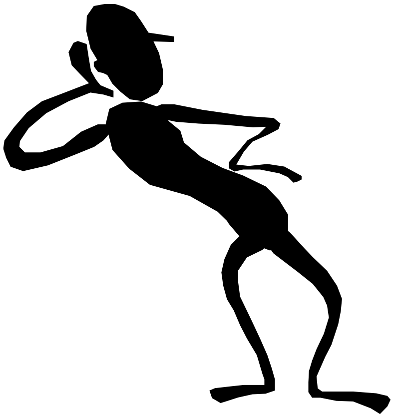
- Have you dug down into the soil?
- What is it like?
- Was it easy to dig?
- How deep did you dig down?

The following questions aim at assessing compaction and what may have been done to prevent it.

- Have you tried inserting a screwdriver into the soil?
- Did it go in easily or was it hard to insert?
- Do people frequently walk over that soil?
- Does any equipment or vehicles run over the soil?
- Does water enter easily or run off the soil?
- Is the soil mulched?
- What mulch was used?

Active Listening

Use "active listening" techniques or paraphrasing to restate what you have learned. By stating what is understood, both you and the client confirm a reference point to proceed in the conversation. An example is "So, you're saying that your soil is a clay that is not mulched and not frequently walked on?"



This may lead to a clarifying statement such as "That is not what I'm saying. What I mean is …" This is O.K. because it can clarify important points in the communication.

Neutral Comments

Another way to keep the exchange moving is to use neutral comments. These comments acknowledge listening and prompt further information. Tone is important in using neutral comments. Sound interested but don't insert judgmental overtones into the comments. Examples of neutral comments are:

- You noticed a white substance in the soil.
- You found no earthworms.
- You used deicing salts on the walk

Wait Time

Use "wait time." Don't be afraid of "dead air" in a conversation. It's common to want to keep the conversation going by keeping the air filled with talk. Ask the client a question then pause for the answer. They may take some time to get their thoughts together, remember what happened or consider how to get their words out before they respond. Don't be tempted to fill in a question before they have a chance to answer the last one.

- Does your soil crumble easily when you press on the clods? . . . PAUSE
- How much compost did you add to the soil when you planted? . . . PAUSE

Listen For

"Listening for" information is an important skill to develop. When listening for information, you pick up clues to pursue with further questions. This approach has a higher probability of leading to solving a problem. It is very different than a "listen from" point of view that tries to fit information into a preconceived scenario. "Listen for" often pursues false leads, eliminates them and then pursues other trails. This kind of detective work can be fun, and only practice will enable you to develop this skill.

Author: Carl Wilson, Colorado State University Extension, (retired) Revised by Mary Small, CSU Extension

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MASTER GARDENER
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Irrigation Management

Learning Objectives

At the end of this unit, the student will be able to:

- Describe issues around Colorado's (western) water situation.
- Describe design criteria for efficient landscape irrigation.
- Describe maintenance criteria for efficient landscape irrigation.
- Describe management criteria for efficient landscape irrigation.
- Perform a lawn irrigation check-up.
- Set a controller for efficient landscape irrigation.

Reference /Additional Reading

CMG GardenNotes

#260	Irrigation Management: References and Review Questions
#261	Colorado's Water Situation
#262	Water Movement Through the Landscape
#263	Understanding Irrigation Management Factors
#264	Irrigation Equipment
#265	Methods to Schedule Home Lawn Irrigation
#266	Converting Inches to Minutes
#267	Watering Efficiently
#268	Worksheet: Home Lawn Irrigation Check-Up

CSU Extension Fact Sheets and *PlantTalk Colorado*

- Automatic Sprinkler System Overview – Planttalk #2201
- Drip Irrigation for Home Gardens – Fact Sheet #4.702
- Efficient Irrigation – Planttalk #1903
- Graywater Reuse and Rainwater Harvesting – Fact Sheet #6.702
- Irrigation: Inspecting and Correcting Turf Irrigation Systems – Fact Sheet #4.722
- Water Conservation In and Around the Home – Fact Sheet #9.952
- Watering Colorado Soils – Planttalk #1621
- Watering Established Lawns – Fact Sheet #7.199

Websites

- Colorado Springs Utility: http://et.csu.org/
- Denver Water: www.denverwater.org
- Northern Colorado Water Conservancy District: www.ncwcd.org

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Curriculum developed by David Whiting (CSU Extension, retired), Carl Wilson, (CSU Extension, retired), and Catherine Moravec (Colorado Springs Utilities.
Revision: Kurt M. Jones, Chaffee County Extension Director (9/2017).

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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Review Questions

Colorado's Water Situation

1. Describe the western water rights doctrine of "prior appropriation" or "first-in-time, first-in-right." How does it differ from the "riparian" water rights system used in eastern states?

2. What percent of Colorado's water supply is used for landscape irrigation?

3. During the summer irrigation season, what percent of a community's water supply is typically used for landscape irrigation?

4. On a community-wide basis, what percent of the water used for landscape irrigation is wasted due to poor design, maintenance, and management of the irrigation systems?

5. Explain how landscape irrigation affects a community's water infrastructure? What is the primary purpose behind community water schedules, such as every third day or every other day?

6. What is the typical multi-year drought cycle in Colorado's climate?

7. How does population growth play into Colorado's water situation?

Water Movement Through the Landscape

8. List how water enters the landscape. Explain how water is stored in the landscape. List how water leaves the landscape.

9. What is ET? What factors influence ET rates?

Understanding Irrigation Management

10. Describe how these factors influence irrigation management:

    a. Location of soil moisture
    b. Type of soil
    c. Water holding capacity
    d. ET
    e. Rooting depth

11. How does improving a sandy soil with organic matter influence irrigation management? How does improving a clayey soil with organic matter influence irrigation management?

12. Define *water holding capacity*, *saturation*, *field capacity*, *permanent wilting point*, and *available water*.

13. Compare the historical ET for a lawn in spring, summer, and fall.

14. Based on a soil's typical water-holding capacity, describe the amount of water to apply and frequency of irrigation for sandy, sandy loam and loamy/clayey soils with a six-inch, 12-inch and 24-inch rooting depth in the spring, summer and fall.

15. Describe the textbook amount of water to apply if a lawn required water every two, three, four, or five days in the typical summer.

16. Describe how these factors influence irrigation management:

    a. Exposure
    b. Previous irrigation pattern
    c. Stage of growth

17. Give examples of mechanisms that plants use to tolerant/escape drought.

Irrigation Equipment

18. Explain basic components of an in-ground sprinkler system, including the following:

    - Point of connection
    - Pressure regulator
    - Backflow prevention device
    - Supply line
    - Valve box
    - Valves
    - Secondary lines
    - Controller

- Winter drainage

19. Describe the advantages and limitations of pop-up spray heads and rotor heads.
20. Describe the strengths and weaknesses of an in-ground sprinkler system.

21. Describe basic components of a drip system, including the following:

    - In-line filter
    - Pressure regulator
    - Half-inch tubing
    - Quarter-inch microtubing
    - Drip emitters
    - In-line drip tubing
    - Micro-sprayers

22. Describe a drip system made with soaker hose or soaker tubing.

23. Describe the strengths and weaknesses of drip irrigation.

24. Describe the strengths and weaknesses of hose-end, hand watering

Methods to Schedule Irrigation

25. Describe irrigation scheduling by the Type of Sprinkler Method.

26. Describe irrigation by the Precipitation Rate Method. Explain how to do a Precipitation Rate (Catch Can) Test.

27. What is the purpose of cycle and soak? Explain how to add cycle and soak to an irrigation scheduling method.

28. What is an ET controller? What is a soil moisture sensor?

29. Explain how to fine-tune an irrigation schedule.

Watering Efficiently

30. Of the seven principles of water wise gardening, why does watering efficiently have the greatest potential for water conservation in the typical home landscape?

31. With attention to irrigation design, maintenance, and management, what is the potential water savings for a typical home landscape?

32. List factors to consider with irrigation zones.

33. Describe design criteria for uniform water distribution.

34. Describe maintenance techniques for water wise irrigation management.

35. Describe management techniques for water wise irrigation management.

Irrigation Check-Up

36. What is the purpose of an irrigation check-up?

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CMG GardenNotes #261

Colorado's Water Situation

Western Water Rights – *Doctrine of Prior Appropriations*

In Colorado and other western states, water rights are based on the ***Doctrine of Prior Appropriation*** or "first-in- time, first-in-right". Rights are established when water is put to beneficial use.

A water right is a property right to use a specified quantity of the state's water for a specified purpose. As a property right, water rights can be sold, leased, or rented (like other personal properties such as a home, apartment, or car). With the *prior appropriation doctrine* used in western states, a property owner does not own the water that rains, snows, or flows across or is adjacent to his/her property.

By contrast, eastern states follow some form of "riparian" water right (i.e., water rights belong to landowners bordering the water source). Without an understanding of the *doctrine of prior appropriation*, newcomers and residents may fail to realize that the purchase of land does not necessarily include the rights to irrigation water.

Under the *prior appropriation doctrine*, water rights are established by putting the water into ***beneficial use***. The person or organization putting the water to beneficial use requests the ***water courts*** to legally recognize the right with a ***decree***.

In the establishment of water rights, the water judge decrees the location at which the water will be withdrawn, the amount to be withdrawn, the use of the water, and assigns a ***priority date***. Claims with earlier priority dates have ***senior rights***; claims with more recent priority dates have ***junior rights***.

During times of reduced rainfall or drought, *senior rights* (water rights established in early years) take precedence over *junior rights* (water rights established in recent years). Water use will be cut off for junior rights, protecting senior rights.

When a water use is changed, the water courts reissue the decree amending the owner, location, amount, or use. The priority date will be based on the previous priority date. Since Colorado's water supply fluctuates continually and the typical available water in a river basin is already owned with established water rights, issues of senior and junior rights become very complex in drought scenarios.

Colorado's water future – *"As Colorado's water consumption reaches the limits of its allotment under interstate compacts and treaties, intensive water management will become even more critical. Water management decisions will involve examinations of all options. Conversation will become indispensable…. Inevitably, as each generation must learn, the land and the waters will instruct us in the ways of community."* (Citizen's Guide to Colorado Water Law)

Administration

In Colorado, the Office of the State Engineer, Colorado Division of Water Resources, administers water rights. It monitors the amount of water being taken from surface and underground sources, and oversees distribution based on the priority of water rights.

Interstate water rights are set in federal agreements based on stream flows for the Platt, Colorado, and Arkansas River basins.

Water Quality Terminology

Regulated by the EPA, ***drinking water*** or ***potable water*** is water of sufficiently high quality for safe human consumption. The drinking water in many Colorado communities is of higher quality than most bottled water. Over large parts of the world, humans have inadequate access to potable water, and use sources contaminated with unsafe levels of dissolved chemicals, suspended soils, disease vectors, and pathogens.

Nonpotable water refers to water not processed to drinking-water standards. ***Raw water*** refers to untreated water taken directly from rivers and lakes.

Wastewater is any water that has been adversely affected in quality by human activities. This includes domestic, municipal, or industrial liquid waste products disposed of by flushing them with water through a pipe system. ***Sewage*** technically refers to wastewater contaminated with feces and urine. However, in popular usage, sewage refers to wastewater. ***Gray water*** refers to water from the bath/shower and washing machine. ***Black water*** refers to water with feces and urine (from the toilet).

Reclaimed water or ***recycled water*** is former wastewater (sewage) that has been treated to removed solids and certain impurities. In most situations, it is returned to the river system, being the non-consumptive use portion of water rights. That is, the reclaimed water returned to stream flow becomes someone's water right downstream. In Colorado, some parks, golf courses, and industrial properties are irrigated with reclaimed water. Reclaimed water may be high in salt, limiting its use for landscape irrigation.

Sources of Landscape Irrigation Water

In many communities, most landscape irrigation is done with potable, drinking water purchased from the city or community water provider (who owns the water right or purchases the water wholesale). The source of water may be stream flow (from snowmelt with storage in the reservoir system) or wells. During the summer irrigation season, this puts a high demand on the water treatment facilities. To deal with this, many communities aggressively market landscape water conservation.

In the west, many larger landscape sites (golf courses, parks, and industrial sites) are irrigated with nonpotable water or raw water. In some western communities, homes have a waterline for drinking water and a second, nonpotable waterline for irrigation. This creates significant savings in water treatment costs.

Wells

For rural homes, a common water source is groundwater (wells). The Colorado Division of Water Resources also regulates the drilling and use of groundwater. In the past, the lack of strict regulations caused a significant drop in the water table in some communities, creating problems for well users. Today the use of wells is regulated, limiting the amount of water that can be withdrawn. In recent years, new domestic well permits have been very restrictive, prohibiting outdoor irrigation. Folks moving to their rural ranchette are often shocked when they learn that they may not irrigate the landscape with their well water.

On the high plains of eastern Douglas and El Paso Counties, the community water source is non-renewable groundwater (wells). This water supply is not refilled with annual rain and snowmelt. Conservation is extremely critical.

Rain Water and Gray Water

Landscape design can be creative in reducing the surface runoff of rain and snowmelt (reducing pollution of surface water). However, in Colorado state law prohibits the intentional interception and diversion of rain and snowmelt (that is, the collection of the water in a retention system for later use), including rain barrels. This is an issue of water rights, as the water already belongs to someone downstream. Collection of rain and snowmelt could interfere with another’s water right.

A new exception which went into effect August 1, 2016 allows rain barrels to be installed at single-family households and multi-family households with four (4) or fewer units. A maximum of two (2) rain barrels can be used at each household and the combined storage of the 2 rain barrels cannot exceed 110 gallons. Rain barrels can only be used to capture rainwater from rooftop downspouts and the captured rainwater must be used on the same property from which the rainwater was captured, for only outdoor purposes, including to water outdoor lawns, plants and/or gardens. Rain barrel water cannot be used for drinking or other indoor water uses.

Colorado House Bill 13-1044, which was passed and signed during the 2013 legislative session, provides municipalities, counties, and groundwater management districts the authority to authorize graywater use and enforce ordinances. Under HB-13- 1044, graywater can be used to flush toilets and irrigate landscapes at residential, multi-residential and commercial locations. As of the 2017 revision of this publication, only the City and County of Denver has permitted graywater uses for irrigation, and only for sub-surface or drip irrigation of non-food crops.

For additional information on using gray water and harvesting rainwater in Colorado, refer to CSU Extension fact sheet #6.702, *Graywater Reuse and Rainwater Harvesting*, and the *Rainwater Harvesting in* Colorado fact sheet number 6.707, available on the CSU web site at http://extension.colostate.edu

Colorado's Water Use

Eighty percent of Colorado's water supply falls on the Western Slope. With the high population along the Front Range and major agriculture in northeastern Colorado, 80% of the water use (that is 80% of the water rights) is along the Front Range and High Plains. Table 1 gives the breakdown of water use in a typical year.

Table 1. Where does Colorado's water go?

Agriculture	86%
Domestic/municipal	7%
Recreation and fisheries	3%
Industrial and commercial	2%
Augmentation	1%
Recharge	1%

Source: Colorado State Engineer's Office, 2004

Production agriculture is the primary user of Colorado's water supply, using 85 to 90% for food production. To grow the typical American meal it takes 500 to 2,000 gallons of water. On an annual basis, it takes 1.6 million gallons of water to grow the food for the typical American diet of 2,000 calories per day. (Source: Michigan State University Institute of Water Research)

Although the individual farmer can be rather inefficient in use, the runoff water returning to the system is used repeatedly by other farmers down the line, resulting in a 90% system-wide efficiency.

Landscape irrigation – Depending on the year, approximately 7 to 10% of Colorado's water supply is used for landscape irrigation, including home lawns and yards, public and commercial landscapes, parks, and golf courses. During the summer irrigation season, 50 to 75% of a community's water use may be for landscape irrigation. Because it is highly visible, landscape irrigation is often targeted for conservation.

Based on community water use, the average landscape receives twice the amount of irrigation water that plants actually need. This is due to poor irrigation system design, maintenance, and management. In research of actual yard-by-yard comparisons, most gardeners are rather efficient; however, others may be applying 5 to 10 times the amount of water actually needed!

With the rapid growth in Colorado's population, some farmers have sold, leased, or rented water rights to communities. This creates a significant shift in water use during periods of drought and creates long-term dynamics between agriculture and urbanization.

Other demands on water flows come with power generation, recreational use, and wildlife habitats. As an important side issue, during periods of drought (decreased stream flow), hydroelectric power generation will also decrease.

A standard unit for measuring large quantities of water is the ***acre-foot***. An acre-foot is the amount of water needed to cover an acre of land to a depth of one foot, or 325,851 gallons. The standard unit of measuring water flow is cubic feet per second, or cfs. One cfs equals 7.48 gallons per second or 448.83 gallons per minute.

Community Water Infrastructure

A community typically invests $30,000 to $60,000 per new household for the water and sewer treatment infrastructure. Due to landscape irrigation, Colorado communities typically experience 10 to 15 days per year when water use greatly exceeds average use. Because peak demand actually occurs only a few days a year, developing the water processing and delivery infrastructure to adequately meet water needs during these few peak days is very expensive. One Colorado community, for example, is facing a $35 million expansion to its water-processing infrastructure to meet peak demand for just five days a year!

The high cost of meeting peak water demand is why communities often adopt irrigation schedules based on address (like odd/even days or other set irrigation day programs). Schedules are designed to spread the water demand more evenly over the week. Just imagine the water infrastructure that would be required if most residents decided to water the lawn on a Saturday morning during a hot week!

Odd/even or set watering day water restrictions do not effectively reduce total water usage. An underlying fear with gardeners is that they cannot hold off irrigation until their next turn, so the lawn is watered just because it is their turn. Irrigation restrictions that allow for no irrigation on some days of the week more effectively conserve water.

Population Growth and Water Conservation

Colorado's rapid population growth creates growing pains for Colorado's water supply. Due to planning by forefathers, some communities have good water resources, including senior rights. Other communities seriously lack sufficient water rights to support growth. Residents who do not understand western water rights may have strong values and opinions about where water should and should not be used during shortages. Under western water rights, market price to purchase water rights will determine who has water. What are you willing to pay?

Water conservation, both indoors and outdoors, is essential for communities to meet the water demands for growth. Some communities with limited water resources have put restrictions on new building permits. This could be viewed as a form of discrimination aimed at keeping newcomers out of the "white" community.

Other communities, with limited water resources, have allowed for growth by purchasing “surplus” water from water rights holders (such as other communities or farmers). Some of the extreme water restrictions during the drought of 2002 are examples of what happens in years when “surplus” water is not available for purchase.

With growth, water conservation is also critical even for those communities with senior water rights. For example, Denver Water and Colorado Springs Utilities, two of the state’s larger water providers, are running out of water resources to support continued growth at current usage rates. Conservation is essential.

Water for growth must come from water conservation. This will be through voluntary conservation and aggressive pricing structures to push conservation. Since Colorado’s climate typically has a multi-year drought about every 20 years, water conservation is important to all residents.

CMG GardenNotes on Irrigation Management

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Revision: Kurt M. Jones, Chaffee County Extension Director (9/2017).

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CMG GardenNotes #262

Water Movement through the Landscape

Outline:

Soil-Plant-Water System

Water constantly moves in and out of landscapes. Scientists use the concept of the soil–plant–water system to explain the complex ways water moves in landscapes. The ***soil–plant–water system*** describes water entries, storage and exits in a landscape from the plant's perspective. Understanding how water moves through a landscape is important when designing or using an irrigation system.

Most plants constantly use water, but store little in their tissues. Therefore, plants rely on the soil water reserves being periodically replenished through entries of water into the soil–plant–water system.

Water Entries

Water enters the landscape in several ways. First, water enters through **precipitation**, such as rain or snow. Second, gardeners may add water through **irrigation**. Third, water may run over the surface of the landscape from a neighboring area (**run-on**). Fourth, water may enter as **seepage** from groundwater.

In different landscapes, some entry methods are more important than others. For example, in a wet climate most water enters through precipitation. Alternatively, in dry climates like many areas of Colorado and the West, most water enters via irrigation. If a landscape is located below a heavily irrigated property or below a melting snowfield, run-on or seepage may be the most important entry. Taking water entries into account helps gardeners determine how much water must be added through irrigation to keep plants healthy.

Water Storage

In most landscapes, soil is the major water storage site for plants. Once water has entered the landscape through precipitation, irrigation, run-on, or seepage, water penetrates the soil surface through **infiltration**.

Water infiltrates into sandy soils much more quickly than into clayey soils. For example, a sandy soil may take in 4 inches per hour, but a clayey soil may take in only 0.5 inches of water per hour—8 times more slowly. To prevent water waste via runoff, gardeners should take the soil's infiltration rate into account when scheduling landscape irrigation.

Once water infiltrates the soil surface, it **percolates** downward and sideways through the soil profile. Water moves rapidly through large soil pores, and slowly through small pores. Therefore, sandy soils with primarily large pores will accept and release water readily, holding little. On the other hand, clayey soils with primarily small pores will wet and dry slowly.

After water percolates through the soil profile, some of the water will be stored in small pores, and a water films surrounding soil particles. Plants can use some of the stored water (called plant**-available water)** by extracting it with their roots. However, some of the water is held so tightly by small pores or particle surfaces that plant roots cannot extract it. This water is **unavailable** to plants.

When plants need more water than is available in the soil, they experience **water stress**. Because water is a component of photosynthates, photosynthesis stops and growth stops. Furthermore, water stress compromises plant defense systems, making them more susceptible to abiotic stress factors as well as insect and disease problems.

Some soils store more water than others. The amount of water held in the soil and available to plant depends on the following factors:

- Clay content (the amount of small pore space) to hold water.
- Soil organic content – Organic matter holds ten times more water than sand.
- Rooting depth – Plants with deeper roots reach a larger water supply.

Water Exits

Water eventually leaves the landscape. Water may exit by running over the land surface (**runoff**). It may leave the system through **off-target application**, such as sprinklers that apply water to the sidewalk rather than the soil. Sometimes, water percolates below the plant's root zone (**leaching**).

Water **evaporates** from the soil surface, causing soils to dry from the top downwards. Mulches help ameliorate water loss by reducing evaporation from the soil surface. Mulches also improve plant growth by helping to maintain moisture in the top layer of soil, thereby stabilizing soil moisture around roots.

Some water is taken up by plant roots, transported through plant tissues and used in photosynthesis for plant growth. Most of the water taken up by plants is **transpired** out leaf surfaces. Because evaporation and transpiration are often the two most important water exits in landscapes, scientists combine these two pathways into one term called *evapotranspiration*.

Evapotranspiration (abbreviated as **ET**) is a measurement of water use combining water used by plants for transpiration, photosynthesis, and growth, plus water lost from the soil surface evaporation. It is most often defined as a rate of water loss, such as 1/4 inch per day. In this example, an ET of 1/4 inch per day means that a 1/4 inch depth of water was lost from the soil–plant–water system through evaporation and transpiration.

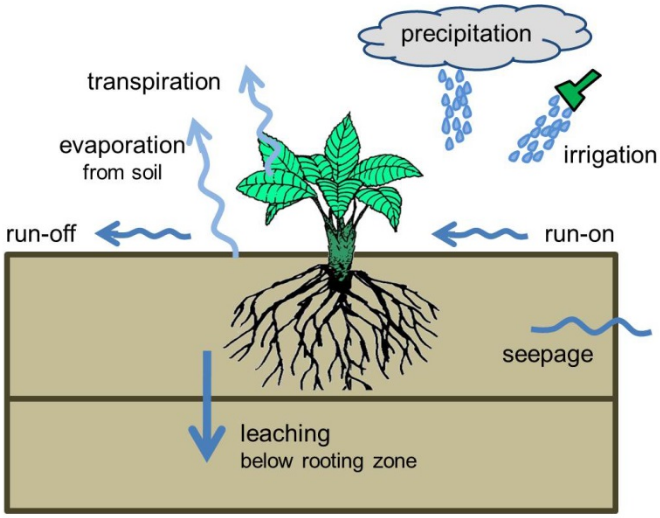
ET measurements help gardeners make informed decisions about how much irrigation water to add. In some Colorado communities, ET rates are available on-line through weather stations or water utilities.

ET rates change daily through the growing season. High ET rates occur when there is 1) bright sunshine, 2) high wind, 3) high temperature, and/or 4) low humidity.

Summary

Water entries and exits are summarized in Figure 1. In order to maximize plant health in dry climates of Colorado and the West, gardeners can take two approaches. First, they can apply soil management practices to increase soil water storage. This helps ensure adequate water supplies for plants when needed. Second, gardeners can use effective irrigation management practices to ensure that irrigation water is made available to plants and not wasted.

Figure 1: Typical water entries and exits in the soil – plant – water system.



Authors: Catherine Moravec, Colorado Springs Utilities and David Whiting, Colorado State University Extension (retired). Artwork by David Whiting; used by permission.
Revision: Kurt M. Jones, Chaffee County Extension Director (9/2017).

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CMG GardenNotes #263

Understanding Irrigation Management Factors

Outline:

Poor watering practices lead to many common landscape problems, including iron chlorosis, low plant vigor, foliar diseases, root rots, and water pollution. On a community-wide basis, landscape irrigation typically uses twice the amount of water that the plants actually need.

Several complex factors work together in irrigation management, including the following:

- The soil's ***water-holding capacity*** (the quantity of water held by the soil)
- ***Evapotranspiration, ET,*** (a measurement of actual water use by the plant and lost from the soil by evaporation). ET is a factor of weather (temperature, wind, humidity, and solar radiation) and plant growth.
- Rooting depth.
- The plant's ability to extract water from the soil.
- The plant's water need.

Location of Soil Moisture

Following dry winters or summer droughts, soils may be dry in the top layers with moisture only in deeper layers. Following extended drought, it is possible that soils may be dry in deep layers and wet only in the top few inches following a light rain or irrigation.

Dry soils tend to resist wetting. Alternating irrigation applications with shutoffs to allow water to soak in (cycle and soak irrigation) may be necessary to wet a dry soil profile.

Irrigation management is basically applying the correct amount of water at the correct frequency to supply water needs of the plants. Additional water would be wasted as it would leach below the rooting zone.

Type of Soil

Soil texture, structure and organic matter content determine the water-holding capacity and water movement of a soil. Water coats the soil particles and organic matter, and is held in small pore space by cohesion (chemical forces by which water molecules stick together). Air fills the large pore space.

In large pore space, water readily moves downward by ***gravitational pull***. In small spore space, water moves slowly in all directions by ***capillary action***. Figure 1 illustrated water movement in a sandy soil with large pore space and clayey soil with small pore space. [Figure 1]

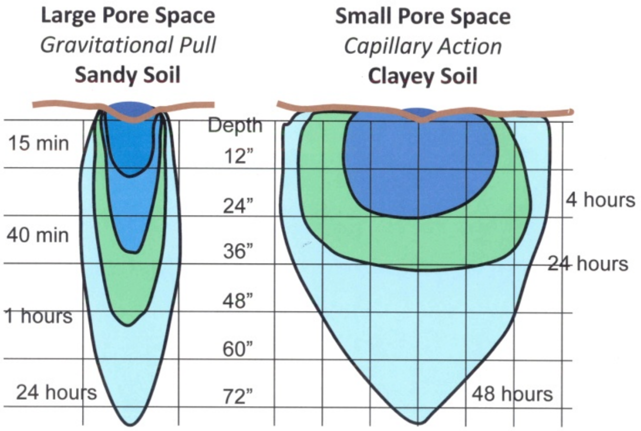


Figure 1. Comparative movement of water in sandy and clayey soils

Sandy Soil – Large pore space dominate sandy soil, giving it rapid drainage. Thus, surface runoff of irrigation water is generally not a concern with sandy soil. Water movement is primarily in a downward direction by gravitational pull in the large pore space with limited sideward and upward movement by capillary action in the small pore space. Thus, in drip irrigation the emitters must be placed closer together than in clayey soils.

Sandy soils have a low water-holding capacity due to the lack of small pore space. Organic matter, which holds ten times more water than sand, significantly improves the water-holding capacity of sandy soils.

As a point of clarification, plants on sandy soils do not use more water than plants on clayey soils. **With the limited water holding capacity, sandy soils simply need lighter and more frequent irrigations than clayey soils.** Water readily moves below the rooting zone when too much is applied at a time.

Clayey Soil – Small pore space dominates clayey soil, giving it high water-holding capacity. However, the lack of large pore space greatly limits water movement. Water is slow to infiltrate into clayey soil, often leading to surface run-off problems. Cycle and soak irrigation is appropriate on clayey soils to slow application rates and reduce surface runoff.

In clayey soils, soil *structure* (creating secondary large pore space) also directly influences water movement and soil oxygen levels. Compaction (a reduction in pore space) further limits water movement and reduces soil oxygen levels, resulting in a shallow rooting depth. The total water supply available to plants is reduced by the shallower rooting.

With higher water-holding capacity but limited drainage, clayey soils need heavier, but less frequent irrigations than sandy soils. Watering too often can aggravate low soil oxygen levels. Because water moves slowly in all directions by capillary action, drip emitters may be placed further apart than in sandy soils.

For additional discussion on texture, structure and pore space, refer to CMG GardenNotes #213, *Managing Soil Tilth*.

Water-Holding Capacity

The terms, *saturation*, *field capacity*, *wilting point*, and *available water* describe the amount of water held in a soil. [Figure 2]

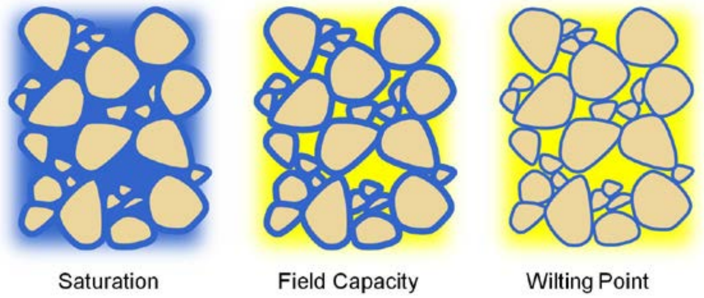


Figure 2. At ***saturation*** water fills the pore spaces. **At *field capacity*** air occupies the large pore spaces while water fills the small pore spaces. At the ***wilting point***, plants cannot extract additional water from the soil.

Saturation refers to the situation when water fills both the large and small pore spaces. With water replacing air in the large pore spaces, root functions temporarily stop (since roots require oxygen for water and nutrient uptake).

Prolonged periods without root oxygen will cause most plants to wilt (due to a lack of water uptake), to show general symptoms of stress, to decline (due to a lack of root function) and to die (due to root dieback). During summer flooding of the Mississippi River in Iowa and Illinois it was observed that healthy trees were somewhat tolerant of a short-term flooding period, whereas trees under stress or in a state of decline were very intolerant.

Field capacity refers to the situation when excess water has drained out by gravitational pull. Air occupies the large pore space. Water coats the soil particles and organic matter and fills the small pore space. A handful of soil at or above field capacity will glisten in the sunlight. In clayey and/or compacted soils, the lack of large pore space slows or prohibits water movement down through the soil profile, keeping soils above field capacity for a longer period of time and limiting plant growth.

Permanent wilting point refers to the situation when a plant wilts beyond recovery due to a lack of water in the soil. At this point the soil feels dry to the touch. However, it still holds about half of its water; the plant just does not have the ability to extract it. Plants vary in their ability to extract water from the soil.

Available water is the amount of the water held in a soil between *field capacity* and the *permanent wilting point*. This represents the quantity of water "available" or usable by the plant. Note from the illustration below that the amount of *available water* is low in a sandy soil. Loamy soils have the largest amount of *available water*. In clayey soils, the amount of *available water* decreases slightly as capillary action holds the water so tightly that plants cannot extract it. [Figure 3]

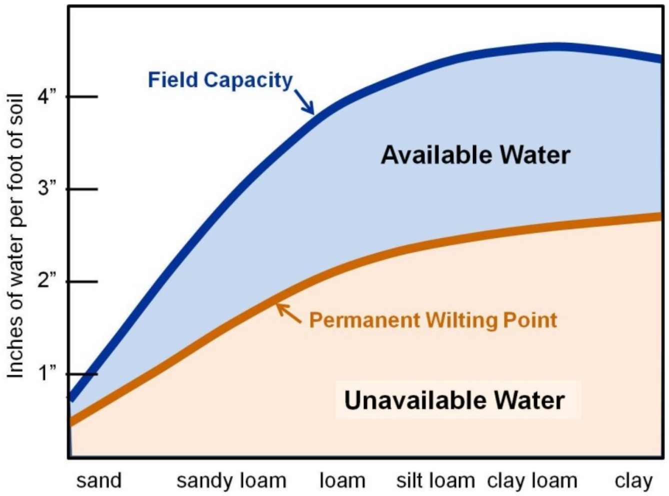


Figure 3. Relationship between soil texture and available water

Evapotranspiration, ET

Evapotranspiration, ET, is the rate at which a crop uses water for transpiration and growth plus evaporation from the soil surface. Primary influences on ET include weather factors (temperature, wind, humidity, and solar radiation) and the stage of plant growth.

On hot, dry, windy days, ET will be higher. On cool, humid days, ET will be lower. In the summer, ET changes significantly from day to day. To illustrate seasonal variations, the typical irrigation requirement for cool season turf in Colorado is given in Table 1. [Table 1]

Table 1.
Weekly Water Requirement for Cool Season Lawns in Colorado

Inches of water (irrigation and rain) per week

Late April	May	June	July	August	September	Early October
0.75"	1.0"	1.0"	1.5"	1.5"	1.0"	0.75"

Rooting Depth

Irrigation management should be taken into account the rooting depth, adding water to the actual root area. Root systems may be contained or spreading. Annual plants tend to have contained root systems, whereas woody trees and shrubs have more wide-reaching roots.

A newly planted annual flower or shallow-rooted plant cannot obtain water from deeper soil depths. Deep watering of these plants is wasteful.

<u>Roots only grow where there are adequate levels of soil oxygen</u>. In clayey or compacted soils, where a lack of large pore space restricts oxygen levels, roots will be shallow. Plants with a shallow rooting depth simply have a smaller profile of soil water to use. [Figure 4]

A plant with deeper roots will need less frequent but heavier irrigation than the same plant with shallow roots. This, however, should not be interpreted as necessarily using less water. For example, turf-type fall fescue may root more deeply than Kentucky bluegrass (if soil oxygen levels allow). With deeper rooting, it requires less frequent irrigations, but irrigations must be heavier to recharge the rooting zone. Actual water-use rates of Kentucky bluegrass and tall fescue are similar.

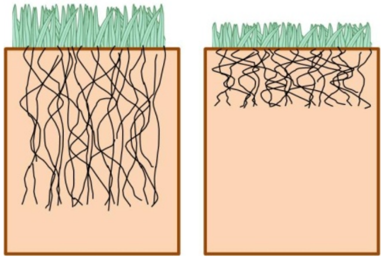


Figure 4. Plants with a deeper rooting systems reach a larger supply of water and can go longer between irrigations. With deeper rooting, irrigations will be less frequent but heavier to recharge the larger rooting zone. In compacted or clayey soils, low levels of soil oxygen limit rooting depth, thus reducing the supply of available water.

Irrigation: How Much? How Often?

Table 2 illustrates the relationship of the soil water-holding capacity, ET and rooting depth.

These textbook figures make a good starting point for understanding irrigation management. Most automatic sprinkler systems are set to keep the lawn green in the summer. (i.e., set for the higher summer water need). Without seasonal adjustments on the irrigation controller the lawn will be over-irrigated in the spring and fall by about 40%. This springtime over-irrigation is a primary contributing factor to iron chlorosis.

Table 2. Irrigation Summary of a Textbook Soil

	Soil Type		
	Sandy	**Sandy Loam**	**Loamy & Clayey**
Available water per foot of soil	0.5”	0.75”	1”
<u>6-inch rooting depths</u>			
Inches of available water and **Inches of water to apply per irrigation** (Additional amounts would leach below the rooting zone.)	**0.25”**	**0.38”**	**0.5”**
Typical days between lawn irrigation			
Spring/Fall (at 1.0 inches/week)	1.8 days	2.7 days	3.6 days
Summer (at 1.5 inches/week)	1.2 days	1.8 days	2.4 days
<u>12-inch rooting depth</u>			
Inches of available water, and **Inches of water to apply per irrigation** (Additional amounts would leach below the rooting zone.)	**0.5”**	**0.75”**	**1”**
Typical days between lawn irrigation			
Spring/Fall (at 1.0 inches/week)	3.6 days	5.3 days	7.1 days
Summer (at 1.5 inches/week)	2.4 days	3.6 days	4.8 days
<u>24-inch rooting depth</u>			
Inches available water and **Inches of water to apply per irrigation** (Additional amounts would leach below the rooting zone.)	**1”**	**1.5”**	**2”**
Typical days between lawn irrigation			
Spring/Fall (at 1.0 inches/week)	7.1 days	10.7 days	14.2 days
Summer (at 1. 5 inches/week)	4.8 days	7.1days	9.5days

Fine-Tuning for the Site

The textbook figures are a good starting point to understand irrigation management. When coupled with careful observations, a gardener can quickly fine-tune his/her irrigation schedule to the site-specific irrigation demands.

On a typical July day, if the lawn is using an average of 0.20 inch per day, you can estimate the water-holding capacity and rooting depth by observing irrigation needs. For example:

- **<u>If the lawn will go five days on one-inch of water</u>**, and additional water won’t extend the interval between required irrigations, the water-holding capacity (for this soil and rooting depth) is 1 inch. <u>One inch would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone.</u> The ideal irrigation would be 1 inch of water every 5 days.

- **<u>If the lawn will go four days on 0.80 inch of water</u>**, and additional water won't extend the interval between required irrigations, the water-holding capacity (for this soil and rooting depth) is 0.80 inch. <u>This would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone.</u> The ideal irrigation would be 0.8 inches of water every 4 days.

- **<u>If the lawn will go two days on 0.40 inch of water</u>**, and additional water won't extend the interval between required irrigations, the water-holding capacity (for this soil and rooting depth) is 0.40 inch. <u>This would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone</u>. Irrigation options include the following: The ideal irrigation would be 0.4 inches of water every 2 days.

These textbooks figures don't take into account exposure, wind or irrigation system efficiency. They make a good start point, **but will need adjustments to fine-tune it to the specific site.** For example:

- In full shade (not under large trees), water use could be 30% lower.
- In unusually hot weather or in open, windy sites, water use could be 20% to over 50% higher.
- In the rooting area of large trees, water use could be 30% to 50% higher (as the tree is pulling water as well as the plants in the shade under the tree).

For examples, in the author's landscape, the front lawn (open site with constant summer wind) uses 20% more water than the normal ET. While the back lawn (sheltered from the wind by the house and wood fence) uses the normal ET.

So the trick for efficient irrigation is to start with the textbook numbers then fine tune them based on observation. **Based on actual observations for each zone, adjust the run time up/down in 10% increment to fine-tune the irrigation.**

These examples are based on typical July weather. <u>For cooler spring and fall seasons, the amount of water to apply generally remains the same, with a longer interval between irrigations.</u>

Other Factors Influencing Irrigation Management

Other factors also have a direct influence on the <u>actual</u> water-holding capacity and irrigation demands, for example:

- **Exposure** – The plant's exposures greatly influences water demand. Sun, heat and wind increase water demand. Shade decreases water demand. Water use for a lawn on a windy, southwest-facing slope could be double the water use of a lawn in full sun but sheltered from wind and extreme heat.

- **Soil organic matter content** – Since organic matter holds over ten times more water than sand, a sandy soil with good organic content (around 4 to 5%) will hold more water than indicated in the table above. Over time, clayey soils with good organic content may have an improved soil structure, supporting a deeper rooting depth.

- **Previous irrigation pattern** – Plants adjust rooting depth (to the extent that soil oxygen levels allow) to where soil water is available. Frequent irrigation eliminates the need for plants to develop a deep rooting system. A shallow rooting system makes the plant less resilient to hot, dry weather.

- **Stage of growth** – The stage of growth also influences ET. Water needs increase as a plant grows in size during the season and peaks during flowering and fruit development.

  Compared to the rooting system of a mature plant, newly planted or seeded crops don't have the root systems to explore a large volume of soil for water. Recently planted and seeded crops will require frequent, light irrigations. In our dry climate, even "xeric" plants generally need regular irrigation to establish.

  Confusion about plant water requirements can arise from changing needs as plants move through their life cycles. For example, newly planted trees are extremely intolerant of water stress. Established trees in good health are rather tolerant of short-term water stress. Older trees in decline are intolerant of water stress. General statements about the ability of trees to tolerate dry situations need to take into account life-cycle stages.

- **Water demand of a plant** – Plants vary greatly in the demand for water to 1) support growth, and 2) survive dry spells. (Note that the two are not necessarily related.)

- **Ability to extract water** – Plants vary in their ability to extract water from the soil. For most plants, the *available water* is about 50% of the soil's total water supply before reaching the *permanent wilting point*. Onions are an example of a crop that can only extract about 40%.

- **Drought mechanism** – A similar, but unrelated, issue is the plant's ability to survive on dry soil. Plants have evolved with a variety of drought mechanisms, for example:

    - Small leaves, waxy leaves, hairy leaves, and light-colored leaves are characteristics of many plants with lower water requirements.
    - Some plants, like cacti, have internal water storage supplies and waxy coatings.
    - Many plants, like impatiens, readily wilt as an internal water conservation measure.
    - Trees close the stomata in the leaves, shutting down photosynthesis, during water stress.
    - Some plants, like Kentucky bluegrass, can go dormant under water stress.
    - Kentucky bluegrass slows growth as soils begin to dry down. (Does your irrigation management capitalize on this dry-down, also reducing your mowing?)
    - Tall fescue is an example of plants that survive short-term dry soil conditions by rooting more deeply (if soil conditions allow) to reach a larger water supply. But tall fescue can't go dormant.

Tools to Evaluate Soil Moisture

Gardeners have a number of tools available to evaluate the amount of moisture in their soil.

Plant observation is a good guide to soil moisture. Look for color change and wilting. For example, Kentucky bluegrass will change from a blue-green to gray-blue with water stress. Footprints in the lawn that do not rebound within 60 minutes are another symptom to watch for. Use of an indicator plant in a perennial flower bed is also useful. Certain perennials such as *Ligularia stenocephala* 'The Rocket' and *Eupatorium rugosum* (White Snakeroot) often wilt before other perennial flowers, indicating irrigation will shortly be required.

The **hand feel method** used when digging in soil is more evidence of moisture content. Is the soil powder dry, medium moist or even muddy?

The ease with which a **probe** can be inserted can be telling. A screwdriver will punch into the soil more easily when wet than when dry. However, this can be very misleading, as a clayey soil may be difficult when wet and impossible when dry. A sandy soil may be easy when dry and easier when wet.

Soil moisture meters are available. A simple, houseplant water meter can be used outdoors. Although the exact number reading may give little information, the overall indication of wet or dry is useful. It will read on the wet side when the soil has high nutrients or salts, and on the dry side when the soil is low in nutrients and salt. Permanently buried soil moisture sensors are available to automatically activate irrigation systems when the soil has dried.

CMG GardenNotes on Irrigation Management

#260	Irrigation Management: References and Review Questions
#261	Colorado's Water Situation
#262	Water Movement Through the Landscape
#263	Understanding Irrigation Management Factors
#264	Irrigation Equipment
#265	Methods to Schedule Home Lawn Irrigation
#266	Converting Inches to Minutes
#267	Watering Efficiently
#268	Home Lawn Irrigation Check-Up

Authors: David Whiting (CSU Extension, retired), with Carl Wilson (CSU Extension, retired). Artwork by David Whiting; used by permission.
Revision: Kurt M. Jones, Chaffee County Extension Director (9/2017).

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

Revised September, 2017

CMG GardenNotes #264

Irrigation Equipment

Equipment for delivery of landscape irrigation water ranges from automated in-ground sprinkler systems and drip irrigation systems to hose-end watering. A basic outline of each with their strengths and limitations follows.

In-Ground Sprinklers

Different types of irrigation equipment are most effective to water various types of planting in the home landscape. For lawns, sprinkler irrigation with pop-up spray heads and rotor heads are generally used. Because each type of sprinkler delivers water at a different rate, do not mix sprinkler types in a zone.

All sprinkler systems must comply with local building codes, requiring building permits and inspection. In-ground sprinkler systems have the following basic components.

Point of Connection – The system starts at the point of connection where the supply line connects to the water supply. This is in the basement of the typical house. The size of the pipe and water pressure determine water flow and thus influence design of the system (how many heads can run at one time).

A **pressure regulator** provides uniform, lower water pressure for uniform water delivery. This is typically found just before the point of connection. It should be set at 30 to 40 psi for the landscape irrigation system and household water use. Sprinkler systems have maintenance problems and values may fail to shut off when the pressure is above 80 psi. Pressure regulators are typically not found in older homes. Due to increased uniformity of water delivery, adding a pressure regulator may result in significant water savings in landscape irrigation.

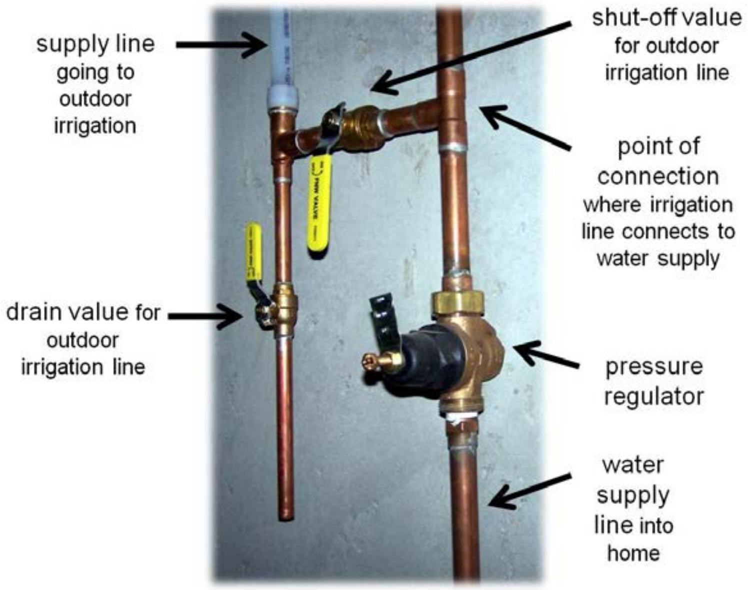


Figure 1. Point of connection with pressure regulator, shut-off value for outdoor line and drain valve that drains the outdoor line to the backflow prevention device (located just outside the house).

Local building codes require a **backflow prevention device** to protect the community's water supply. This is typically placed where the water line comes out of the house. Some valves have a backflow prevention device build into the value. The type to use depends on the local building code. [Figure 2]

Figure 2. Required by local building codes, backflow prevention devices are typically located where the line comes outside from the house.

The main **supply line** (water line holding water under pressure throughout the summer) splits in a **valve box** to a **valve** for each zone. To minimize maintenance headaches, use Schedule 40 PVC pipe for below-ground supply lines and copper pipe for any above-ground pipe. PVC fitting are connected with special glue. Copper pipefittings are soldered. [Figure 3]

Figure 3. Valve box with two zone valves.

Beyond the valve, **secondary lines** (lines that have water only when the zone is running) go to sprinkler heads. Being easy to work with, these are generally made of flexible black poly pipe. Connect poly pipe fitting with pinch clamps.

The size of the pipe and the water pressure determine the number of sprinkler heads that can be used per zone. Various brands of sprinkler equipment have planning booklets with specific details for their product lines.

A **controller** (timer) runs the system from a central location (typically in the garage). In the home garden market, there are many styles of controllers with a variety of features. [Figure 4]

Figure 4. Controller – Many brands offer a variety of features.

In climates where the soil freezes, the lines need to be **drained** in the winter. This starts by turning off the water with the valve near the point of connection and opening the internal drain line. This drains the line to the backflow prevention valve (which is outdoors at the high point in the system).

Depending on how the system was designed, there are several methods to drain the supply line and secondary lines. Some systems are "blown out" by connecting an air compressor. Other systems have valves that are manually opened, allowing for drainage by gravity. In some systems, secondary lines have self-draining valves that automatically drain the line each time the water is turned off.

Pop-Up Spray Heads

This is a generic name for sprinklers that automatically "pop up" with a fan-shaped spray pattern and do not rotate when running. The head retracts by spring action when the water is turned off. [Figure 5]

Figure 5. Pop-up spray heads are used for small areas, 15 feet wide and less.

Delivery pattern – Pop-ups spray heads are best suited for small to moderate sized home lawn areas (larger than seven to ten feet wide up to 30 to 45 feet wide) and irregular or curvilinear areas.

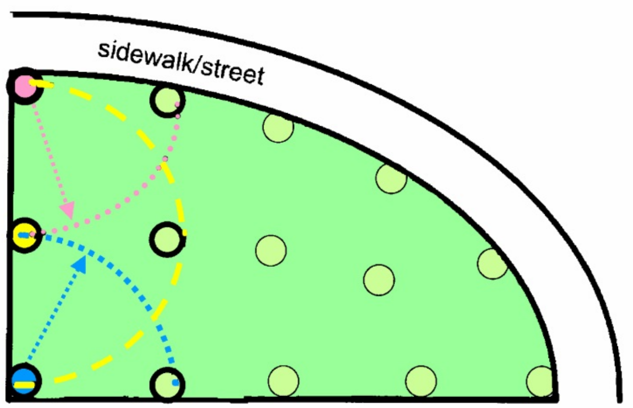
Pop-up spray nozzles are most common with 15, 12, 10, and 8 foot radii. The radius can usually be adjusted down about 30%, using the nozzle's adjustment screw. Therefore, a commonly available ten-foot nozzle can be reasonably adjusted down to seven feet. Any greater adjustment would significantly distort the pattern, resulting in poor application efficiency.

The spray pattern of a pop-up spray head depends on choosing nozzles to water quarter circles, half circles, or full circles. Some manufacturers offer adjustable arch nozzles that can be set at any angle. However, do not use adjustable nozzles where a fixed nozzle would work, as the uniformity of water delivery is not as high.

Some specialty patterns to handle narrow, rectangular turf areas are available (often called "end-strip," "center-strip" or "side-strip" nozzles). However, nozzle performance is not as uniform compared to quarter-circle, half-circle, or full-circle nozzles.

Within any given brand, spray nozzles have "match precipitation rates." That is, a half-circle head uses half the amount of water per hour as a full-circle head. With match precipitation rates, full, half and quarter circles may be used in the same zone. It is also acceptable to mix a combination of nozzle radii in a zone.

Figure 6. For uniform water distribution, the spray head needs to release water above the grass height.



Pop-up height – For uniform water distribution, the sprinkler heads should rise above the grass height, making the 4-inch pop-up style most popular. High pop-up heads, with a 12-inch rise, are suitable for ground-cover areas and lower flowerbeds. [Figure 6]

Pressure – Pop-up spray heads work best with water pressure around 30-40 psi. The water pressure at some homes may be significantly higher, and an in-line pressure regulator will be needed in these cases. A sprinkler producing a "mist cloud" around the head is a common symptom of excessive pressure. This gives a distorted distribution pattern (significantly increasing water use) and leads to increased maintenance problems.

In addition, a grade change of more than eight vertical feet on a single zone will result in significantly higher pressure at the lower end, creating distribution problems.

Small Areas – Small areas less than seven to ten feet wide are difficult to sprinkle irrigate efficiently with pop-up spray heads. Consider landscape alternatives. For example, that small side yard between houses may be an excellent site for a low maintenance, non-planted, non-irrigated mulch area. Alternatively, the small area could be a shrub/flower bed watered with drip irrigation. A narrow lawn strip may be watered efficiently with the new sub-surface drip for lawns.

Precipitation rate – Pop-up spray heads have a high water delivery rate (***precipitation rate***) of 1 to 2½ inches per hour. At the typical rate of 1½ inches per hour, the zone would apply 1/2 inch of water in just 20 minutes.

Rotor Head

Rotor heads mechanically rotate to distribute the spray of water. Impact and gear-driven heads are two common types in the home garden trade. [Figures 7 and 8]

Rotor heads in the home garden trade are best suited for larger lawn areas, generally 18 to 24 foot radius and greater. Some rotor-type heads in the commercial line have a radius of 30 to 90 feet.

Figure 7. Impact or impulse heads rotate as the water stream coming from the nozzle hits a spring-loaded arm. Impact heads tend to experience fewer problems with marginal (dirty) water quality.

Figure 8. Gear-driven heads use the flowing water to turn a series of gears that rotate the head. Gear-driven heads are quieter to operate than impact heads.

The spray pattern depends on the head. Most can be set at any angle from 15º up to a full circle. Some are adjusted at 15º increments. Others are designed for a quarter-circle, half-circle or full-circle spray pattern.

In rotor head design, do not mix quarter, half and full circle patterns in the same zone. The water flow is the same for each head, but the area covered will be different. For example, a full circle (covering twice the area of a half circle) will have half the precipitation rate of a half circle. The full circle will need to run twice as long to apply the same amount of water as the half circle.

Pressure – Rotor heads typically operate at 30 to 90 psi, 30 to 40 psi being most common for heads in the home garden trade. Better quality heads have built-in pressure regulators.

Precipitation rate – Rotors are more uniform in water distribution than pop-up spray heads and take much longer to water. As a rule of thumb, rotor heads deliver water at a rate of ¼ to ¾ inch per hour. At the typical precipitation rate of ½ inch per hour, it would take 60 minutes to apply ½ inch of water. The slower precipitation rate can be an advantage on clayey or compacted soils where water infiltration rates are slow.

Multi-Stream Rotors

The newer multi-trajectory rotating streams, provide unmatched uniformity in water distribution for significant water savings. They have a lower application rate, reducing runoff on compacted, clayey soils and slopes. The streams of water are large enough to resist wind disturbance, so they reduce the amount of water blowing onto driveways, sidewalks, and roads.

Several manufacturers offer multi-stream rotors in today’s market, including Hunter MP Rotator, Toro Precision Series, Rainbird R-VAN, and others. Generally used by landscape contractors, multi-stream rotors are less common in the home garden trade. For the home gardener, they may be found online.

Almost any type of sprinkler head can be retrofitted with an MP Rotator® sprinkler, including spray heads and traditional rotors. MP Rotators® can apply water to distances ranging from four to 30 feet. They can also be used to water narrow planting strips, which are often difficult to water effectively with traditional sprinkler heads.

Depending on the head, they perform best at 30 to 40 psi. With matched precipitation rates, quarter, half and full heads may be mixed in a zone.

Strengths and Weaknesses of In-Ground Sprinklers

Strengths of in-ground sprinklers include the following:

- Convenience
- Time savings
- Usefulness for irrigating small areas
- Very efficient if well-designed, maintained and managed according to plant water needs (ET).

Weaknesses of in-ground sprinklers are that they can be very inefficient if poorly designed, maintained, or managed. Being “too” convenient, many gardeners give them little attention, significantly wasting water.

Bubblers

Small groupings of flowers and other small plants can be efficiently watered with bubblers, which flood an area and rely on the natural wicking action of the soil to spread the water.

They are ideal for level shrub and ground cover areas. Heads are typically placed at three to five feet intervals or placed by individual plants for spot watering. Stream bubblers are directional and come in a variety of spray patterns.

Bubblers deliver water faster than drip emitters and are used to water trees and shrubs. Refer to manufacturers’ literature for design and management criteria related to various models.

Drip Systems

For flower and shrub beds, small fruits and vegetable gardens, drip emitters, drip lines, micro-sprayers, and soaker hoses are popular.

Water use rates, weed seed germination, and foliar disease problems are reduced in drip systems that do not spray water into the air and over the plants and the soil surface. As a rule of thumb, a drip system coupled with mulch can reduce water needs by 50%.

Drip emitters, micro-sprayers, and drip lines require clean water, which is relatively free of soil particles, algae, and salts. In-line filters are part of the system. Water quality is generally not a problem when using potable water sources. However, with non-potable water sources, the filtering system required may be expensive and high-maintenance, making drip impractical.

Drip systems work with lower pressures (typically around 20 psi), generally using **in-line pressure regulators**. The system snaps together with small fittings. No gluing or bands are required. It is much easier to work with if the tubing has been warmed by the sun for an hour. [Figure 9]

Figure 9. In-line filter and pressure regulator going to drip line poly tubing.

The system is put together with half-inch and quarter-inch poly tubing, fittings and emitters. For the main line and branch lines, **half-inch poly tubing** is used. The **quarter-inch micro-tubing** serves as feeder line to individual drippers or micro-sprinklers. Ideally, the tubing is on the soil surface under the mulch.

- **Drip emitters** deliver water at a slow, consistent rate, such as one-half gallon, one gallon, or two gallons per hour. Emitters can connect to the branch line or extend on micro-tubing out to individual plants or pots. Small annuals and perennials typically have one emitter per plant. Several would be used spaced around larger perennials, shrubs, and small trees. [Figure 10]

Figure 10. Drip emitter on ½" poly tubing

As a point of clarification, some gardeners mistakenly think that using half, one, and two gallon per hour drippers is an effective method to manage differing water needs. Although this works to a small degree, the concept is basically flawed. The two-gallon per hour drippers will have significantly larger wetting zones than the half-gallon per hour dripper. However, plants with the higher water needs (two-gallon/hour drippers) do not necessarily have a larger root spread. Likewise, plants with lower water needs (half-gallon/hour dripper) will not necessarily have a smaller root spread (in fact, a large root spread is what makes some plants more xeric). The factor missing here is irrigation frequency to match the water needs.

- **In-line drip tubing** is a quarter-inch micro-tubing with built-in emitters spaced at six, 12, or 24 inch intervals. The 12-inch spacing is readily available in the home garden trade. These are great for snaking through a bed area. For sandy soils, spacing of the tubing should be at 12 inches. For clayey soils, spacing may be at 18 to 24 inches for perennial beds.

- **Micro-sprayers**, often held up on a spike, cover a radius of two to 13 feet. Delivery rates vary from 0.1 to 10 inches per hour, depending on the head selected. Because water is sprayed in the air, drift and water waste in wind resembles sprinklers more than ground-applied drip. Micro-sprayers work with a very small droplet size that readily evaporates. For this reason, their efficiency in Colorado's low humidity is questionable.

Specifications on design and management vary among manufacturers and types selected. Refer to the manufacturer's literature for details. Typical run times are 60 to 90 minutes.

Drip systems are easy to automate by connecting the zones to valves and a controller (like an in-ground system for a lawn). For ease of programming to the specific watering needs of the drip system, use a dedicated controller for multiple drip zones. In small yards, a single zone or two could be added to the controller used for the lawn, but they would run on a different program than the lawn to match the different watering needs.

When connected to the garden hose, the zone can be automated with single-zone controllers that connect with hose-end fittings at the tap. Some simple models turn the water off after a set number of minutes or gallons. More elaborate battery-operated models turn the water on and off at the day and time interval set by the gardener. [Figure 13]

Like any irrigation system, drip systems require routine maintenance. They are not an install-and-forget type of system.

For additional information on drip irrigation, refer to CSU Extension Fact Sheet #4.702, *Drip Irrigation for Home Grounds.*

Soaker Hose and Soaker Tubing

The **soaker hose** is a different type of drip system that allows water to seep out the entire length of a porous hose. They are great for raised bed gardens and flower beds. In sandy soils, space runs at 12 inches. For flower and shrubs beds on clayey soil, space runs at 18-24 inches. In a raised bed vegetable garden (where uniform delivery to small vegetables is important), make three to four runs up and down a four-foot wide bed. Typical run time is 10 to 20 minutes.

- **Quarter-inch Soaker Tubing –** Quarter-inch soaker tubing is availble in the drip irrigation section at garden stores. Cut the soaker tubing to desired length and connect with drip system components. An in-line pressure regulator (Figure 10) is required; otherwise, the fitting may pop or leak.

- **Half-Inch Soaker Hose** – Some brands (like *Swans Soaker Hose*) are a ½-inch hose that connect with a standard hose fitting. These are found in the garden hose section. It can be cut to any length and connected with garden hose fittings.

  A small plastic disc fits inside the female hose connection as a flow regulator. To adequately water the garden with the reduced water flow, it may need to run for around an hour. For better performance, use the pressure regulators with hose-end fittings found with the drip irrigation supplies (Figure 11). To adequately water the garden with this type of regulator, the drip line runs 10 to 20 minutes. Without a pressure regulator of some type, the soaker hose tends to rupture, sending out steams of water at spots rather than dripping along the line. [Figure 11]

Figure 11. Tap, pressure regulator (with hose connections) and half-inch drip hose in raised bed garden.

  This half-inch hose style is more tolerant of small amounts of dirt, algae, or salts in the water than other types of drip systems and may be successful on some non-potable water sources. Periodically, open up the end of the hose and flush out soil deposits.

Because the soaker tubing has a higher delivery rate, it cannot be on the same zone as other in-line drip tubing, button emitters, or bubblers.

Strengths and Weaknesses of Drip Irrigation

- **Strengths** of drip irrigation include the following:
    - Convenience.
    - Water saving.
    - Operates with low water pressure.
    - Easy to change when the plantings change.
    - Does not require trenches for installation.
    - Readily automated on a multi-zone controller or single-zone controllers that connect to the faucet.

- **Weaknesses** of drip irrigation include the following:
    - Require good-quality water and filtration.
    - Maintenance difficulty in seeing if systems are operating and need to check water delivery to individual plants.
    - Cost: for large areas, the cost will be significantly higher than a sprinkler system.
    - Unsuitable for watering large trees.

Subsurface Drip

Subsurface drip is a relatively new way to water lawns and flowerbeds. Tubes are permanently buried below ground. Water soaks upward and laterally so subsurface drip works in clay-containing soils, but not well in sands.

Generally installed by a trained and experienced professional, subsurface drip requires very exact installation depth and spacing. Without proper attention to installation, the lawn becomes striped with green and dry strips. Studies being conducted by the Northern Colorado Water Conservation District find that water use is similar to a well-designed sprinkler system.

Strengths of subsurface drip include:

- Convenience.
- Operation at low pressure.
- Equipment located out of sight, where it is less prone to damage.
- Easy to water anytime day or night, even when the lawn is being used.
- Application of water directly to the root zone.
- Easy to automate with soil moisture sensors.
- Potential to inject fertilizers with the irrigation water.

Weaknesses of subsurface drip include:

- Requires high-quality water.
- Inability to see if it is operating correctly and need to dig it up if it is not.
- Prohibition of inserting stakes in the ground.

- Requires professional installation.
- Relatively high cost.
- Evolving technology that has not stood the test of time.

Hose-End and Hand Watering

Hose-end watering devices include various types of spray heads, water wands and water breakers, soaker hoses, and soil needles. Such devices are commonly used for temporary situations and where permanent installations are impractical or not desired.

Hose-end watering is very inefficient in uniformity of water delivery, resulting in high water use. However, significant water savings may occur because gardeners generally do not water until the lawn/garden show signs of being dry.

A common problem with hand-held water wands is that folks tend to only water the surface, rather than deep watering of the root system. Avoid soil needles because they apply the water below the primary root system of trees, shrubs, and flowers.

A hand-moved sprinkler can be automated with single-zone controllers that connect with hose-end fittings at the tap. Some simple models turn the water off after a set number of minutes or gallons. More elaborate battery-operated models turn the water on and off at the day and time interval set by the gardener. [Figure 12]

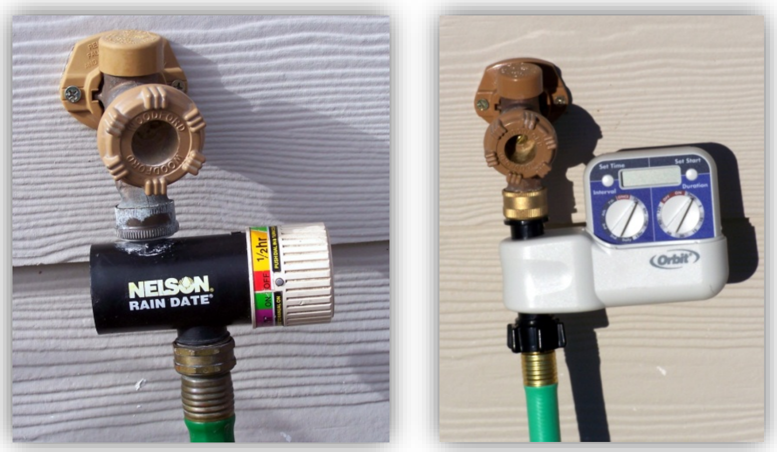


Figure 12. Single-zone controllers connect to the hose line. Left: This style is manually turned on and automatically turns off after a set number of minutes. Right: This battery powered controller turns water on and off at the day and time intervals set by the gardener.

Strengths and Weaknesses of Hose-End Watering

Strengths of hose-end and hand watering include the following:

- Relative low cost of equipment.
- Ability to water plants differently and usefulness for spot watering.
- Allows for close observation that may result in more timely care of plants.

- Being outside in the yard encourages neighborhood relationships.

Weaknesses of hose-end hand watering include the following:

- Time-consuming.
- Poor uniformity of water distribution with hand-placed sprinklers, leading to high water use.
- Hand-held watering often leads to surface watering rather than effectively watering the root zone.
- Wasting water by allowing it to run too long.

Summary

Any type of irrigation system (in-ground sprinklers, drip, or hand watering) can be very efficient with attention to detail. Likewise, any type of irrigation can be inefficient, wasting water. What makes a system efficient or inefficient is not the equipment, but rather the attention given by the gardener.

CMG GardenNotes on Irrigation Management

#260	Irrigation Management: References and Review Questions
#261	Colorado's Water Situation
#262	Water Movement Through the Landscape
#263	Understanding Irrigation Management Factors
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#265	Methods to Schedule Home Lawn Irrigation
#266	Converting Inches to Minutes
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Revised by Kurt M. Jones, Chaffee County Extension Director

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CMG GardenNotes #265

Methods to Schedule Home Lawn Irrigation

Irrigation Scheduling

In many areas of the semiarid West, gardeners cannot count on natural precipitation to deliver moisture at the right times or in sufficient amounts to grow most introduced landscape plants. Supplemental irrigation is necessary unless the plant pallet is limited to species tolerant of natural precipitation levels. Due to limited precipitation and periodic droughts that limit available water supplies, using efficient irrigation is of interest to all.

Scheduling landscape irrigation is a critical part of lawn and garden care. When irrigating, gardeners have two goals: 1) water enough to keep plants healthy, and 2) minimize water waste.

Irrigation management comes down to two basic questions: 1) how much, and 2) how often. Gardeners often hear recommendations such as “water deeply and infrequently” or “water to adequate depth without runoff.” Such advice is usually too broad to translate into effective irrigation management practices.

Rather than using broad generalizations, this *CMG GardenNotes* looks at several management approaches with differences in the time investment and potential water savings. **The textbook figures will need to be fine-tuned to the specific site needs, taking into account soils, exposure, heat, wind, and other water-use factors.**

Methods focus on cool-season turf, such as Kentucky bluegrass and turf-type tall fescue. Xeric and dry-land plants may need significantly less water.

Sprinkler-Type Method

One of the easiest ways to schedule an irrigation system is based on sprinkler type. Different types of sprinklers deliver very different amounts of water in the same amount of time. By considering sprinkler type, gardeners can begin to match their watering practices to the lawn's water needs.

Pop-up spray heads typically apply 1-2½ inches of water per hour, whereas rotor heads only deliver ¼ to ¾ inch of water per hour. Therefore, zones that have pop-up spray heads can run for a short time, while zones with rotors will need to run longer to deliver the same amount of water.

A gardener could estimate that a zone with pop-up spray heads applies 1¾ inches of water per hour, and zones with rotor head apply about ½ inch per hour on average. Table 1 estimates run time (based on historical water use). The typical Colorado soil requires that this be split between a couple of irrigations.

Table 1.
Estimated Sprinkler Run Time Based on Sprinkler Type for Cool-Season Lawns

	Late April	May & June	July & August	September	Early October
Inches of water per week (irrigation plus rain)	0.75"	1.0"	1.5"	1.0"	0.75"

Run Time (minutes/week)	Late April	May & June	July & August	September	Early October
Pop-up Spray Head[1]					
Irrigated 1 time per week[3]	**26**	**34**	**52**	**34**	**26**
Irrigated 2 times per week[4]	**13**	**17**	**26**	**17**	**13**
Irrigated 3 times per week	9	11	17	11	9
Irrigated every 6 days	22	29	45	29	22
Irrigated every 5 days	19	24	37	24	19
Irrigated every 4 days	15	19	30	19	15
Irrigated every 3 days	11	15	22	15	11
Irrigated every 2 days	7	10	15	10	7
Rotor Head[2]					
Irrigated 1 time per week[3]	**90**	**120**	**180**	**120**	**90**
Irrigated 2 times per week[4]	**45**	**60**	**90**	**60**	**45**
Irrigated 3 times per week	30	40	60	40	30
Irrigated every 6 days	77	103	154	103	77
Irrigated every 5 days	64	86	129	86	64
Irrigated every 4 days	51	69	103	69	51
Irrigated every 3 days	39	51	77	51	39
Irrigated every 2 days	26	34	51	34	26
Percent of July/August	**50%**	**67%**	**100%**	**67%**	**50%**

[1] Pop-up spray head estimated at 1 ¾" per hour.
[2] Rotor head estimated at ½" per hour.
[3] Recommended for most Colorado soils in the spring and fall
[4] Recommended for most Colorado soils in the summer

An easy tool for making seasonal adjustments is the **Percent Key** found on most controllers. The controller would be set for the July/August irrigation schedule. The percent key would be set at 50%, 67% or 100%, based on the season.

The method will need fine-tuning as described below to match the actual water need for the site based on soil, exposure, heat, wind, etc.

Although this method outlines a starting point for gardeners who want an easy approach, it does not factor in the actual water application rates for each zone.

Precipitation Rate Method

A far better approach is to do a ***Precipitation Rate (Catch Can) Test*** on each zone to determine the actual water delivery rate (know as ***precipitation rate***). The actual precipitation rate is determined by the sprinkler type and brand, water pressure and head spacing. It is generally slightly different for each zone.

To do the calculations you will need six identical, straight-sided, flat-bottomed cans such as soup, fruit, or vegetable cans. (Do not use short cans like tuna cans as they are too shallow, and water may splash out.) You will need a ruler, a watch and paper/pen to record your findings. Many water providers and sod growers have calibrated plastic cups specifically designed for this test. Again, six are needed.

Precipitation Rate (Catch Can) Test

Step 1. Place six identical, straight-sided, flat-bottomed cans randomly around the area between sprinkler heads in the zone.

Step 2. Turn on the sprinklers for exactly ten minutes.

Step 3. Pour all the water into one can.

Step 4. With a ruler, measure the depth of the water in the can. This is your **precipitation rate in inches per hour**. Write it down for future reference.

Step 5. Repeat steps 1 and 2 for each irrigation zone.

Step 6. Use Tables 2 & 3 to calculate the run time for each zone.

Note: if the amount of water in some containers is significantly more or less than others, the system is poorly designed or head(s) are malfunctioning.

In many lawn sections, one zone waters the area from the left while another zone waters the same area from the right. In this situation, cut run times for zones in half, so that each applies half of the needed water.

An easy way to make seasonal adjustments is with the **Percent Key** found on most controllers. The controller would be set for the July/August irrigation schedule. The percent key would be set at 50%, 67% or 100% based on the season.

The method will need fine-tuning as described below to match the actual water need for the site based on soil, exposure, heat, wind, etc.

Table 2.
Minutes to Run Sprinklers PER WEEK Based on Precipitation Rates
For Cool-Season Turf in Colorado

	Late	May &	July &		Early

	April	June	August	September	October
Inches of water per week (irrigation plus rain)	**0.75”**	**1.0”**	**1.5”**	**1.0”**	**0.75”**
Precipitation Rate					
1/4	180	240	360	240	180
3/8	120	160	240	160	120
1/2	90	120	180	120	90
5/8	72	96	144	96	72
3/4	60	80	120	80	60
7/8	52	69	103	69	52
1	45	60	90	60	45
1 1/8	40	53	80	53	40
1 1/4	36	48	72	48	36
1 3/8	33	44	65	44	33
1 1/2	30	40	60	40	30
1 5/8	28	37	55	37	28
1 3/4	26	34	51	34	26
1 7/8	24	32	48	32	24
2	23	30	45	30	23
2 1/8	22	28	42	28	22
2 1/4	20	27	40	27	20
2 3/8	19	25	38	35	19
2 1/2	18	24	36	24	18
2 5/8	17	23	34	23	17
2 3/4	16	22	33	22	16
2 7/8	16	21	31	21	16
3	15	20	30	20	15
Percent of July/August	**50%**	**67%**	**100%**	**67%**	**50%**

Table 3.

Conversion of Run time PER WEEK to Run Time PER IRRIGATION

Irrigations Per Week	Conversion to Run Time Per Irrigation
1 time per week[1]	minutes per week
2 times per week[2]	minutes per week / 2
3 times per week	minutes per week / 3
Every 6 days	minutes per week X 0.86
Every 5 days	minutes per week X 0.71
Every 4 days	minutes per week X 0.57
Every 3 days	minutes per week X 0.43
Every 2 days	minutes per week X 0.29

[3] Recommended for most Colorado soils in the spring and fall

[4] Recommended for most Colorado soils in the summer

Determining the number of irrigations per week becomes complex as soil water-holding capacity and rooting depth are factored in. For details, refer to CMG GardenNotes #263, *Understanding Irrigation Management Factors*.

However, many gardeners know by experience how often they need to irrigate. For the majority of Colorado soils, irrigating once per week works in the spring and fall, and twice a week works in the summer. Watering as infrequently and deeply as the soil allows gives better resilience during hot spells and helps reduce many weed species.

Adding Cycle and Soak Features

On slopes or compacted, clayey soils, water is generally applied faster than it can soak into the soil, resulting in water being wasted as it runs off-site. The ***cycle and soak*** approach cuts the irrigation period into multiple short runs with soak-in time in between. Programming a controller for cycle and soak is simply a matter of using multiple start times.

Adding Cycle and Soak

Step 1. From the methods discussed above, calculate the total run time for the irrigation.

Step 2. Using Table 4, figure the number of cycles and soaks desired.

For example, if the run time is 26 minutes, three cycles are suggested.

Step 3. Divide the run time per irrigation by the number of cycles to get the run time per cycle.

For example, if the run time is 26 minutes and three cycles will be used, run time per cycle is nine minutes (26 / 3 = 8.67, rounded to 9).

Step 4. Set program with multiple start times, as needed. Generally, the controller is set to cycle again after all the zones have run. If the controller only has a few zones, start times need to be at least one hour apart.

Table 4.
Estimated Number of Cycles to Reduce Surface Runoff

Type of Sprinklers	Run Time Per Irrigation	Number of Cycles
Pop-up Spray Heads	Greater than 16 minutes	2
	Greater than 24 minutes	3
Rotor Heads	Greater than 48	2
	Greater than 72	3

Observation and Manual Control Method

A simple method to manage lawn irrigation and conserve water is to manually activate the controller as needed. With careful attention, this method can maximize plant health and water savings since the gardener continually adjusts the irrigation system to actual weather and lawn needs. The downside of this method is that it takes daily attention to the lawn's water needs.

Run times on the controller are set as previously described. The difference is that the controller is turned to the "off" position. It is manually activated when the lawn shows signs of water stress (color change from bluish-green to grayish-blue and footprints are still visible an hour or more later). After the zones run through, the controller is turned back to "off".

Using Emerging Technology

Advances in irrigation technology have led to several innovations. ET Controllers and soil-moisture sensors are examples. Even though they may be more expensive or require professional installation, these products can be used to further improve water delivery to a landscape. Because they automate the irrigation controller, they can potentially reduce the amount of effort needed to water effectively.

ET Controllers

The ET controller is a relatively new piece of equipment that automatically adjusts the irrigation to the daily ET. ET controllers are designed to water only enough to fulfill the lawn's water need, thereby reducing over and under watering.

Some models use "Historical ET," which is a multi-year average for the day. With these, dry spots will pop up with extreme heat over multiple days. They do not take into account actual rain received locally.

For a small annual fee, other models connect by cell phone, Wi-Fi, or satellite communication networks to download actual ET and rainfall from a local weather station system. On a day-by-day basis, they adjust the irrigation to match actual water need.

For additional information on ET controllers and the use of ET in irrigation management, refer to the *Northern Colorado Water Conservancy District* website at www.ncwcd.org.

Soil-Moisture Sensors

Soil-moisture sensors measure the water content of the soil, allowing the controller to run only when soil dries down to a threshold level. One of the advantages of a soil-moisture sensor is that it uses on-site soil conditions to control the irrigation system. Usually one sensor is buried in the home landscape in a "representative" area. Run times for reduced irrigation zones or shady zones are programmed into the controller relative to the representative zone.

Rain Shut-off Sensors

Rain shut-off devices, also known as rain sensors, interrupt the schedule of an irrigation controller when a specific amount of rain has fallen. They are wired into the irrigation controller and placed in an open area where they are exposed to rainfall. They save water by preventing an irrigation system from running during moderate and heavy rains. Many states, but not Colorado, require rain shut-off sensors on automated systems.

Fine-Tuning Any Scheduling Method

Any scheduling method will need fine-tuning to match the actual water need of the site based on soil type, exposure, wind, heat, rooting depth, etc. This is done by careful observation of the lawn.

When adjusting all zones, the **Percent Key** on most controllers provides an easy method to fine-tune for the actual site by adjusting the percentage up/down in 10% increments, as needed. It can also be adjusted by increasing/decreasing the run time for each zone in 10% increments, as needed.

When adjusting a single zone, adjust the run times for that zone up/down in 10% increments, as needed.

In typical summer weather, if the lawn starts to become dry between irrigations, increase the run time in 10% increments, as needed. By trial and error, it is easy to fine-tune each irrigation zone. On multiple days of unusually hot weather, dry spots should pop up if the controller is precisely fine-tuned. In unusually hot weather, if dry spots do not pop up, the lawn is being over-watered. Cut back the time in 10% increments, as needed, to fine-tune each zone.

Many water providers encourage homeowners to water their yards between 9 p.m. and 9 a.m. Winds are typically less at night, and evaporation loss will be lower.

Author: David Whiting, Colorado State University Extension, (retired).
Revision: Kurt M. Jones, Chaffee County Extension Director (9/2017).

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CMG GardenNotes #266

Converting Inches to Minutes

Most gardeners realize that temperatures affect the water needs of lawns and gardens. The difficulty is that water is usually measured in inches while the irrigation controller (timer) works in minutes. The challenge is to make minutes equal to inches so that the correct amount of water is applied to the lawn or garden. It's easy to make the conversion. First calculate the precipitation rate for each irrigation zone. Then convert inches to minutes using the formula or the table.

Calculate the Precipitation Rate

The following steps need to be done for each irrigation zone (or each location you placed the sprinkler if you're a "hose dragger"). To do the calculations you will need 6 identical straight-sided, flat-bottomed cans or cups such as soup, fruit or vegetable cans. (Do not use short cans like tuna cans as they are too shallow, and water will splash out.) You will need a ruler, a watch, and paper/pen to record your findings. Many sod growers and local water providers give out small rain gauges with a ruler on the side for this measurement. You will need 6 of the same type.

Steps

1. Place six identical, straight-sided, flat-bottomed cans between sprinkler heads in the zone.
2. Turn on the sprinklers for exactly ten minutes.
3. Pour all the water into one can.
4. With a ruler, measure the depth of the water in the can. This is your precipitation rate in inches per hour.
5. Write down the number near your controller for future reference.
6. Repeat steps 1-5 for each irrigation zone.

Table 1. Conversion of fractions to decimals

1/16 = .06
1/8 = .13
3/16 = .19
1/4 = .25
5/16 = .31
3/8 = .38
7/16 = .44
1/2 = .50
9/16 = .56
5/8 = .63
11/16 = .69
3/4 = .75
13/16 = .81
7/8 = .88
15/16 = .94

Convert Inches to Minutes

Once you know the precipitation rate for each zone, you can look up the run time in the table or calculate it by using the following formula:

$$\textbf{Run Time}\text{ (minutes)} = \frac{\textbf{Water to apply}\text{ (inches)}}{\textbf{Precipitation rate}\text{ (inches/hour)}} \times \textbf{60 minutes/hr}$$

Example: You have done the above steps and calculated that this sprinkler zone has a precipitation rate of 1.5 inches per hour. You desire to apply one-half inch of water.

$$\text{Run Time} = \frac{\text{0.5 inches}}{\text{1.5 inches/hr.}} \times \text{60 minutes/hr} = \text{20 minutes}$$

You need to calculate this for each zone. Don’t make the common mistake of assuming that all zones are the same. In the typical yard, they are not!

Table 2. Sprinkler Run Time Table (in minutes) – by 1/8th inch

Precipitation Rate (inches per hour)	**Water to be Applied** (inches)													
	0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
1/4	48	72	96	120	144	168	192	216	240	264	288	312	336	360
3/8	32	48	64	80	96	112	128	144	160	176	192	208	224	240
1/2	24	36	48	60	72	84	96	108	120	132	144	156	168	180
5/8	19	29	38	48	58	67	77	86	96	106	115	125	134	144
3/4	16	24	32	40	48	56	64	72	80	88	96	104	112	120
7/8	14	21	27	34	41	48	55	62	69	75	82	89	96	103
1	12	18	24	30	36	42	48	54	60	66	72	78	84	90
1 1/8	11	16	21	27	32	37	43	48	53	59	64	69	75	80
1 1/4	10	14	19	24	29	34	38	43	48	53	58	62	67	72
1 3/8	9	13	17	22	26	31	35	39	44	48	52	57	61	65
1 1/2	8	12	16	**20**	24	28	32	36	40	44	48	52	56	60
1 5/8	7	11	15	18	22	26	30	33	37	41	44	48	52	55
1 3/4	7	10	14	17	21	24	27	31	34	38	41	45	48	51
1 7/8	6	10	13	16	19	22	26	29	32	35	38	42	45	48
2	6	9	12	15	18	21	24	27	30	33	36	39	42	45
2 1/8	6	8	11	14	17	20	23	25	28	31	34	37	40	42
2 1/4	5	8	11	13	16	19	21	24	27	29	32	35	37	40
2 3/8	5	8	10	13	15	18	20	23	25	28	30	33	35	38
2 1/2	5	7	10	12	14	17	19	22	24	26	29	31	34	36
2 5/8	5	7	9	11	14	16	18	21	23	25	27	30	32	34
2 3/4	4	7	9	11	13	15	17	20	22	24	26	28	31	33
2 7/8	4	6	8	10	13	15	17	19	21	23	25	27	29	31
3	4	6	8	10	12	14	16	18	20	22	24	26	28	30

Select the precipitation rate of your sprinkler zone along the left column and move right until you are in the column of the amount of water to be applied. This is the number of minutes to run your sprinkler.
Example: Your sprinkler applies water at 1 1/2 inches per hour and you want to apply 0.5 inch, it takes 20 minutes.

Table 3. **Sprinkler Run Time Table (in minutes) – by 1/10th inch**

Precipitation Rate	**Water to Be bpplied (**inches)													
(inches per hour)	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
0.20	60	90	120	150	180	210	240	270	300	330	360	390	420	450
0.30	40	60	80	100	120	140	160	180	200	220	240	260	280	300
0.40	30	45	60	75	90	105	120	135	150	165	180	195	210	225
0.50	24	36	48	60	72	84	96	108	120	132	144	156	168	180
0.60	20	30	40	50	60	70	80	90	100	110	120	130	140	150
0.70	17	26	34	43	51	60	69	77	86	94	103	111	120	129
0.80	15	22	30	37	45	52	60	67	75	82	90	97	105	113
0.90	13	20	27	33	40	47	53	60	67	73	80	87	93	100
1.00	12	18	24	30	36	72	48	54	60	66	72	78	81	90
1.10	11	16	22	27	33	38	44	49	55	60	66	71	76	82
1.20	10	15	20	25	30	35	40	45	50	55	60	65	76	75
1.30	9	14	18	23	28	32	37	42	46	51	55	60	65	69
1.40	9	12	17	21	26	30	34	39	43	47	51	56	60	64
1.50	8	12	16	**20**	24	28	32	36	40	44	48	52	56	60
1.60	8	11	15	19	22	26	30	34	37	41	45	49	52	56
1.70	7	11	14	18	21	25	28	32	35	39	42	46	49	53
1.80	7	10	13	17	20	23	27	30	33	37	40	43	47	50
1.90	7	9	13	16	19	22	25	28	32	35	38	41	44	47
2.00	6	9	12	15	18	21	24	27	30	33	36	39	42	45
2.10	6	9	11	14	17	20	23	26	29	31	34	37	40	43
2.20	6	8	11	14	16	19	22	25	27	30	33	35	38	41
2.30	5	8	10	13	16	18	21	23	26	29	31	34	37	39
2.40	5	7	10	12	15	17	20	22	25	27	30	32	35	37
2.50	5	7	10	12	14	17	19	22	24	26	29	31	34	36

Select the precipitation rate of your sprinkler zone along the left column and move right until you are in the column of the amount of water to be applied. This is the number of minutes to run your sprinkler.
Example: Your sprinkler applies water at 1.5 inches per hour and you want to apply 0.5 inch, it takes 20 minutes.

Author: David Whiting, Colorado State University Extension (retired).
Revision: Kurt M. Jones, Chaffee County Extension Director (9/2017).

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

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CMG GardenNotes #267

Watering Efficiently

Of the seven principles of water-wise gardening, attention to irrigation efficiency has the greatest potential for water conservation for most residents. In the typical home yard, extra attention to irrigation system design, maintenance and management could reduce water use by 20 to 70%, or 40% on average.

Irrigation Zones Reflect Water Need

Unfortunately, in the design of many home irrigation systems, little attention is given to zoning by water need.

- **Zone by irrigation demand** – The following examples have different water requirements and should be independent irrigation zones.
    - Lawns—Routine irrigation
    - Lawns—Reduced irrigation
    - Lawns—Limited irrigation or non-irrigated
    - Mixed flower and shrub beds—Routine irrigation
    - Mixed flower and shrub beds—Reduced irrigation
    - Mixed flower and shrub beds—Limited irrigation
    - Vegetables – routine irrigation
    - Tree fruits – reduced irrigation
    - Small fruits – routine to reduced irrigation depending on the fruit

- **Zone by exposure** – Because exposure to sun, heat, and wind also plays a significant role in water requirements, irrigation zones should reflect exposure levels. For example, lawn on an open, windy, southwest-facing slope will have considerably higher water requirements than the average lawn. Design this southwest slope as an independent irrigation zone.

  Areas in full or partial shade may have lower irrigation needs than areas in full sun. As a rule of thumb, if a shady area is outside of the rooting zone of large trees, water use may be 30 to 50% lower. If the shady area is in the rooting zone of large trees, water use will be similar to full sun (the tree pulling water from the soil is not in the shade.) Irrigation zones should reflect site needs.

- **Drip irrigation** in flower and shrub beds, small fruit gardens, and vegetable gardens can reduce water usage by 50% when coupled with organic mulch. For details on drip irrigation, refer to *CMG GardenNotes #263*, Irrigation Equipment.

Sprinkler Design Criteria for Uniform Water Distribution

Unfortunately, in the design of many home (and commercial) sprinkler systems, little attention is given to design criteria for water conservation.

Sprinklers do not deliver a uniform quantity of water over their distribution area. Thus to keep the dryer spots (i.e., spots that receive less water) green the rest of the area receives more water than needed. Designing sprinkler layouts to provide a more uniform water delivery can reduce water use by 25 to 50%. Most home lawn sprinkler systems have a 30 to 40% efficiency rating, whereas a 70 to 80% rating is very achievable with attention to design and management.

Sprinkler design criteria for uniform water distribution include the following:

1. **Head-to-head coverage** – Designs with head-to-head coverage (i.e., the water from a sprinkler head reaches the neighboring sprinkler heads) generally give the most uniform delivery. A 10 to 20% overlap may actually give the best uniformity. In other words, space heads at 90% of their radius of throw. For example if the radius of a pop-up spray head is 15 feet, the ideal spacing would be 13.5 feet (15’ x 90%); and maximum spacing would be 15 feet. Wider spacing could increase water use by 25 to 50%. [Figure 1]

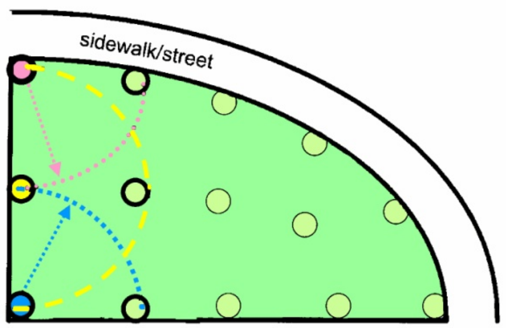


Figure 1. A standard in sprinkler design is head-to-head coverage. Ten to 15% overlap may give even better uniformity.

2. ***Line out* the edge** – In the design process, start by *lining out* the edges (i.e., run a line of sprinkler heads down the edge of the lawn or irrigated area), spraying onto the lawn but not onto the sidewalk, street or non-irrigated area. [Figure 2]

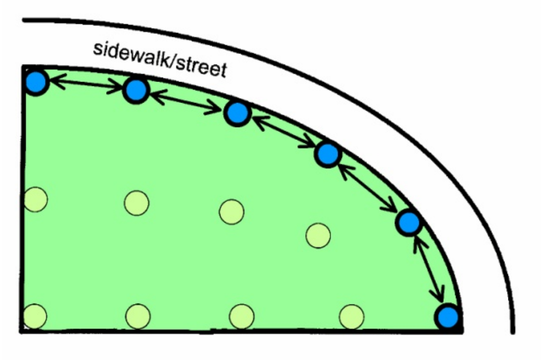


Figure 2. Start the layout by lining out the edge, running a row of sprinkler heads along the edge of the irrigated/non-irrigated areas.

In sprinkler design, avoid layouts where sprinkler heads spray from the center of the lawn area out onto the sidewalk. It either wastes 20% of the water as it over-sprays onto the sidewalk or creates a dry lawn area along the edge. [Figure 3]

If our society is going to deal with limited water supplies, it has to become unacceptable for the homeowner, private and commercial property manager or government entity to apply irrigation water onto roads, sidewalks and parking lots.

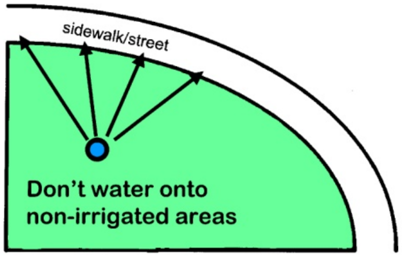


Figure 3. Spraying from the center out onto a sidewalk or non-irrigated area is unacceptable in water-wise landscaping.

3. **Arrange heads in square or triangular patterns** – In the next step of the irrigation design process, fill in larger areas with sprinkler heads in square or triangular patterns. Square and triangular head patterns give the most uniform water delivery. [Figure 4]

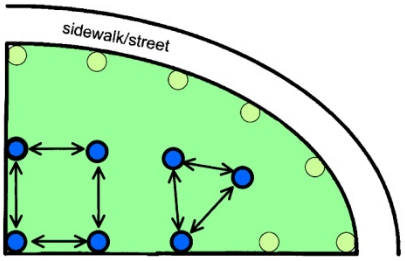


Figure 4. For uniform water delivery, fill in heads in square and triangular patterns.

In irregularly shaped areas, heads easily fall into pentagon (five-sided) patterns. Avoid these as it creates an area that receives less water than other parts of the lawn. [Figure 5]

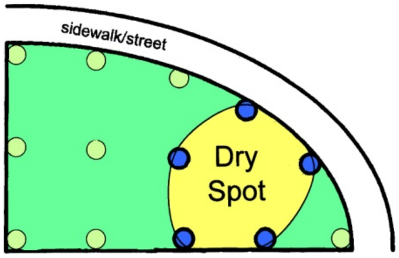


Figure 5. Avoid pentagon-shaped head layout. The area receives less water, creating a dry spot.

4. **Avoid irrigating small, irregularly shaped areas** – It is impractical to sprinkle irrigate small areas (less than eight feet wide) and irregularly shaped patches without applying water where it is not needed. In small or irregularly shaped areas, consider replacing lawns with plantings that can be watered with drip irrigation, or consider non-irrigated options. For example, in the narrow side yards around urban homes, consider a low-water-requiring ground cover or a non-irrigated mulch area.

5. **Use recommended water pressure** – Water distribution patterns change with pressure. Use the pressure recommended for the specific sprinkler head in use. Most sprinklers in the home garden trade are designed to operate at 30 to 40 psi. Commercial heads typically operate at 40 to 100 psi, and some heads have built-in pressure regulators.

New homes typically have a pressure regulator where the water line enters the home. In older homes, adding a pressure regulator may significantly reduce landscape water use.

Sprinkler Maintenance Criteria for Uniform Water Distribution

We have all noticed that blown sprinkler head down the street that goes unfixed for weeks. A problem with automatic sprinkler systems is that the gardener may not be aware of a system malfunction. Check the irrigation system's operations frequently.

As water-wise gardening concepts spread in our community, we need to adapt the practice of alerting neighbors to popped sprinkler heads and other system malfunctions. With an automated sprinkler system, many residents or landscape managers may be unaware of the mechanical failure.

Maintenance issues for uniform water distribution include the following:

- **Arc adjustment** – Sprinkler heads (particularly rotor-type heads) frequently require adjustment of delivery angle to keep water on the irrigated areas and off non-irrigated areas. [Figure 6]

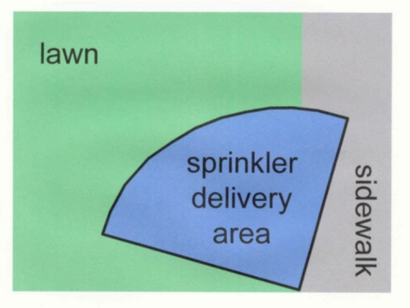
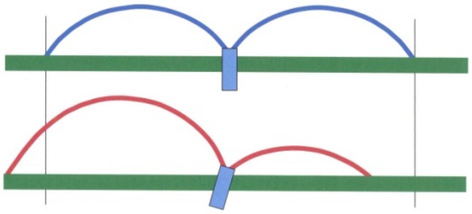


Figure 6. Heads frequently shift their delivery arc. Frequent adjustment is required.

- **Adjust radius of throw** – As discussed in design, water from one sprinkler head needs to reach adjacent heads for uniform delivery. A 10 to 20% overlap is preferred where it does not spray a non-irrigated area. Occasional adjustment on the radius of throw may be needed. This is done with a screw adjustment on the nozzle or changing out the nozzle to one with a different radius.

- **Adjust sprinkler heads to vertical** – Distribution patterns change when the head tilts off vertical alignment. To correct it, remove a donut shape of sod around the head with a shovel. Carefully loosen the soil around the head. Realign the head to vertical, and then firmly pack soil around the base of the head before replacing the sod. [Figure 7]

Figure 7. Heads require frequent adjustment back to vertical. Tilted heads change the distribution pattern.



- **Adjust head height** – When water flow does not clear the grass height, the distribution pattern can be distorted. Raise heads to release water above grass height. On the other hand, sprinkler heads set excessively high can be a trip hazard and can interfere with mowing. [Figure 8]

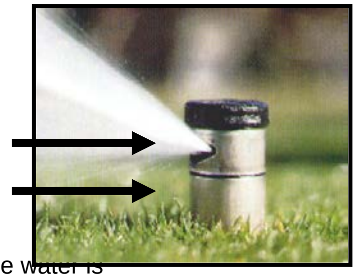


Figure 8. Raise height of head to a point where water is released well above the grass height.

To correct this, remove a donut shape of sod around the head with a shovel. Carefully loosen the soil around the head. Adjust head to the correct height, and then firmly pack soil around the base of the head before replacing the sod.

- **Replace worn nozzles** – As sprinkler nozzles wear, distribution patterns change, giving a less uniform water delivery. Periodically replace old, worn nozzles. [Figure 9]

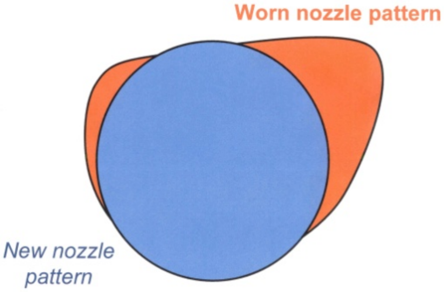


Figure 9. Worn nozzles distort the delivery pattern.

- **Adjust pressure** – A mist cloud around a sprinkler head indicates that the water pressure is too high for the head. Reduce pressure to avoid wasting water. A pressure regulator can be added to the main supply line. When adjusting pressure, slowly drop the pressure until you see water flow just start to drop, then up the pressure just a touch.

- **Replace leaky valves** – In an irrigation valve, the rubber diaphragm that actually turns water on and off ages over time. Valves that do not shut off completely need the diaphragm or entire valve replaced. Values often fail to shut off if the pressure is above 80 psi.

Sprinkler Management Criteria for Water-Wise Irrigation

Sprinkler management addresses two primary questions, how much and how often. Irrigation scheduling is discussed in more detail in *CMG GardenNotes #265*, Methods to Schedule Home Lawn Irrigation.

- **Know the *precipitation rate* for each irrigation zone, and adjust run time to match water need of each zone.** – The first step in irrigation management is to calculate the precipitation rate for each zone. Once the precipitation rate is know, the controller can be set to deliver the desired amount of water. Because distribution patterns and precipitation rates generally vary from zone to zone, run times should be set for each irrigation zone based on precipitation rates.

Most irrigation controllers are set with all zones receiving the same run time. This results in zones that need less water being over-watered.

- **Adjust irrigation controller for the season** – As summer temperatures increase, water use goes up; as cooler fall weather moves in, water use goes down. Unfortunately, most gardeners have their controllers set for the summer, and never adjust the controllers for the season. Most lawns and gardens are over-watered by 40% in the spring and fall. Iron chlorosis is a common symptom of springtime over-watering. Several methods can be used for irrigation scheduling. For details, refer to CMG GardenNotes #265, *Methods to Schedule Home Lawn Irrigation.*

- **Water bluegrass at 80% ET** – When water is available, Kentucky bluegrass uses significantly more water than what it actually needs to remain green. Bluegrass also slows its water use and growth rate as soil moisture decreases. Watered at 80% ET, a home bluegrass lawn will remain thick and green. Watered at 60% ET, a home bluegrass lawn will remain green, but not as thick.

- **Summer-dormant Kentucky bluegrass** – Where appropriate for the use of the site, summer-dormant Kentucky bluegrass has a very low seasonal water use. It requires only 14 inches of rain and irrigation per year (applied in the spring and fall). For additional details, refer to *CMG GardenNotes #412*, Water-Wise Landscape Design: Selecting Turf Options.

- **Turn off sprinklers in rainy weather** – Manually shutting off the sprinkler system during rainy weather is another effective management tool. An inexpensive investment (around $25) to help manage the irrigation system is a rain shut-off sensor. In many parts of the country, but not Colorado at this time, local ordinances require rain shut-off sensors.

- **Soak and cycle** – On slopes and on compacted or clayey soils water can be applied much faster than it can infiltrate into the soil, leading to surface run-off. To deal with this, use multiple short-run cycles that allow the water to soak in between cycles. Most controllers readily accommodate this with multiple start times.

  On clayey soil with pop-up spray heads, apply about quarter-inch per cycle (about eight to ten minutes) with two or three cycles to apply one-half-inch to three-quarters-inch of water per irrigation. Runs are typically spaced an hour apart or, more commonly, after all the zones have run it cycles again.

- **Dry spots** – The common approach for managing dry spots is to increase the amount of water applied. Although it may green up the dry spots, it also over-waters the rest of the lawn, wasting water.

  To evaluate a dry spot, first place some identical, straight-sided, flat bottomed cans (like soup or vegetable cans) out to measure the water applied. Compare the amount of water received in the dry spot to the amount of water received in green areas. If the dry spot receives significantly less water, it is a water delivery problem (like a malfunctioning head or design problem). If similar amounts of water are being received, the problem is soil/plant related (like compaction, thatch and root damage).

Note: as the gardener fine-tunes the management of his/her irrigation system, dry spots will show up in hot weather. This indicates that he/she is successfully walking the edge on ideal irrigation management.

- **Aeration** is a primary tool to increase water infiltration. Aeration may be useful spring and fall on lawns with a lot of traffic (children and dogs), compacted, clayey soils and slopes. Refer to lawn care information for details.

- **Water deeply and infrequently** to develop a deep root system that gives the plants more resilience in hot, dry weather.

- **Water at night or early morning hours –** To reduce water loss from evaporation, water between 9:00 in the evening and 9:00 in the morning. In many areas, wind drift is less in the early morning hours. (Note: Some cities experience peak water use from 4 to 6 in the morning as automatic sprinkler systems come on. To help the community avoid spikes in water demand, remember the suggested watering window is 9 in the evening to 9 in the morning, not just 4 to 6.)

Additional Information – *CMG GardenNotes* on Irrigation Management

#260	Irrigation Management: References and Review Questions
#261	Colorado’s Water Situation
#262	Water Movement Through the Landscape
#263	Understanding Irrigation Management Factors
#264	Irrigation Equipment
#265	Methods to Schedule Home Lawn Irrigation
#266	Converting Inches to Minutes
#267	Watering Efficiently
#268	Home Lawn Irrigation Check-Up

Author: David Whiting, Colorado State University Extension (retired).
Artwork by David Whiting; used by permission.
Revision: Kurt M. Jones, Chaffee County Extension Director (9/2017).

Revised September, 2017

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #268

Irrigation Management Worksheet:
Lawn In-Ground Sprinkler System Check-UP

Name: ___________________

This activity is a check-up on an in-ground lawn sprinkler system. If you don't have access to an in-ground sprinkler system for the activity, please contact the instructor for an alternative activity.

To complete the irrigation check-up, you will need the following items:

- 6, identical straight-sided, flat bottom cans or cups (do not use tuna or other short cans)
- Watch
- Ruler
- Colored flags or other marking tools (screwdrivers or sticks) to mark sprinkler heads by zone (helpful)
- Calculator
- Screwdriver and/or soil probe

Why do an irrigation check-up

For most residents, attention to irrigation efficiency has the greatest potential for water conservation of all the principles of water wise landscaping. In the typical home yard, extra attention to irrigation system design, maintenance, and management will reduce water use by 20% to 70%; 40% being average.

The purpose of a lawn irrigation check-up is a systematic evaluation of the irrigation system design, maintenance, and management. It will identify areas where adjustments will make a minor or major impact on water conservation and lawn quality. Run times for each sprinkler zone will be calculated based on the precipitation rate of each zone.

The check-up is only a tool to help the gardener identify where the system is working adequately and where adjustments need to be made. Actual water conservation comes as findings are incorporated.

Note: Carry out a normal watering the day before doing the check-up.

Step 1 – Visually evaluate the lawn

1. How does the lawn look?

☐ Green (high input lawn)
☐ Green (moderate input lawn)
☐ Green (low input lawn)
☐ Dry spots: _____% of lawn
☐ Dry/Dormant

☐ Thick
☐ Thin

☐ Weed free
☐ Few weeds
☐ Weedy

2. Soil conditions

1. Stick a screwdriver in the ground to get a sense about soil compaction. The ease or difficulty at which the screwdriver can be pushed into a <u>moist</u> soil gives a grasp of soil compaction.

2. If possible, use a soil probe to get a sense on soil texture, compaction, soil layers, rooting depth, and thatch layer. Note: On compacted or rocky soil, it may impossible to push a soil probe into the soil. On extremely compacted soils, it may even be impossible to push a screwdriver into the soil.

- Soil compaction
  ☐ Little to no compaction (screwdriver/probe readily goes in)
  ☐ Moderate compaction (screwdriver/probe hard to push in)
  ☐ Severe compaction (screwdriver/probe extremely difficult to impossible to push in)
  ☐ Aeration needed to increase infiltration

- Soil texture
  ☐ Coarse texture (sandy)
  ☐ Moderate texture (loamy)
  ☐ Fine texture (clayey)

- Soil profile
  ☐ Changes in soil texture evident
  ☐ Hardpan layer
  ☐ Evidence of drainage problems (such as surface pooling)

- Thatch layer
  ☐ Less than 1/2 inch
  ☐ Greater than 1/2 inch
    ☐ Aeration needed to manage thatch

- Runoff potential
  ☐ Low potential
  ☐ High potential (use cycle and soak application)
    ☐ Due to slope
    ☐ Due to soil conditions (compaction and clayey soils)
    ☐ Due to heavy thatch

3. Current irrigation pattern

- During the summer (July/August) the lawn is typically watered ____________________ (days) for ____minutes

- During the typical July/August weather, the lawn can go ____ days between irrigation before getting dry.

  - Multiply the number of days (maximum) between summer irrigations by 0.20 to estimate the water holding capacity for the soil and rooting depth at this site. This is the maximum amount of water to apply per irrigation.

  - **___ days x 0.20 inches = _____ inches per irrigation (maximum)**

4. Notes

Step 2 – Current Controller Settings

Record current settings from the controller including watering days, start time(s) and run times. Note Precipitation rates and inches applied may be calculated later. This will be used to document water saving potential from the check-up.

Controller is set for ___________________ (month).

Table: Step 4 – Current Setting and Inches Applied

Zone	Zone Identity	Watering day(s)	Start time(s)	Run time	Precipitation Rate	Inches Applied
1						
2						
3						
4						
5						
6						

Step 3 – Identify and Evaluate Irrigation Zones

A. Identify the location of each sprinkler head in each zone (a group of sprinkler heads that come on at the same time). Using difference colors of landscape flags or other marking devices (like screwdriver or stick pushed in the ground near each head) is helpful. Sprinklers may need to be turned on to find and identify sprinkler heads by zone.

B. Evaluate the following hydrozone layouts

Step 3. Irrigation Zones	OK – Concept incorporated	Minor – Benefits received with minor adjustments or implementation	Major – Benefits received with major adjustments or implementation	Not applicable to site
Irrigation Zones				
1. Lawn zones separate from flower and shrub bed zones				
2. Lawn areas zoned by irrigation demand (i.e., high input, moderate input, and low input areas on separate irrigation zones)				
3. Zone by exposure (i.e., extreme exposures, full sun, partial shade, full shade, and slopes on separate irrigation zones)				
4. Drip or bubblers used in flowerbeds, shrub beds, small fruits, and vegetable gardens				
5. Design avoids sprinkler irritation on small, irregular shaped areas (generally areas less than 10 feet wide)				

C. If design does not meet this criteria, consider upgrading the irrigation system.

D. Notes:

Step 4 – Evaluate sprinkler performance

Turn on sprinklers and evaluate sprinkler performance as outlined below, repeating steps for each zone.

A. Design criteria for even water distribution

1. **Head to head coverage** – Does the water from each head reach neighboring heads? [*The Science of Gardening*, page 620]

Table 4a1 – Head to Head Coverage						
Zone	1	2	3	4	5	6
Yes = OK						
NO = adjustments needed*						

* In some situations adjusting heads or changing nozzles may correct the problem. In other situations, the system design may need to be up-graded for water conservation.

2. **Lined-out –** Are sprinkler heads "lined-out" along the edge of non-irrigated areas (watering form the outside in)? [*The Science of Gardening*, page 620]

Table 4a2 – Lined-out						
Zone	1	2	3	4	5	6
Yes = OK						
NO = upgrade needed*						

* If no, consider upgrading the sprinkler system for improved water conservation.

3. **Head layout –** Are sprinkler heads arranged in triangle and square patterns, avoiding pentagon patterns? [*The Science of Gardening*, page 621]

Table 4a3 – Head Layout						
Zone	1	2	3	4	5	6
Yes = OK						
NO = upgrade needed*						

* If no, consider upgrading the sprinkler system for improved water conservation.

4. **Zone uniformity** – Are all head in a zone the same brand and type?

Table 4a4 – Zone Uniformity						
Zone	1	2	3	4	5	6
Yes = OK						
NO = adjustments needed*						

* In some situations, replacing heads may correct the problem. In other situations, the system design may need to be up-graded for water conservation.

5. **Pressure –** Is there a mist cloud around sprinkler heads? [The Science of Gardening, page 621]

Table 4a5 – Pressure / Mist Cloud						
Zone	1	2	3	4	5	6
Yes = OK						
NO = adjustments needed*						

* A mist cloud indicates excessive pressure. Lower pressure to conserve water. In some situations, this may involve installation of an in-line pressure regulator.

6. **Notes/Comments**

B. Maintenance criteria for even water distribution

1. **Delivery arc –** For each head does the delivery angle need adjustments (to avoid spraying the sidewalk, driveway, or other areas outside the zone)? [*The Science of Gardening*, page 621]

Table 4b1 – Delivery Arc						
Zone	1	2	3	4	5	6
No = OK						
Yes = adjustments needed						
Identify heads needing adjustments						

2. **Vertical adjustment** – Do heads need adjustment to vertical (straight up and down)? [*The Science of Gardening*, page 622]

Table 4b2 – Vertical adjustment						
Zone	1	2	3	4	5	6
No = OK						
Yes = adjustments needed*						
Identify heads needing adjustments						

* Heads off vertical will distort the delivery pattern. Adjust to vertical to conserve water.

3. **Height** – Is nozzle releasing water above grass height? [*The Science of Gardening*, page 622]

Table 4b3 – Height						
Zone	1	2	3	4	5	6
Yes = OK						
No = adjustments needed*						
Identify heads needing adjustments						

* When water doesn't clear grass height, distribution pattern may be distorted. Raise head.

4. **Worn Nozzles**– Look at the fan created by the water spray for each head. Is it uniform around the arc? This is rather difficult to evaluate by line of sight. [*The Science of Gardening*, page 622]

Table 4b4 – Worn Nozzles						
Zone	1	2	3	4	5	6
Yes = OK						
No = adjustments needed*						
Identify heads needing adjustments						

* Replace worn nozzles to improve distribution pattern.

5. **Replace leaky valves –** In the irrigation valve, the rubber diaphragm that actually turns water on and off ages over time. Valves that do not shut-off completely need the diaphragm or entire valve replaced. [*The Science of Gardening*, page 622]

Table 4b5 – Leaky Valves						
Zone	1	2	3	4	5	6
Valve not leaking = OK						
Valve leaking = needing replacement						

6. **Evaluate dry spots** – If the zone has a dry spot, place some cans on the dry spot and on the green areas. After running the sprinkler for their normal time, compare the amount of water received in each can. [*The Science of Gardening*, page 622]

Table 4b6 – Evaluate Dry Spot						
Zone	1	2	3	4	5	6
No dry spots						
Dry spot(s) receiving less water than the green areas[1]						
Dry spot(s) receiving similar amounts of water as green areas[2]						

[1] When the amount of water received in dry area cans is significantly less than the green area cans, poor water distribution is a primary contributor. Evaluate irrigation design and maintenance issue.

[2] When the amount of water received in both the green area cans and dry area cans is similar, the problem is not directly related to sprinkler performance. Evaluate other growth factors, including soil compaction, thatch, run-off, insect or disease problems, etc.

<u>Adjusts identified in step 4 need to be performed before continuing to step 5.</u>

Step 5 – Perform precipitation rate (catch can) test

Perform a precipitation rate test (catch can test) for <u>each</u> zone, recording the precipitation rates in **Run Time Table.** [*The Science of Gardening*, page 631]

<u>Precipitation Rate (Catch Can Test)</u>

To do the calculations you will need 6 identical, straight-sided, flat bottom, cans or coffee mugs such as soup cans, fruit or vegetable cans, or coffee cans. (Do not use short cans like tuna cans as they are too shallow and water may splash out.) You will need a ruler, a watch, and paper/pen to record your findings.

Steps

a. Place 6 identical, straight-sided, flat bottom cans or coffee mugs randomly around the area between sprinkler heads in the zone.
b. Turn on the sprinklers for exactly 10 minutes.
c. Pour all the water into one can.
d. With a ruler, measure the depth of the water in the can. This is your precipitation rate in inches per hour.
e. Write down the rate for each zone in **Table: Step 8**
f. Repeat steps 1-5 for each irrigation zone.

Note: if the amount of water in some containers is significantly more or less than others, it indicates that the system is poorly designed or head(s) are malfunctioning.

Table 5 – Precipitation Rate						
1. Zone	1	2	3	4	5	6
2. Precipitation Rate (inches/hour)						

Step 6 – Calculate system run times for each zone

A. Working down through the table, calculate the run time per irrigation.

Table 6a – Run Times						
Zone	**1**	**2**	**3**	**4**	**5**	**6**
1. Historical Summer ET amount of water to apply	1.5”/week					
2. Precipitation Rate – inches/hour from catch can test, Table 5, Row 2						
3. Run time per week (July/August) Based on Precipitation Rate for the zone (line 3), look this up from Table 50-2 (page 612) or Table 52-1 (page 632).						
4. Number of irrigations/week Refer to Step 1-3 above						
5. Run time per irrigation Convert the ***Run Time per Week*** (line 4) to ***Run Time per Irrigation*** using table 50-3 (page 612) or Table 52-2 (page 633)						

B. Adding Cycle and Soak

Most clayey and/or compacted soils cannot absorb water as quickly as sprinklers apply it. Many clayey soils, typical of the Front Range, absorb about ¼ inch of water per hour. Therefore, the most effective watering schedule on these soils would be to set each zone to deliver no more than ¼ inch per cycle with multiple cycles. For example, if the lawn is to have ½ inch of water, set controller to apply ¼ inch and cycle back an hour later to apply the second ¼ inch. If the lawn was to have ¾ inch, set the controller to apply ¼ inch per cycle with 3 cycles.

Soak and cycle is particularly helpful on slopes to avoid wasteful surface runoff.

Use Table 50-4 (page 613) or Table 52-3 (page 633) to determine if Cycle and Soak is desired.

Table 6b – Cycle and Soak						
Zone	**1**	**2**	**3**	**4**	**5**	**6**
1. Need for *Cycle and Soak*? Yes/No						
2. Run Time Per Irrigation from Table 6a, Line 65						
3. Number of cycles from Table 50-4 (page 613) or Table 52-3 (page 633)						
4. Run Time Per Cycle Divide ***Run Time per Irrigation*** (line 2) by ***Number of Cycles*** (line 3)						

Step 7 – Start time(s)

a. Determine the first start time

Most communities suggest nighttime irrigation, between 9 p.m. and 9 a.m. Winds are typically less in the early morning, and evaporation loss will be lower. However, many communities experience peak water use from 4 to 6 a.m. as many sprinklers come on, so remember that the irrigation window is 9 to 9, not just 4 in the morning.

Enter your first start time into Table **7–Start Time(s), row 1**

b. Adding additional start times for Cycle and Soak (if needed)

1. Add all the Run Time per CYCLE together.
2. **Cycle Time** – Round this up to the next ¼ or ½ hour (depending on what start time intervals are used in your controller start options). This is the time to run through all the zones. Add this to **Table 7-Start Time(s), Rows 2 and 4** below. Or add 1 hour if the total run time is less than 60 minutes.
3. Add this to the first start time for the second start time. Record your second start time in **Table 7-Start Times) Row 3, Start Time 2**.
4. Likewise, if a third cycle is needed, add this to the second start time to get the third start time. Record this in **Table 7-Start Times) Row 5, Start Time 2**.

Table 7 – Start Time(s)	
1. Start time 1	
2. Total cycle time	
3. Start time 2 (if needed) [add line 1 to line 2]	
4. Total cycle time	
5. Start time 3 (if needed) [add line 3 to line 4]	

Step 8. Set the Controller for July/August Run Time

1. Set the run times for each zone as listed in **Table 6a, line 6** if Cycle and Soak is not used, or **Table 6b, line 4** if Cycle and Soak is used.

2. Set the start time(s) as given in Table 7-Start Time(s)

Step 9. Seasonal Adjustment

A simple way to adjust for the season is to use the *Percent Key* found on most controllers.

- For Late April and early October, set the percentage to 50%
- For May/June and September, set the percentage to 67%

An alternative method is to repeat Step 6 to 8 for the spring/fall season.

Step 10. Fine-Tune to Match Site Specific Needs

These textbook figures are a good start point in irrigation management. However, any scheduling method will need fine-tuning to match the actual water need of the site based on the exposure, wind, heat, and shade. This is done by careful observation of the lawn.

- **When adjusting all zones**, the *Percent Key* on most controllers makes an easy method to fine-tune for the actual site by adjusting the percentage up/down in 10% increments, as needed. It can also be done by adjusting the run time of each zone up/down in 10% increments, as needed.

- **When adjusting a single zone**, adjust the run time for that zone up/down in 10% increments, as needed.

In the typical summer weather, if the lawn starts to become dry between irrigations, increase the run time in 10% increments, as needed. By experience, it is easy to fine-tune each irrigation zone. In multiple days of unseasonably hot weather, dry spots should begin to pop up if the controller if precisely fine-tuned. In unseasonably hot weather, if dry spots do not pop up, the lawn is being overwatered. Cut back the time in 10% increments, as needed to fine-tune each zone.

The following guidelines may help you understand some needs for adjustments:

- In full shade (not under a large tree), water use (ET) could be 30% less.
- In hot and/or windy sites, water use (ET) could be 20% to over 50% higher.
- In the rooting area of large shade trees, water use (ET) could be 30% to 50% higher.

Author: David Whiting, Extension Consumer Horticulture Specialist (retired), Colorado State University Extension.
Revision: Kurt M. Jones, Chaffee County Extension Director (9/2017).

Revised: September, 2017

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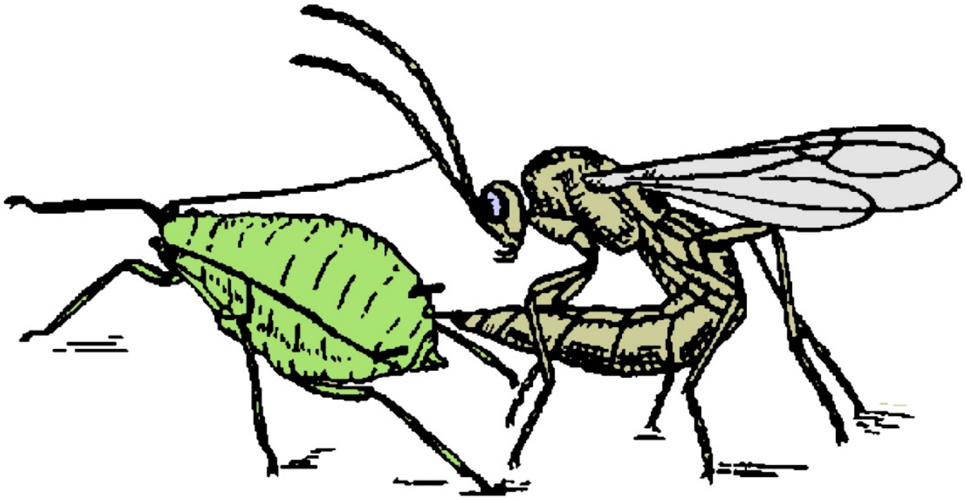

Identifying Insects

Reference

CMG GardenNotes

#310 Identifying Insects: Reference and Study Questions
#311 Taxonomy of Arthropods (Insects and Insect Relatives)
#312 Insect Anatomy and Growth
#313 Insect Orders
#314 Key #1—Key to Insects Associated with Gardening
#315 Key #2—Key to Insect Orders
#316 Worksheet: Identifying Insects
#317 Homework: Identifying Insects
#318 Homework: Entomology

Books

- ***Garden Insects of North America*** by Whitney Cranshaw. Princeton University Press. 2004.
- ***Insects and Diseases of Woody Plants of the Central Rockies*** by Dr. Whitney Cranshaw, Colorado State University Extension # 506A. 2004.
- ***Pests of the West*** by Dr. Whitney Cranshaw. Fulcrum Publishing. 1998. ISBN: 1-55591-401-2

Curriuclum developed by David E Whiting, Extension Consumer Horticulture Specialist (retired), Colorado State University. Revised by Mary Small, Colorado State University Extension.

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Revised July 2017

Learning Objectives

At the end of this unit, the student will be able to:

- Identify common insects to taxonomic orders.

Review Questions

1. Describe the identifying characteristics of the following orders:

    a. *Coleoptera* (beetles)
        1) Adults
        2) Typical *grubs*
        3) Some borer larva in trees

    b. *Diptera* (flies)
        1) Adults
        2) Larva: *maggot*

    c. *Hemiptera*, *Suborder Heteroptera*,(true bugs)

    d. *Hemiptera, suborder Homoptera*
        1) Aphids
        2) Scale

    e. *Hymenoptera* (bees, wasps, sawflies, etc.)
        1) Adults
        2) Sawfly larva

    f. *Lepidoptera*
        1) Adults (butterflies, moths)
        2) Larva: *caterpillars*

    g. *Orthoptera* (Grasshoppers, katydids, and crickets)

2. How do you quickly tell the following orders of insects apart?

    a. Caterpillars (*Lepidoptera* larva) from sawfly larva (*Hymenoptera*)
    b. *Diptera* adults (flies) from *Hymenoptera* adults (bees, sawflies, hornets etc.)
    c. Hemiptera, *Homoptera* suborder nymphs from *Heteroptera* suborder nymphs
    d. Hemiptera, *Homoptera* suborder adults and *Hemiptera* suborder adults
    e. *Beetles* (Coleoptera) from true bugs (*Hemiptera, suborder Heteroptera*), and cockroaches (*Blattaria*)

3. What orders and families have maggot or maggot-like larva?

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CMG GardenNotes #311

Taxonomy of Arthropods
(Insects and Insect Relatives)

Introduction

Insects and Mankind

Insects are the most abundant and diverse form of life found on earth. Over three-quarters-of a million species are known to exist, more than the number of all kinds of animals and plants put together. Insects are a vital part of the world's ecosystem.

Insects are a major link in the world food chain. Insects like bees, wasps, flies, bugs, and beetles pollinate crops. Insects destroy various weeds in the same manner that they can injure crops. Insects improve the physical conditions of the soil, and promote its fertility by decomposing plant residues and aerating the soil. Insects help control insect pests as predators and parasites. Only a few of the thousands of species are pests of mankind or his crops.

Most books list insect pests according to host plants, or by orders (beetles, bugs, flies, etc.) and families (aphids, scales, leaf beetles, etc.). When gardeners can identify insects to order, they will be able to identify the majority of pests by the process of elimination. Most routine garden pests are readily identifiable to order, some to families. However, there are always a few insects, with atypical appearances, that do not fit standard descriptions.

Insect Orders

"Order" is one of the levels of taxonomy. Most common names for insects describe the insect *orders*. For example, "beetle" is the common name for members of the *Coleoptera* order, and "butterflies" and "moths" for the *Lepidoptera* order.

Insect Identification

Identifying an insect is easy when:

- The insect is large enough to see.
- The insect is associated with plant damage.
- The insect has typical characteristics for the order and family.

Insect identification is more difficult when:

- The insect is too small to see characteristics.
- The insect is not associated with plant damage.
- The insect has atypical characteristics for the order or family.
- The insect has moved on, leaving only damage symptoms.

Taxonomy of *Arthropoda* (Insects and Insect Relatives)

The phylum *Arthropoda* includes insects, plus spiders, mites, tick, sowbugs, centipedes, millipedes, and more. They are characterized by chitinous exoskeletons, segmented bodies and jointed appendages.

Class

- ***Arachnida*** — Spiders, mites, ticks, scorpions, and daddy-long-legs
- ***Chipoda*** — Centipedes
- ***Crustacae*** — Lobsters, crabs, shrimp, sowbugs, and pillbugs
- ***Diplopoda*** — Millipedes
- ***Symphyla*** — Garden centipedes
- ***Hexapoda*** (or *Insecta*) — Insects

Orders of Hexapoda

- ***Coleoptera*** — Beetles
- ***Diptera*** — Flies
- ***Lepidoptera*** — Butterflies and moths
- ***Hemiptera*** — True bugs
- ***Homoptera*** — Aphids, cicadas, leafhoppers, scales
- ***Hymenoptera*** — Ants, bees, hornets, sawflies, wasps
- etc.

Family

Some insects, such as beetles, are easy to identify to family, while others, like flies, are more difficult.

Genus and species

Actual identification of an insect to genus and species requires a very high level of expertise.

Insect Relatives

Class: *Arachnida*

Spiders, Mites, Ticks, Scorpions, Daddy-Long-Legs

Arachnids (spiders, mites, and ticks) have four pair of legs and two body regions, the ***cephalothorax*** (a fusion of head and thorax) and the abdomen. [Figure 1]

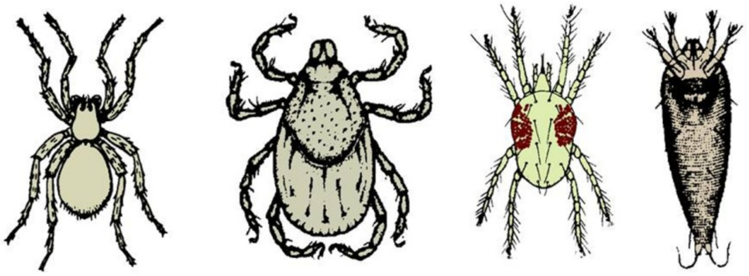

Figure 1. Arachnids (left to right): spider, dog tick, two-spotted mite, eriophyid mite

Class: *Crustacea*

Sowbugs, Pillbugs, Shrimp, Lobster, and Crayfish

Pillbugs and sowbugs are land crustaceans that usually have 5-7 pair of legs. They have two pair antennae and two body regions. The pillbug will roll into a ball, the sowbug cannot. [Figure 2]

Pillbugs and sowbugs are organic matter feeders, occasionally feeding on tender roots. Pillbugs and sowbugs can become a pest when numbers become very high or when they invade a home.

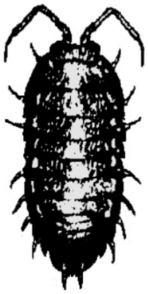

Figure 2. Sowbug

Class: *Diplopoda*

Millipedes

Millipedes have <u>two pair of legs per body segment</u> (except the first three). The body is usually cylindrical, 1 to 1 1/2 inches long, with short antennae. They may have 15 to 150 body segments, with 30 being common. [Figure 3]

Millipedes are usually found in damp and dark places, such as under leaves, under stones or boards, in rotting wood and in soils high in organic materials. If touched or picked up when crawling, they will curl up. They frequently invade homes, especially after a heavy rainstorm. They are not known to bite people. However, some species will give off an ill-smelling fluid. Most are scavengers and feed on decaying plant materials and overripe fruit. A few species attack living plants.

Figure 3. Millipede

Class: *Chilopoda*

Centipedes

Centipedes have flattened bodies with typically 40-50 body segments and one pair of legs per body segment. [Figure 4]

They are predatory, feeding on small spiders, carpet beetles, sowbugs, millipedes, and other small insets.

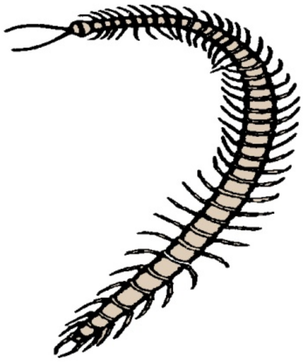

Figure 4. Centipede

Class: *Symphyla*

Garden Centipede

Garden centipedes are small (1/4” long), translucent relatives of centipedes. They have 12 pairs of legs at maturity and are usually found in the upper 6 inches of soil. They feed on germinating seeds and underground parts of plants. Centipedes, predatory mites and predaceous ground beetles are predators of symphylans.

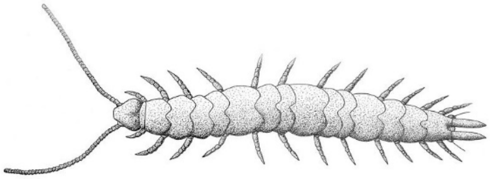

Fig 5. Garden Symphylan

Author: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension.
Line drawings: USDA; Symphyla: Wikimedia Commons. Revised by Mary Small, CSU Extension.

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CMG GardenNotes #312

Insect Anatomy and Growth

Outline

Identification and classification of insects is based on their structure and physiology. A basic understanding of insect physiology will enable the gardener to identify most insects to order and some to family.

External Structure

The exterior body wall, called an ***exoskeleton***, provides the structural support for the insect. It is composed of five distinct layers made of waxy lipoproteins and *chitin* (a cellulose like polymerized glucosamine). The acid resistant exoskeleton protects the insect from excessive dryness, humidity, and disease organisms.

This external skeleton is somewhat cylindrical and typically made up of 21 hardened, ring-like *segments*. These segments are arranged in three groups or body regions, the ***head***, ***thorax*** and ***abdomen***. The body may be covered by ***setae*** (hairs*)* and may have external protuberances, such as horns, spines, or spurs. [Figure 1]

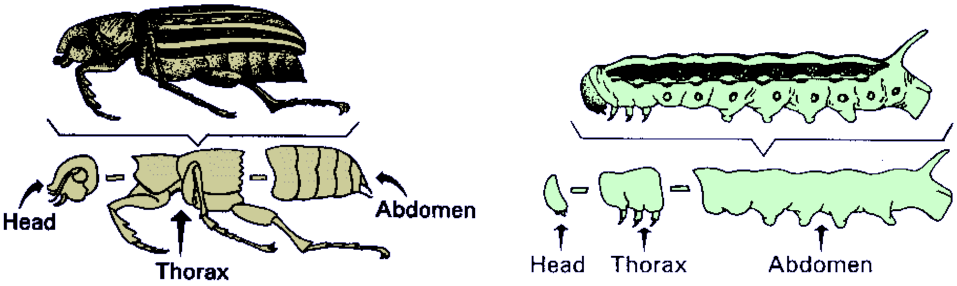


Figure 1. Body regions of beetle (left) and caterpillar (right).
[Line drawing: Colorado State University Extension]

Head

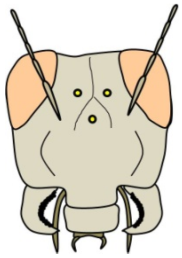
The head serves as a sensory center and for the intake of food. Main features of an insect's head include the eyes, antennae, and mouthparts.

Eyes

Insects have two types of eyes. To detect movement, most adult insects have a pair of lateral **compound eyes** comprised of multiple *ommatidium* (cornea). The number of ommatidia in the eye determines how well insects see. For example, dragonflies have approximately 50,000 per eye, house flies about 4,000 and ants about 50. These large compound eyes often occupy the greater portion of the insect head. Insects with large compound eyes are often predators, while insects with small compound eyes are often the prey. [Figure 2]

The ***ocelli*** or simple eyes are used for light responsiveness. Two or three are typically located between the larger compound eyes on most insect adults. Some immatures may have one to eight lateral ocelli. [Figure 2]

Figure 2. Grasshopper head; note large eyes, three ocelli between eyes, and large mandibles (chewing mouthparts). [Line drawing: David Whiting]



Antennae

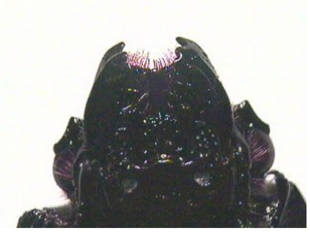
All adult insects and many immature stages have a pair of segmented antennae, used for sensory function. Many modifications in form occur and these variations are often used in identification.

Mouthparts

The most remarkably complicated structural feature of insects is the mouth. Mouthparts are modified for various types of feeding, chewing, or sucking.

The ***mandibles*** or ***chewing mouthparts*** move horizontally on insects. Insects with chewing mouthparts consume the plant or insect they are feeding upon. [Figure 3]

Figure 3. Chewing mouthparts of a beetle. [Photograph by David Whiting]



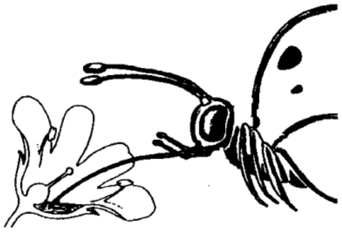
Sucking-type mouthparts vary greatly for different feeding habits. ***Piercing-sucking*** mouthparts are typical of the *Hemiptera* (true bugs), *Homoptera* (aphids, scales) and blood sucking lice, fleas, mosquitoes, and the so-called biting flies. These are designed to punch and suck on the plant's sap, victim's blood, or in the case of predatory insects to suck out the insides of the victims. [Figures 4 & 5]

Figure 4. **Piercing-sucking mouthparts of a cicada** — Insects with piercing-sucking mouthparts feed on plant sap, blood, or in the case of predators, their victim's insides. They do not consume the plant or insect tissues. [Photograph by David Whiting]

Figure 5. **Lapping mouthparts** — Flies are an example of an insects with lapping mouthparts. . [Line drawing: Colorado State University Extension]

The **siphoning** type found in butterflies and moths is a long coiled tube designed to suck up nectar. It looks like a cinnamon roll coiled up under the head. [Figure 6]

Figure 6. **Siphoning mouthparts** — Butterflies and moths have a coiled siphoning tube. To reach the nectar in flowers, the uncoiled tube may be longer than the butterfly's body. [Line drawing: Colorado State University Extension]



Intermediate types of mouthparts include the ***rasping-sucking*** type found in thrips, and the ***chewing-lapping*** types found in honey bees, wasps, and bumble bees.

Thorax

The **thorax** is made up of three segments (*prothorax, mesothorax and metathorax*).

Legs – A pair of legs is attached on each thorax segment. The insect's leg consists of five independent movable parts. Legs may be specially adapted for leaping, walking, digging, grasping, swimming, etc.

Wings – Insects may have one or two pairs of wings or no wings. The wings are attached to the latter two thorax segments. The wing ***venation*** (arrangement of the veins) is different for each species of insect and is often a means of identification. Wing surfaces are covered with fine hairs, scales or may be bare. On beetles, the thickened front wing, call ***elytra***, serves for protection when not in flight.

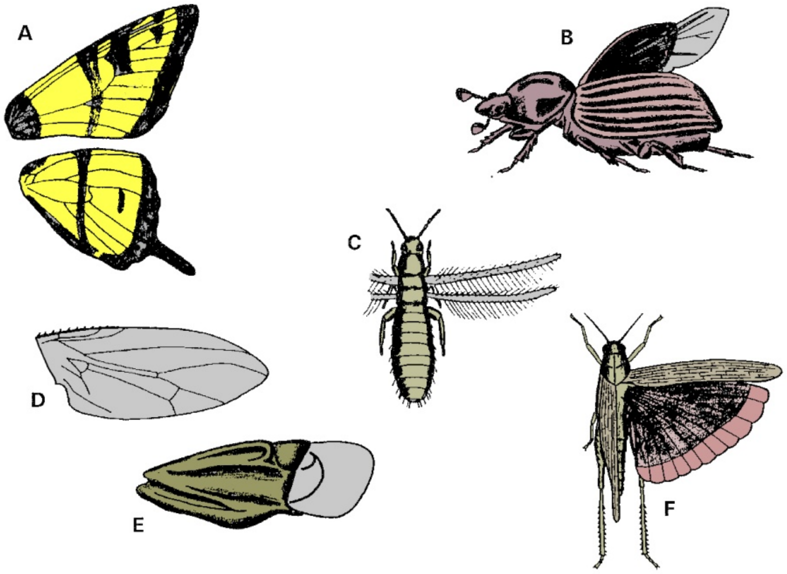


Figure 7. Types of insect wings: (A) scaly wing of moths and butterflies, (B) armor-like (elytron) and membranous wings of beetles, (C) feather wings of thrips, (D) membranous wing of a fly, (E) half-leathery/half-membranous wings (memelytron) of true bugs, and (F) wings of grasshoppers. Line drawing: Colorado State University Extension]

Abdomen

The **abdomen** may have eleven or twelve segments, but in most cases they are difficult to distinguish.

Prolegs (fleshy leg-like projections) occur on some larva such as caterpillars and sawfly larva. Prolegs, with tiny crochet-type hooks on the bottoms help the insect cling to plants. [Figure 8]

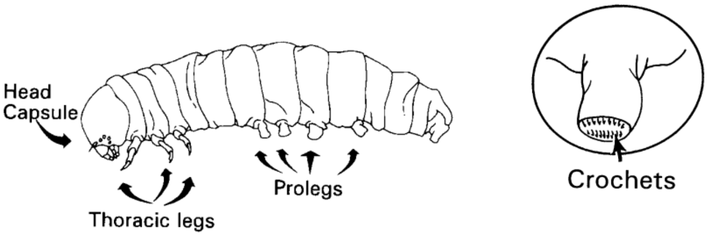


Figure 8. **Prolegs** (leg-like appendages on the abdomen of caterpillars and sawfly larvae) have small crochet-like hooks that help the insect cling to plants. [Line drawing: Colorado State University Extension]

Some insects have a pair of appendages called ***cerci*** at the tip of the abdomen. The pinchers on earwigs are the best-known example of cerci. Cerci may be short, as in grasshoppers, termites and cockroaches, extremely long as in mayflies, or curved as in the earwigs. They are sensory structures and may be used for defense or capturing prey. [Figure 9]

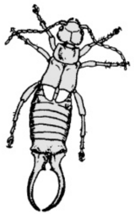


Figure 9. Earwig with cerci (pinchers) on end of abdomen.

Some groups have additional long segmented ***filaments***, which appear like antennae. [Figure 10]

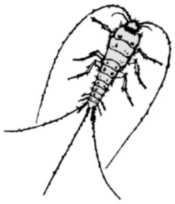


Figure 10. Silverfish with three filaments on end of abdomen.

The females of some insects have a prominent structure for depositing eggs, called an ovipositor. In bees, wasps, and ants the ovipositor is modified into a stinger. [Figure 11]

Figure 11. Horntail with large ovipositor on end of abdomen

The ***spiracles***, external openings used for respiration, are also present on the abdomen. Digestion, respiration, excretion, and reproduction are the main functions of the abdomen.

Internal Structure and Physiology

The muscular, digestive, circulatory, respiratory, nervous, and reproductive systems of insects are highly efficient. The insect's skeletal system has already been discussed as part of the external structure.

While insect **muscles** are very small, they are very strong and often capable of extremely rapid contractions. Grasshoppers are said to have over 900 distinct muscles and some caterpillars over 4,000. In comparison to humans, insect muscle tissues are very strong.

The **circulatory system** of insects is an open type. The blood is pumped by the heart from the abdomen toward the head, bathing the organs in the body cavity. Blood functions to transport nutritive materials to the tissues and to carry away certain wastes. With a few exceptions, the blood of insects contains no red corpuscles, and plays no part in respiration.

The **respiratory system** consists of a series of slender branching tubes or *tracheae*, which divide and subdivide throughout the body. Movement of oxygen and carbon dioxide is primarily by diffusion. Breathing-like movements help to ventilate the tracheae.

Insects have a two-part **nervous system**. The sympathetic nervous system controls functions of the heart, digestion, respiration, and possibly other systems. The peripheral nervous system controls sensory stimulations from the external environment.

Most insect **reproduction** is sexual, (the union of an egg cell from the female with the sperm cell from the male). Some species are capable of producing young without fertilization (***parthenogenesis***). A few species carry the eggs internally, giving birth to live young (***ovoviviparous***). Glands of the insect reproductive systems are similar to that found in higher animals.

Growth and Metamorphosis

The series of events from egg to adulthood constitutes the insect's ***life cycle***. The life cycle varies for each insect species. For example, mosquitoes under optimum environmental conditions may develop from egg to adult in 10 days, whereas the periodical cicadas require 13 to 17 years to complete their life cycle.

An understanding of an insects' life cycle is a critical element in insect management practices.

Because the *exoskeleton* cannot expand sufficiently to accommodate an increase in size, it is cast off during the process called ***molting***. The number of moltings varies considerably in the insect world. The form of an insect between successive molts is called an ***instar***.

The ***pupa*** is a non-feeding stage during which the larval structures are transformed into adult structures. ***Cocoon*** refers to pupal cases made of silk from the modified salivary glands of the larva. ***Chrysalis*** is a term that denotes the pupa of a butterfly.

Metamorphosis

One of the most distinctive features of the insect world is ***metamorphosis***, the marked or abrupt change in form, structure, and habit. Four basic types of metamorphosis are observed in the insect world.

No Metamorphosis

Upon hatching from the egg, the young insect with "no metamorphosis" development looks exactly like the adult except for size and minor differences in spines and setae (hairs). Size is the major change between each instar. Some species may molt after sexual maturity. The young and adults live in the same environment, and have the same types of mouthparts and feeding habits. These groups of very primitive, wingless insects include the *Thysanura* (silverfish) and *Collembola* (springtails). [Figure 12]

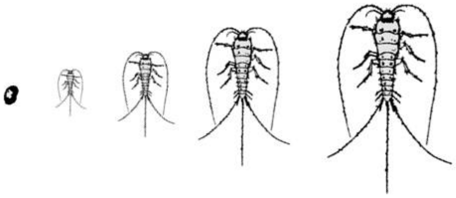


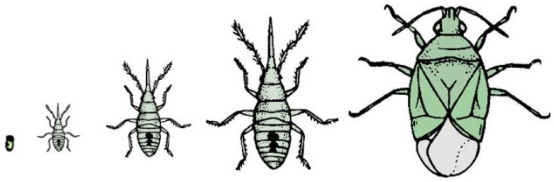
Figure 12. No Metamorphosis of silverfish: from egg (left), nymphs, and adult (right)

Simple Metamorphosis

In simple metamorphosis, the insect goes through three basic changes, egg, nymph, and adult. The nymphs typically go through three to five instars. Some books further divide simple metamorphosis into gradual and incomplete types.

In **gradual metamorphosis**, the newly hatched insect resembles the adult in general body form, but lacks wings and external genital appendages. With each successive molt, the nymph resembles the adult more than it did in the previous instar. Both nymphs and adults have the same type of mouthparts and food habits. Grasshoppers, squash bugs, and aphids are examples of insects with gradual metamorphosis. [Figure 13]

Figure 13. Simple-Gradual Metamorphosis of stink bug: from left to right: egg, nymphs, and adult.



Incomplete metamorphosis is characteristic of some orders with aquatic nymphs, such as *Emphemeroptera* (mayflies), *Odonata* (dragonflies), and *Plecoptera* (stoneflies). The changes that occur during the immature instar stages are more pronounced than in the case of insects with gradual metamorphosis, but not nearly so dramatic as in complete metamorphosis. The young, called *nymphs* or *naiads*, are aquatic insects found in rivers and streams, while the strikingly different fly-like adult is aerial. [Figure 14]

Figure 14. Simple-Incomplete Metamorphosis of Dragonfly from egg (left), naiads, and adult (right)

Complete Metamorphosis

Insects with complete metamorphosis have four developmental stages; **eggs**, **larva**, **pupa**, and **adult**. The insect may have several instars and molts as a larva, but it does not pick-up the characteristics of the adult with each molting. The larval stage is primarily an eating and growing state. All larvae have chewing or modified chewing mouthparts. [Figure 15]

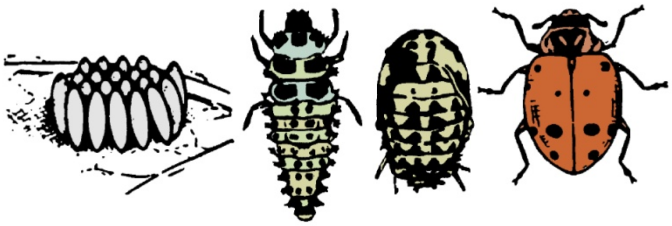


Figure 15. Complete metamorphosis of beetle from left to right: egg, larva (grub), pupa, and adult.

Various names apply to the larvae of insects from different orders. Beetle larvae are known as ***grubs***, butterfly and moth larvae are called ***caterpillars***, and the larvae of flies are known as ***maggots***. Grubs typically have three pair of legs on the thoracic segment and no prolegs on the abdomen. Caterpillars have three pair of legs on the thoracic segment and up to five pair of prolegs (fleshy leg-like structures on the abdomen). By comparison, sawfly larvae have more than five pair of prolegs. Maggots are typically legless.

When the larvae have attained maturity, they cease to feed and following a period of inactivity transform into the pupa stage. In the pupa stage the insect usually remains inactive and does not feed, but undergoes marked physiological and morphological changes. The insect emerges from the pupa stage as a functional adult.

In the case of many insects, provisions are made by nature to protect the helpless pupa. Some seek protection in the ground, while others hide under the bark of trees. Some spin cocoons of silk (moths) or pupate in the last larval skin (flies).

The primary function of the adult insect is reproduction. In many insect groups, the adults die soon after mating and laying eggs. Some adults do little or no feeding.

Insects with complete metamorphosis may have entirely different types of mouthparts and food habits in the larval and adult stages. For example, caterpillars (larva of butterflies and moths) have chewing mouthparts and feed on a variety of materials, while the adults have siphoning mouthparts and normally feed on plant nectar. Flea larvae feed on inert organic materials with their chewing mouthparts, while the adults suck the blood of their hosts.

Diapause is defined as a state or period of suspended activity in any stage of the life cycle. This state is initiated or terminated by environmental stimuli, such as photoperiod (length of the daylight), temperature, moisture, nutrition, or a combination of these. Diapause should not be confused with the cycles in metamorphosis.

Because eggs and pupa are non-feeding stages, they are resistant to insecticides. This is important point to remember when dealing with insect management.

Insect Names

All insects are classified into order, family, genus and species using scientific Latinized names. Scientific names are unique for that insect throughout the world. Genus names always begin with a capital letter, and species names are written entirely in lower case. Scientific names are printed in italics or underlined. In technical papers, the first entry of an insect name is followed with the name of the author whom first described the species. For example the honey bee, first described by Linnaeus is written *Apis mellifera* Linnaeus.

Common names, generally used by the public, often refer the insect to its groups such as orders, suborders, families or subfamilies, rather than individual species.

For example, "beetle" applies to all species in the order *Coleoptera*; “leaf beetle" applies to species in the family *Chrysomelidae*.

Generally, only the insect species commonly known by the public have common names. Most insect species occurring in the world do not have a common name.

Most common names of insects that consist of a single word (i.e., beetles, earwigs, thrips, or termites) refer to an entire order. Most common names applied to families consist of two or more words, the last being the name of the larger groups. For example, Carrion beetles, lady beetles, bark beetles, and blow flies.

Some common names are used for insects in more than one order, such as "fly" and "bug". The correct use and spelling of these words will help you identify orders. When a "bug" belongs to the *Hemiptera* order (often referred to as the "true bugs") it is written as two words (bed bugs, stink bugs, water bugs). When it does not belong to this order, it is written as one word (sowbugs, pillbugs, ladybugs). The same principle applies to "flies" and the fly order *Diptera*. Insects in the Diptera (fly) order are written as two words (house fly, deer fly, flower fly). When the fly-like insect is of another order, it is written as one word (dragonfly, stonefly, Mayfly).

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Line drawings from USDA. Photographs by David Whiting. Reviewed by Mary Small, Colorado State University Extension.

Reviewed July 2017

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #313

Insect Orders

Outline

Anoplura
Sucking Lice

- Feeds by sucking blood from mammals.
- Some species (head lice and crabs lice) feed on humans.

Metamorphosis: Simple/Gradual

Figure 1. Sucking lice

Features: [Figure 1]
- Wingless
- Mouthparts: Piercing/sucking, designed to feed on blood.
- Body: Small head with larger, pear-shaped thorax and nine segmented abdomen.

Blattaria (Subclass of *Dictyoptera*)
Cockroaches and Woodroaches

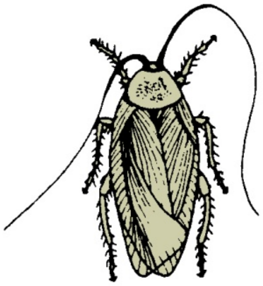


Figure 2. American cockroach

- Most species are found in warmer subtropical to tropical climates.
- The German, Oriental and American cockroach are indoor pests.
- Woodroaches live outdoors feeding on decaying bark and other debris.

Metamorphosis: Simple/Gradual

Features: [Figure 2]
  - Body: Flattened
  - Antennae: Long, thread-like
  - Mouthparts: Chewing
  - Wings: If present, are thickened, semi-transparent with distinct veins and lay flat.

Coleoptera
Beetles and Weevils

- *Coleoptera* is the largest order of insects with 290,000 species worldwide and some 24,000 species in North America.
- Many species are plant feeders; some are predaceous (ground and lady beetles), scavengers (scarab and hide beetles), or aquatic.
- The term *weevil* refers to a snout beetle.

Metamorphosis: Complete [Figure 3]

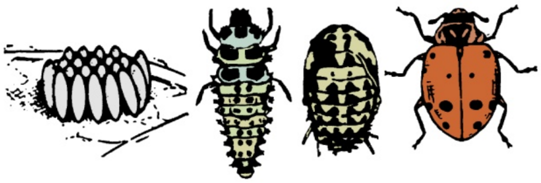


Figure 3. Coleoptera metamorphosis (left to right): egg, grub, pupa, and adult

Adults:
  - Wings: two pair
    - Front pair, called ***elytra***, are greatly thickened and shell-like (form fitting) and make a straight line down the back when at rest.
    - Hind wings are membranous and protected by the front pair.
    - A few beetles are wingless, or have only the front pair.
  - Mouthparts: Chewing
  - Antennae: Noticeable, generally quite stout
  - Cerci (tail-like appendage): None

Larva:
  - Legs:
    - Larva that feed externally on plants are the typical “grub” with head capsule, three pair of legs on thorax, and no prolegs on the abdomen. [Figure 4]

    - Some larva that feed internally in plants (e.g., bark beetles, and wood borers) may be maggot-like with no head capsule and no legs.
- Mouthparts: Chewing

Figure 4. Grub with head capsule, three pair of legs on the thorax, and no prolegs on abdomen.

Beneficial families include:

- Blister beetles, *Meloidae*
- Carrion beetles, *Silphidae*
- Checkered beetles, *Eleridae*
- Darkling beetles, *Tenebrionidae*
- Fireflies, *Lampyridae*
- Ground beetles, *Carabidae*
- Lady beetles, *Coccinellidae*
- Rove beetles, *Staphylinidae*
- Scarab beetles, *Scarabaeidae*
- Soldier beetles, *Cantharidae*
- Tiger beetles, *Cicindelidae*

Pest families include:

- Bark and ambrosia beetles, *Scolytidae*
- Blister beetles, *Meloidae*
- Carpet beetles, *Dermestidae*
- Click beetles or wireworms, *Elateridae*
- Ground beetles, *Carabidae*
- Leaf beetles, *Chrysomelidae*
- Longhorned beetles or roundheaded borers, C*erambycidae*
- Metallic wood beetles or flatheaded borers, *Buprestidae*
- Sap beetles, *Nitidulidae*
- Scarab beetles including rose chafer, *Scarabaeidae*
- Seed beetles, *Bruchidae*
- Weevils, *Curculionidae*

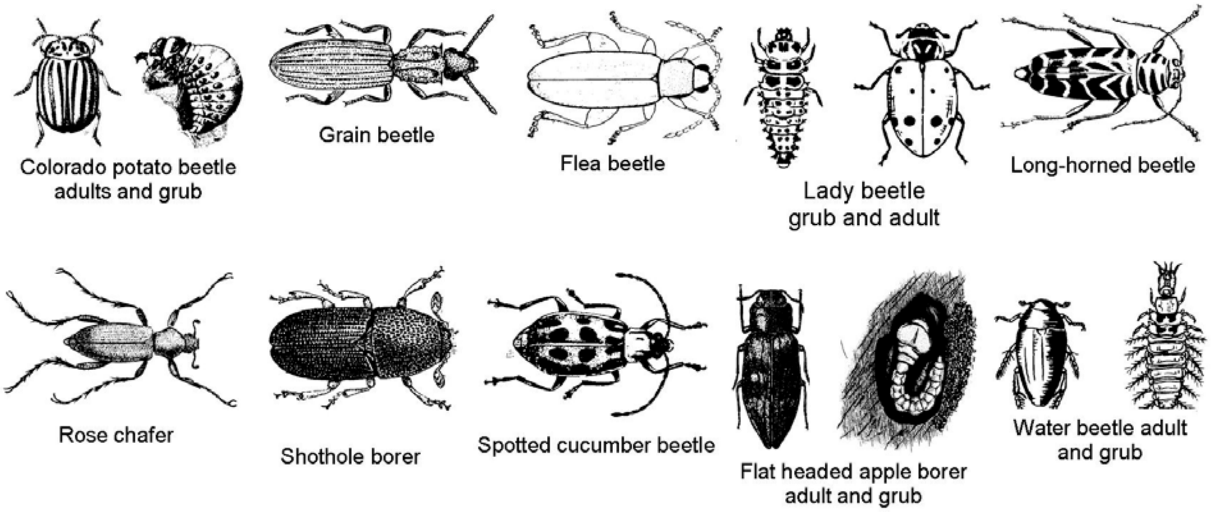


Figure 5. Examples of common beetles

Collembola
Springtails

- Very tiny (1-2 mm) soft-bodied insect almost always associated with soil.
- Very common but rarely observed due to tiny size.
- Most feed on algae, fungi, and other organic matter. Some are predators of other insects and mites found in the soil.

Metamorphosis: None

Features: [Figure 6]

- Wingless
- Mouthparts: Chewing
- "Springtail": (furcula) often present, used to jump.

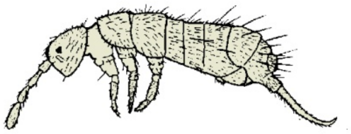


Figure 6. Springtail

Dermaptera
Earwigs

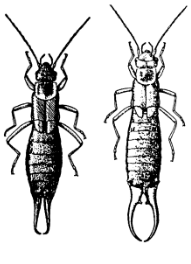
- Introduced from Europe as a biological control.

Metamorphosis: Simple/Gradual

Features: [Figure 7]

- Mouthparts: Chewing; generally feed on decaying organic matter, occasionally on plants and insects.
- Wings: 2 pair
    - Front wings are short, leathery, without venation and meet in a straight line down the back when at rest.
    - Hind wings are membranous, broad, with veins radiating from a center, folded both lengthwise and crosswise when at rest.
    - Note: Wings can be confused with those of beetles, but beetles do not have forceps-like cerci (tail-like appendage).
- Body: Elongated, flattened insects
- Cerci: Strong moveable forceps-like cerci on the abdomen end. Cerci cannot produce a painful pinch, but the mouthparts can.
- Habit: Over-winters as adults. During the day, earwigs hide in dark, moist areas. They are often assumed to cause a plant problem when they may simply be hiding on or near the plant.

Figure 7. Earwigs: Female (left) has straight cerci, male (right) has curved cerci.



Diptera

Flies, Gnats, Midges, and Mosquitoes

- Around 99,000 species worldwide, with some 17,000 in North America.
- Feeding habits vary widely, for example
    - Scavenger (house fly, blow fly)
    - Blood sucking (mosquitoes)
    - Plant galls (gall midges)
    - Predators (flower flies, robber flies)
    - Aquatic

Metamorphosis: Complete [Figure 8]

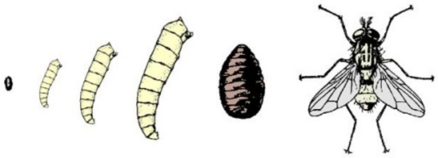


Figure 8. Complete metamorphosis of flies.

Adults [Figures 8-10]

- Wings: One pair, membranous
    - One pair is a quick identifcation for *Diptera*.
    - Note: Count the wings! Some *Diptera* look like bees or wasps. Some *Hymenoptera* (bees and wasps) look like flies. *Diptera* has one pair. *Hymenoptera* have two pair, the hind pair is typically smaller and hidden under the front pair.
- Mouthparts: Highly variable
    - Sponging (house fly)
    - Cutting-lapping (horse fly)
    - Piercing-sucking (mosquito)
- Body: Typically soft bodied and often hairy.

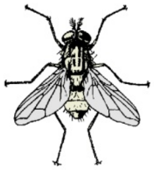


Figure 9. House fly.

Larva [Figures 8 and 10]

- Vary greatly in appearance.
- Larva of advanced forms, like the house fly, are ***maggot*** type
    - No head capsule
    - Mouth hooks
    - Legless
- Lower forms, such as mosquitoes, have a head capsule.

Pupa: Typically pupate in last skin of larva.

Beneficial families include:

- Bee flies, *Bombyliidae*
- Crane flies, *Tipulidae*
- Gall gnats *Cecidomylidae*
- Robber flies, *Asilidae*
- Syrphid or flower flies, *Syrphidae*
- Tachinid flies, *Tachinidae*

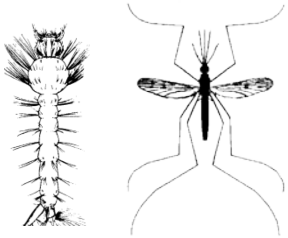


Figure 10. Mosquito maggot and adult.

Pest families include:

- Cabbage, onion, and seed corn maggots, beet leaf miner, *Anthomyiids*
- Biting midges, *Certopogonidae*
- Black flies, *Simuliidae*
- Blow flies, *Calliphoridae*
- Crane flies, *Tipulidae*
- Fruit flies, *Tephritidae*
- Gall gnats *Cecidomylidae*
- Horse and deer flies, *Tabanidae*
- Horse bot flies, *Hippoboscidae*
- Leafminer flies, *Agromyzidae*
- Mosquitoes, *Culicidae*
- Muscids (house flies), *Muscidae*
- Sand flies (no-see-ums), *Psychodidae*
- Syrphid or flower flies, *Syrphidae*
- Vinegar flies, *Drosophilidae*

Ephemeroptera
Mayflies

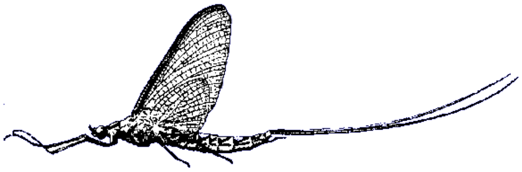
- Small aquatic naiads found in the bottom of streams and lakes. Serves as a source of food for fish.
- No interaction with gardening activities.

Metamorphosis: Simple/Incomplete

Adults: [Figure 11]

- Wings: two pair
  - Front wings large and triangular shaped.
  - Hind wings small and rounded.
  - Wings held vertically over body.
- Antennae: Small, bristle-like
- Filaments: Two very long tail-like filaments.
- Mouthparts: Adults do not feed and only live a few days.

Figure 11. Mayfly adult



Naiads: [Figure 12]

- Body: Aquatic naiads vary in shape, most are broad, and have functional gills along the sides of the abdomen.
- Mouthparts: Chewing.
- Molting: Frequent; 20 to 60 times

Figure 12. Mayfly naiad .

Hemiptera Order, Suborder: Heteroptera

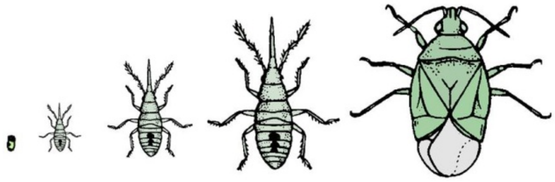
TRUE BUGS: Plant Bugs, Squash Bugs, Stink Bugs

Note: Research has led to the re-ordering of insects. True bugs are the Hemiptera order, but now have their own suborder. In older references you will still find Hemiptera without the suborders.

- This order includes many important insect predators.

Metamorphosis: Simple/Gradual [Figure 13]

Figure 13. Metamorphosis of stink bugs.



Features: [Figure 14]

- Mouthparts: Piercing-sucking
  - Jointed beak is typically visible, and originates from top of head in front of eyes.
- Wings: two pair
  - Front wings (called *hemielytra*) are thickened at base and membranous at end.
  - Hind wings are membranous.
  - When at rest, the wings overlap at the tips forming a large triangular plate (the *scutellum*) on the back.
- Body: Usually broad and somewhat flattened

Beneficial families include:

- Ambush bugs, *Phymatidae*
- Assassin bugs, *Reduvlidae*
- Coreids, *Coreidae*
- Damsel bugs, *Nabidae*
- Flower or minute pirate bugs, *Antocoridae*
- Leaf or plant bugs, *Miridae*
- Stink bugs, *Pentatomidae*

Pest families include:

- Chinch and lygus bugs, *Lygaeidae*
- Coreids, squash bugs, *Coreidae*
- Lace bugs, *Tingidae*
- Stink bugs, *Pentatomidae*

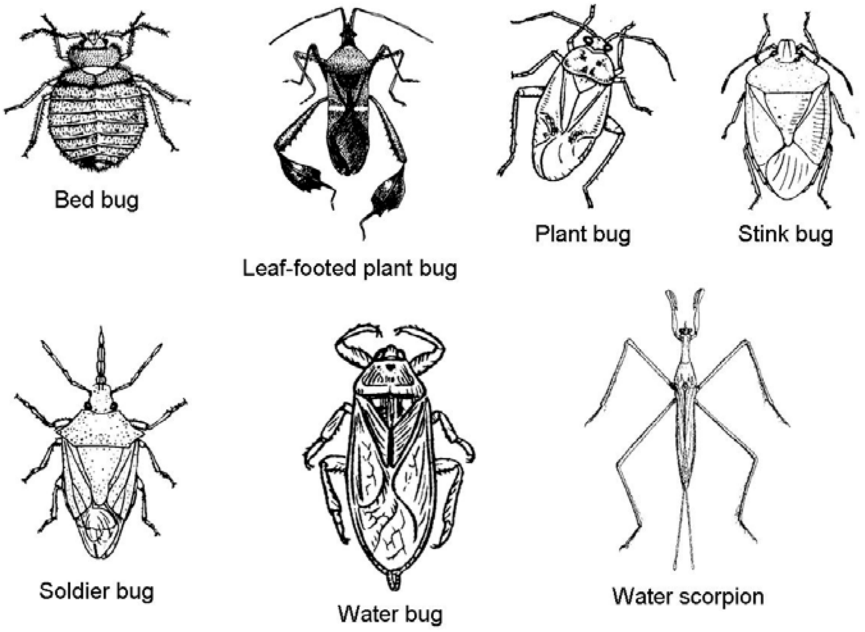


Figure 14. Examples of common *Hemiptera* (true bugs)

Hemiptera Order, Suborder: Auchenorrhyncha
Hemiptera Order, Suborder: Sternorrhynca
Aphids, Cicadas, Leafhoppers, Mealybugs, Scale and Whiteflies

Note: Research has led to the re-ordering of insects. These insects used to be in their own order, Homoptera, but are now a sub-order of Hemiptera. You will still find references to Homoptera. You may also still find references to Hemiptera without the suborders.

- All species are plant feeders, often feeding on phloem sap.
- Excretion of honeydew is common to many members of the order.
- Insects of this order are carriers of several plant pathogens.

Metamorphosis: Simple/Gradual

- Nymphs and adults similar in appearance (except male scales and whiteflies).

Features: [Figure 15]

- Mouthparts: Piercing-sucking
  - *Auchenorrhyncha* mouthparts arise from under the head; *Sternorrhyncha* mouthparts arise from between the forelegs.The jointed beak-like mouthparts not easily visible.

  Note: In contrast, in the *Heteroptera* suborder, mouthparts are more visible and originate from top of head, in front of eyes.
- Wings: two pair
  - Membranous
  - Typically held roof-like at rest
  - Many forms are wingless

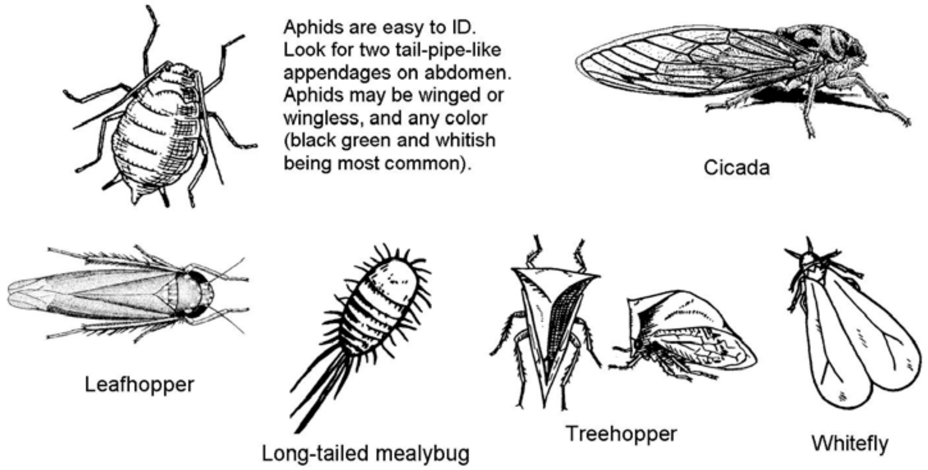
    - Nymphs have no wings, but wing pads may be observed on some older nymphs.

Pest families include:
Suborder Auchenorrhyncha:

- Cicadas, *Cicadidae*
- Leafhoppers, *Cicadellidae*
- Planthoppers, superfamily *Fulgoroidea*
- Spittlebugs, *Cercopidae*
- Treehoppers, *Membracidae*

Suborder Sternorrhyncha:

- Adelgids, *Phylloxeridae*
- Aphids, *Aphididae*
- Armored scales, *Diaspididae*
- Mealybugs, *Pseudococcidae*
- Psyllids (many gall insects), *Psyllidae*
- Soft scale, *Coccidae*
- Whiteflies, *Aleyrodidae*



Aphids are easy to ID. Look for two tail-pipe-like appendages on abdomen. Aphids may be winged or wingless, and any color (black green and whitish being most common).

Figure 15. Examples of common *Hemiptera in either Auchenorrhyncha or Sternorrhyncha*

Hymenoptera

Ants, Bees, Horntails, Sawflies, and Wasps

- Large order with some 103,000 species worldwide and 18,000 in North America.
- Order includes many important parasites and predators.
- This order has the most highly developed insect behaviors and social patterns.
- Most species live in nests.

Metamorphosis: Complete

Adults [Figure 16]

- Wings: 2 pair, membranous
  - Hind wing is usually smaller and often hidden under front wing.
  - Front and hind wings may be attached.
- Mouthparts: Typically chewing or chewing-sucking
- Body: Most species have a distinct constriction between the thorax and abdomen (wasp waist). The sawfly/horntail group does not have a "wasp waist").
- Antennae: Jointed, sometimes elbowed
- Stinger: Female abdomen usually provided with a saw, piercing organ, or stinger.

Larva

- Larvae of most species are rarely observed, often developing in a nest or as an internal parasite.
- Head: Distinct head capsule
- Legs: None (except sawfly larva)
  - Sawfly larva look like caterpillars but have six-plus pair of prolegs.
  - Note: Caterpillars (*Lepidoptera)* have five or fewer pair prolegs.
  - Some sawfly larva are legless and slug-like.
- Mouthparts: Chewing

Wasp or Bee?

Wasps have a slender and thin body, a narrow waist, slender, cylindrical legs and a skin that generally lacks much hair. Yellow jackets, bald-faced hornets, and paper wasps are the most common wasps encountered by people.

Wasps are predators, feeding on insects and other arthropods. During late summer and autumn when insect prey becomes more scarce, many wasps become scavengers and are especially attracted to sweets and other carbohydrates.

Bees are robust-bodied and very hairy compared with wasps. The hair on bees is branched giving them a fuzzy or soft appearance. Their hind legs are flattened, with bristle-fringed areas for collecting and transporting pollen. Bees laden with pollen will appear to have yellow hind legs because of the pollen loads. Bees are vegetarians, feeding on nectar and pollen.

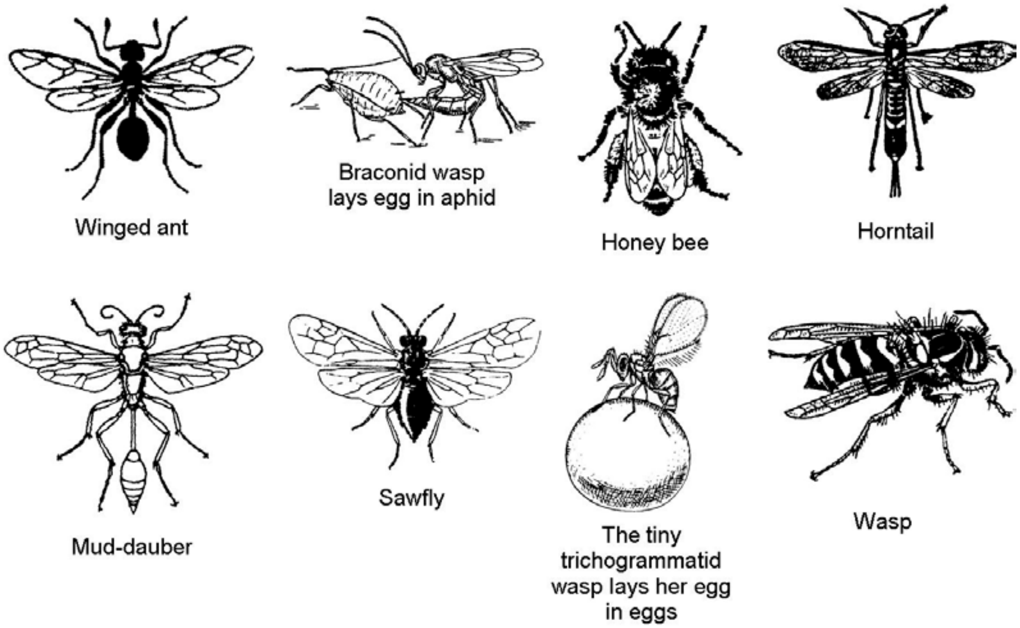
Beneficial families include:

- Ants and parasitic wasps, superfamily *Scolioidea*
- Bees, superfamily *Apoidea*
- Chalcid wasps, *Chalcidoidea*
- Digger wasps, superfamily *Sphecoidea*
- Ichneumon and braconid wasps, superfamily *Ichneumonoidea*
- Social wasps, superfamily *Vespoidea*

Pest families include:

- Ants, superfamily *Scolioidea*
- Gall wasps, superfamily *Cynipoidea*

  - Horntails, superfamily *Siricoidea*
  - Sawflies, *Tenthredinoidae*
  - Social wasps, superfamily *Vespoidea*



Winged ant

Braconid wasp lays egg in aphid

Honey bee

Horntail

Mud-dauber

Sawfly

The tiny trichogrammatid wasp lays her egg in eggs

Wasp

Figure 16. Examples of common *Hymenoptera*

Isoptera
Termites

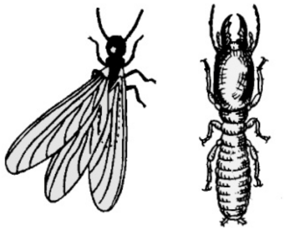
- Termites are social insects living in colonies. Colorado species live below ground.
- Workers avoid exposure and are rarely seen except when disturbed. Only the winged reproductive adults leave the colony.

Metamorphosis: Simple/Gradual

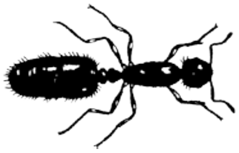
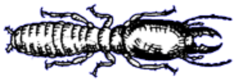
Features: [Figure 17]

  - Color: Creamy white
  - Wings: two pair that are the same size and longer than the body.
  - Body: rectangular-shaped with NO constriction (wasp waist) between thorax and abdomen.
  - Antennae: Straight and beaded
  - Mouthparts: Chewing

Figure 17. Winged adult termite (left), and worker termite (right)



Ant or Termite?

	Ant	**Termite**
		
Color	Black, red, yellowish, etc.	Creamy white
Waistline	"Wasp waist"	No constriction
Antennae	Jointed, sometimes elbowed	Straight and bead-like
Wings on adult	Front wing larger and hind wing smaller; wings may be attached.	Front and hind wings same size, longer than body.
Worker's body	Typical "ant" shape	Rectangular body with large chewing mouthparts
Observed	Commonly seen crawling around	Worker termite rarely seen except when disturbed.

Lepidoptera

Butterflies and Moths

Metamorphosis: Complete

Adults [Figure 18]

- Wings: Two pair
  - Typically covered with small overlapping scales.
  - Often but not always highly colored.
- Mouthparts: Coiled sucking tube designed to siphon fluids like nectar.
  - Some adults do not feed.

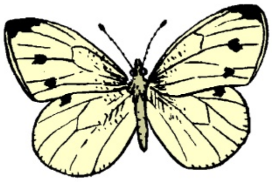
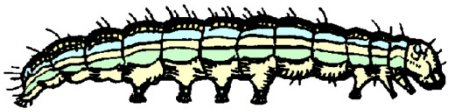


Figure 18. The wings of butterflies and moths are generally covered with colorful scales.

Larva: ***Caterpillars*** [Figure 19]

- Legs: Three pair on thorax
- Prolegs: Up to five pair of prolegs (fleshy leg-like appendage with crochet-like hooks on the end which helps hold the insect to plants).
  - Note: Sawfly larva look like caterpillars but typically have six or more pair prolegs.
- Decorations: Often highly colored or decorated with spines or other appendages.
- Mouthparts: Chewing, with voracious appetites.

Figure 19. Caterpillars (larval stage of Lepidoptera) have three pair of jointed legs on the thorax plus up to five pair of prolegs on the abdomen.



Pupa

- o Cocoon, made of silk spun from saliva glands

Families of interest include:

- o Bagworm moths, *Psychidae*
- o Carpenterworm moths, *Cossidae*
- o Clearwing moths (squash vine borer, lilac borer), *Sesiidae*
- o Giant silkworm moths, *Saturniidae*
- o Leafrollers, Tortricidae
- o Measuringworms, *Geometridae*
- o Monarch, viceroy, red admiral, morningcloak and angelwings butterflies, *Nymphalidae*
- o Noctuids (cutworms, armyworms, fruitworms, corn earworm, cabbage loopers), *Noctuidae*
- o Olethreutid moths, *Olethreutidae*
- o Prominents (redhumped caterpillars), *Notodontidae*
- o Pyralids (corn borer, sod webworm, meal moths), *Pyralidae*
- o Royal moths, *Citheroniidae*
- o Silkworm moths, *Bombycidae*
- o Sphinx or hawk moth, hornworms, *Sphingidae*
- o Swallowtail or parsleyworm, *Papilionidae*
- o Tent caterpillars, *Lasiocampidae*
- o Tineids, (cloths moths), *Tineidae*
- o Tussock moths, *Lymantriidae*
- o White or yellow butterflies (imported cabbageworm), *Pieridae*

Mallophaga

Chewing or Biting Lice

- Tiny parasite of birds and some mammals.
- Feeds on blood, feathers, hair, skin, or sebaceous fluids.

Metamorphosis: Simple/Gradual

Features: [Figure 20]

- o Flattened, oval
- o Head larger than thorax
- o Antenna short
- o Eyes very small or absent
- o No wings
- o Legs short and modified to hold to feathers or fur
- o Lives only on hosts

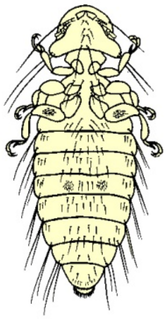


Figure 20. Chewing lice.

Mantodea
Mantids

- Predators of other insects, which they capture with front legs and eat.
- Winter is spent in the egg mass covered with a tough polystyrene-like coat.

Metamorphosis: Simple/Gradual

Features: [Figure 21]
- Legs: Foreleg designed for grasping and holding prey
- Body: Elongated
- Mouthparts: Chewing
- Antennae: Long, thread-like
- Wings: If present, are leathery and over abdomen. Absent in nymphs.

Figure 21. Mantid

Neuroptera
Antlion, Lacewing, Snakeflies, and Dobsonflies

- Order includes many important predators.
- No harmful species are known.
- The antlion is the larva of the common lacewing. Some forms are aquatic.

Metamorphosis: Complete

Adults [Figure 22]
- Wings: Two pairs
  - Membranous, similar in size and texture
  - Large membranous wing, usually with many veins and cross veins.
  - Held roof-like over body when at rest.
- Mouthparts: Chewing; some are predators, while others feed on nectar or pollen.
- Cerci: None
- Tarsus (foot): Five segments

Figure 22. Lacewings: Left: adult, Right: Antlion (lacewing larva)

Larva [Figure 23]
- Mouthparts: Forward-projecting curved pointed jaws designed to grasp prey, which they crush and suck out the insides.

- Body: Often elongated
- Legs: Three pair

Figure 23. Antlion (lacewing larva)

Odonata

Dragonflies and Damselflies

Metamorphosis: Simple/Incomplete

Adults [Figure 24]

- Eyes: Very large eyes that may cover much of head.
- Wings: Two pair
    - Large, elongated, highly veined.
    - Dragonflies hold wings horizontally when at rest. Damselflies project wings back over body when at rest.
- Mouthparts: Chewing, prominent, used to capture and consume winged prey in flight.
- Antennae: Small, bristle-like

Figure 24. Dragonfly adult

Naiads [Figure 25]

- Aquatic insect that feeds on mosquito larva and other aquatic life
- Eyes: Large
- Mouthparts: Uniquely hinged jaw that can project forward to capture prey.
- Gills: Three leaf-like gills at end of abdomen (damselfly only.)

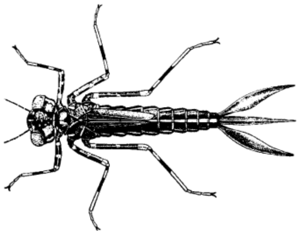


Figure 25. Dragonfly naiad

Orthoptera

Crickets, Grasshoppers, and Katydids

- Note: Older books place mantids (*Mantode*a), walking sticks (*Phasmida*) and roaches (*Blattaria*) in the order *Orthoptera*.
- Most are plant feeders. A few are predators or scavengers.

Metamorphosis: Simple/Gradual

Features [Figure 26]

- Mouthparts: Chewing
- Wings: Two pair
    - Front wings more or less parchment-like with distinct venations.
    - Hind wings membranous and folded fan-like when at rest.
    - Wings may be used to make sounds.
- Legs: Hind legs enlarged for jumping.
- Cerci (tail-like appendages): 1 pair on most adults

Pest families include:

- Crickets, *Gryliidae*
- Short-horned grasshoppers, *Acrididae*
- Long-horned grasshoppers (katydids, meadow grasshoppers, and Mormon crickets), *Tettigoniidae*

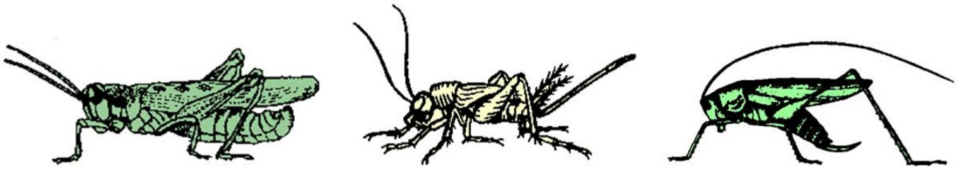


Figure 26. Orthoptera (left to right): grasshopper, cricket, and katydid.

Phasmida

Walking Stick

- Feeds on plant leaves.
- Stick-like form provides camouflage.

Metamorphosis: Simple/Gradual

Features: [Figure 27]

- Body: Very elongated, stick-like
- Mouthparts: Chewing
- Wings: typically none

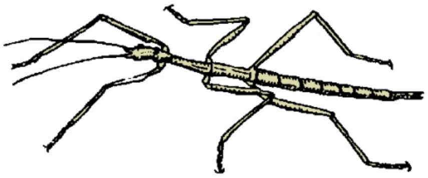


Figure 27. Walking stick

Plecoptera

Stoneflies

- Aquatic naiads cling to stones in streams and serve as food for other aquatic insects and fish.
- There is no direct interaction with gardening activities.

Metamorphosis: Simple/Incomplete

Adults [Figure 28]

- Wings: Two pair, elongated wings fold flat over body when at rest.
- Antennae: Long, filament-like
- Filament: (tail-like): Two

Figure 28 Stonefly adult

Naiads [Figure 29]

- Aquatic naiad typically found under stones in rivers and lake shores.

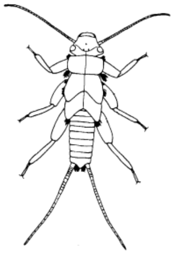


Figure 29. Stonefly naiad.

Psocoptera

Psocids or Booklice

- Common but inconspicuous insect rarely observed due to tiny size.
- Found in warm, damp places feeding on molds, fungi, cereals, pollen, etc.
- Occasionally invade the home.

Metamorphosis: Simple/Gradual

Features: [Figure 30]

- Size: Tiny, less than 1/8 inch
- Wings: Two pair on some adults
    - Held roof-like over body when at rest
    - Front pair larger
    - Veins prominent
    - Non-winged specimens common
- Mouthparts: Chewing
- Antennae: Slender and as long or longer than body

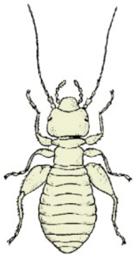


Figure 30. Booklice

Siphonaptera

Fleas

- Household pest of pets and people.

Metamorphosis: Complete

Adults [Figure 31]

- Size: Less than 1/8 inch
- Wingless
- Body: Flattened sideways, dark colored, covered with bristles that project backwards
- Mouthparts: Piercing/sucking, designed to suck blood.

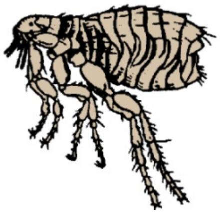


Figure 31. Flea

Thysanoptera

Thrips

- It is a very common insect, but due to tiny size is rarely observed.
- Feeding leaves the plant looking scarred, as they rasp the leaf or flower surface and suck the fluids.

Metamorphosis: Simple/Gradual

Features: [Figure 32]

- Wings: Two pair
    - Slender wings fringed with hairs

        - Often absent.
    - Mouthparts: Rasping-sucking; typically feed on flowers and leaves.
    - Tarsi (feet): One or two segmented, each with a balloon-like structure on the end.
    - Size: Minute, less than 1/8 inch long.

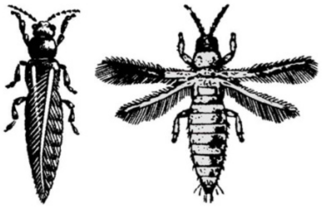


Figure 32. Thrips

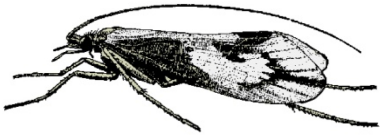
Trichoptera
Caddisflies

- Aquatic naiad.
- Not associated with gardening activities.

Metamorphosis: Simple/Incomplete

Adults [Figure 33]
- Wings: Two pair
    - Covered with fine hairs
    - Held roof-like over body at rest
    - Resemble moths with hairy wings.
- Antennae: Extended back over body

Figure 33. Caddisfly



Naiads
- Aquatic naiad
- Some live in cases constructed of silk, pebbles, sticks, and leaves. Others construct silken nests.
- Some are free-living and actively hunt other insects.

Zygentomaa
Silverfish and Firebrats

- Found in cool, moist, dark places.
- General feeder on starches and carbohydrates, including paper, wall paper, vegetables and grain products.

Metamorphosis: None

Features: [Figure 34]
- Size: Small, ¼” to ½”
- Wingless
- Mouthparts: Chewing
- Cerci: Pair, long tail-like
- Active, fast moving

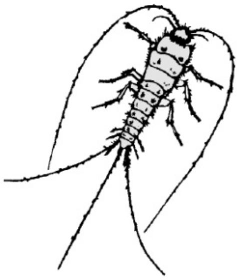


Figure 34. Silverfish

Author: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension. Line drawings from USDA. Revised by Mary Small, Colorado State University.

Revised July 2017

MASTER GARDENER
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CMG GardenNotes #314

Key 1 – Key to Insects Associated with Gardening

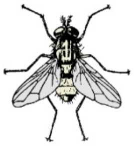
Notes:

- This key covers insect orders commonly associated with gardening and landscape maintenance. Key 2 includes additional orders.
- This simplified key covers insects showing common characteristics for the order. Species with atypical appearances will not work with this simplified key.

1a. Wings present. —— go to 2

1b. Wings absent. —— go to 8

(1a) 2a. One pair of membranous wings. The insect may look like a fly or bee. (Look carefully for a second pair of wings hidden beneath the front pair.) —— ***Diptera* (flies)**
[details page 313-4]



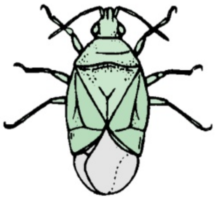
2b. Two pair of wings present. —— go to 3

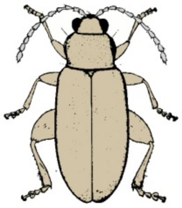
(2b) 3a. Front and hind wings not similar in texture. Front wings parchment-like, shell-like or leathery or thickened. Hind wings more delicate or membranous. —— go to 4

3b. Front and hind wings similar in texture. Either membranous, transparent or covered with powdery-like scales. —— go to 6

(3a) 4a. Chewing mouthparts. —— go to 5

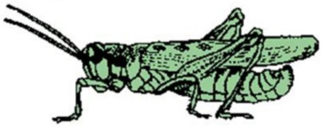
4b. Piercing-sucking mouthparts. Beak-like mouthparts usually easily visible and appear to arise from front of head, ahead of eyes. Front wings thickened at base but membranous and overlapping at tips, so that the wings form a triangle pattern on the back. —— ***Hemiptera,, suborder Heteroptera* (true bugs)**

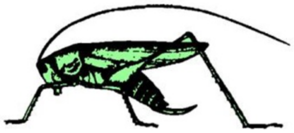


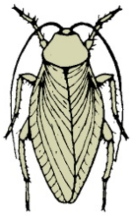


(4a) 5a. Leathery front wings, without veins, lay over body in a shell-like fashion, making a straight line between wings. Hind wings membranous. No cerci (tail-like appendages). —— ***Coleoptera* (beetles)**

5b. Front wings more or less parchment like with a network of veins. Hind wings membranous and folded fan-like when at rest. Hind leg enlarged for jumping. —— ***Orthoptera* (grasshoppers, crickets, katydids)**

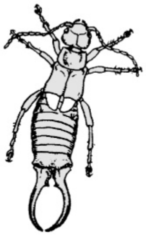






5c. Front wings more or less parchment like with a network of veins. Flattened bodies, thread-like antennae — **Blattaria** (cockroach)

5d. Front leg enlarged for capturing prey. —— ***Mantodea* (mantids)**



5e. Front wings short and leathery. Hind wings membranous. Elongated flattened body with distinct forceps-like pinchers (cerci). —— ***Dermaptera* (earwigs)**

(3b) 6a. Wings membranous. —— go to 7

6b. Wings usually covered with powdery-like scales. Mouthparts coiled sucking tube beneath the head. —— ***Lepidoptera* (butterflies, moths)**

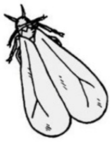
6c. Wings very narrow and fringed with hair. Tiny insect (less than 1/8 inch). Foot ending in balloon-like swelling. —— ***Thysanoptera* (thrips)**

(6a) 7a. Piercing-sucking mouthparts. Jointed beak-like mouthparts not very visible and appear to arise from under the head or between the front legs. Wings generally held roof-like over body when at rest. — ***Hemiptera, suborder***, ***Auchenorrhyncha*** or ***Sternorrhyncha*** **(aphids, cicadas, leafhoppers, psyllids, treehoppers,** and **whiteflies)**


aphid


cicada


leafhopper


whitefly

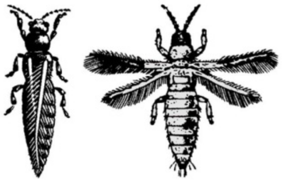
7b. Front wing usually larger than hind wing. Wings may be connected. Chewing or chewing sucking mouthparts. Bee, wasp, or ant like with narrow waist. — ***Hymenoptera*** **(bees, wasps, ants)**

7c. Large membranous wings, usually with many veins and cross veins; similar in size and texture; held roof-like over body when at rest. Antennae longer, not extremely short or bristle-like. Tarsus (foot) with five segments. No cerci (tail-like appendage). — ***Neuroptera*** **(lacewing)**

(1b) 8a. Piercing-sucking, jointed beak-like mouthparts. — go to 9

8b. Chewing mouthparts. — go to 10

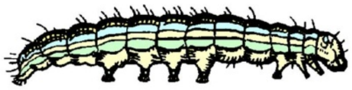
8c. Rasping-sucking mouthparts. Tiny (less than 1/8 inch), slender insects. Balloon-like swelling on end of foot. Often noticed by scarring and deformation of leaves and flowers where it feeds. — ***Thysanoptera*** **(thrips)**

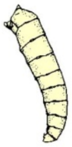


(8a) 9a. Bug-like with jointed beak. Mouthparts usually easily visible and appear to arise from front of head, in front of eyes. — ***Hemiptera, suborder Heteroptera*** **(true bugs)**

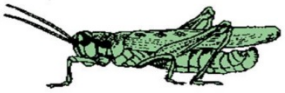
9b. Bug-like with jointed beak. Mouthparts not highly visible and appear to arise from under the head or beween the front pair of legs. — ***Hemiptera, suborder, Auchenorrhyncha or Sternorrhynca*** **(aphids, cicadas. leafhoppers, mealybugs, psyllids, scale)**

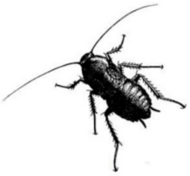
(8b) 10a. Larva-like (i.e., caterpillar-like, grub-like, maggot-like). —— go to 11



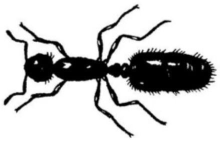
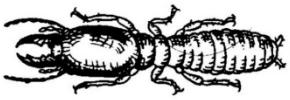


10b. Bug-like with tail-like features (cerci, filaments). —— go to 14

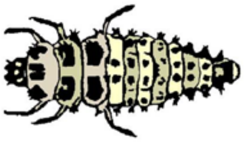




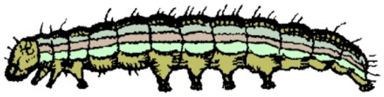
10c. Ant-like. —— go to 15

10d. Dragon-like with lots of appendages and decorations. —— go to 16

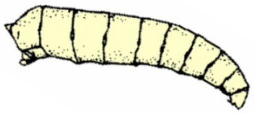



(10a) 11a. Caterpillar-like: soft bodied, three pair of legs on thorax, fleshy leg-like *prolegs* on abdomen. —— go to 12

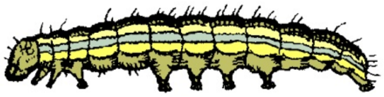


11b. Grub-like: head capsule, three pair of legs on thorax, and no legs on abdomen.
—— typical of ***Coleoptera* (beetle grubs)** [details page 313-2]

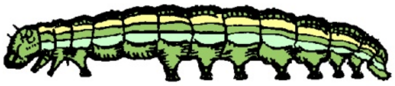
11c. Maggot-like, headless, legless. —— go to 13



(11a) 12a. Up to five pair of prolegs on abdomen. —— ***Lepidoptera* (butterfly and moth caterpillars**)

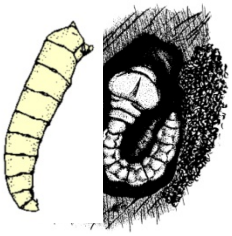


12b. Six or more pair of rolegs on abdomen. —— ***Hymenoptera* (sawfly larva)**



(11c) 13a. Maggot-like: no legs, no head capsule, mouth-hooks. —— typical of ***Diptera* (fly maggots)**

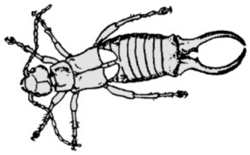
13b. Legless, no head capsule, head area may be enlarged. Insect internal wood or bark borer. —— some ***Coleoptera* (borer larva)**



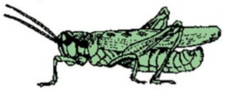
13c. Slug like; foliage feeding. —— ***Hymenoptera* (typical of some sawfly larva)**

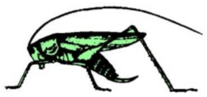
13d. Maggot-like; larva found in nests. ——- ***Hymenoptera* (larva of bees, wasps and ants found in nest)**

(10b) 14a. Elongated flattened body with distinct forceps-like pinchers (cerci), and short leathery front wings. —— ***Dermaptera* (earwigs)**



14b. Hind legs designed for jumping. Antennae tread-like. —— ***Orthoptera* (grasshoppers, crickets, katydids)**

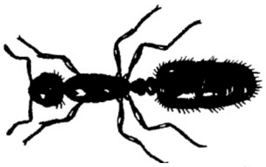




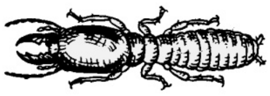
14c. Flattened body, thread-like antennae, thick semi-transparent wings with major venation. Household pest. —— ***Blattaria* (cockroaches)**

14d. Front legs designed for grasping and holding prey. Body elongated. Long, thread-like antennae. —— ***Mantodea* (mantids)**

(10c) 15a. Three distinct body segments. Narrow waist. Elbowed antennae. —— ***Hymenoptera* (ants)**



15b. Looks like a fat ant without a narrow waist. Creamy white. Straight beaded antennae. —— ***Isoptera* (worker termites)**



(10d) 16a. Generally dark colored with bright markings and spines. —— ***Coleoptera* (beetle grubs)**

16b. Forward-projecting, curved pointed jaws designed to grasp prey, which they crush and suck the insides of prey. —— ***Neuroptera* (antlion)**

Author: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension.
Line drawings from USDA. Photographs by David Whiting.Revised by Mary Small, Colorado State University Extension.

Revised July 2017

MASTER GARDENER
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CMG GardenNotes #315

Key 2 – Key to Insects Orders

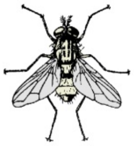
Notes:

- This key covers insect orders commonly and occasionally observed. However, it does not include all orders. Key #1 is similar, but easier, being limited to insect orders commonly associated with gardening and landscape maintenance.
- This simplified key covers insects showing common characteristics for the order. Species with atypical appearances will not work with this simplified key.

1a. Wings present. —— go to 2

1b. Wings absent. —— go to 9

(1a) 2a. One pair of membranous wings. The insect may look like a fly or bee. (Look carefully for a second pair of wings hidden beneath the front pair.) —— ***Diptera* (flies)**



2b. Two pair of wings present. —— go to 3

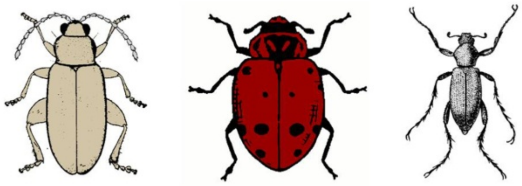
(2b) 3a. Front and hind wings not similar in texture. Front wings parchment-like, shell-like or leathery or thickened. Hind wings more delicate or membranous. —— go to 4

3b. Front and hind wings similar in texture. Either membranous, transparent or covered with powdery-like scales. —— go to 7

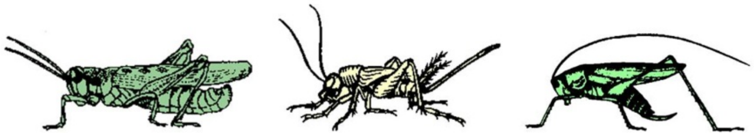
(3a) 4a. Chewing mouthparts. —— go to 5

4b. Piercing-sucking mouthparts. —— go to 6

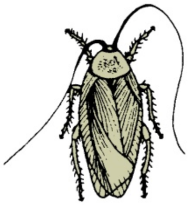
(4a) 5a. Leathery front wings, without veins, lay over body in a shell-like fashion, making a straight line between wings. Hind wings membranous. No cerci (tail-like appendages). —— ***Coleoptera* (beetle)**



5b. Front wings more or less parchment like with a network of veins. Hinds wings membranous, usually broad with folds like a fan. Hind leg enlarged for jumping —— ***Orthoptera* (grasshoppers, crickets, katydids)**

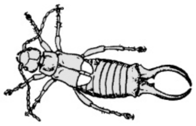


5c. Front wings more or less parchment like with a network of veins. Flattened bodies, thread-like antennae — **Blattaria** (cockroach)

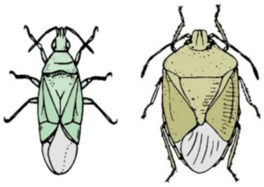


5d. Front wings more or less parchment like with a network of veins. Front legs modified to catch and hold prey. —— ***Mantodea* (mantids)**

5e. Front wings short and leathery. Hind wings membranous. Elongated flattened body with distinct forceps-like pinchers (cerci). —— ***Dermaptera* (earwigs)**

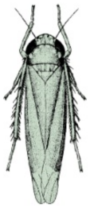


(4b) 6a. Front wings thickened at base but membranous and overlapping at tips, so that the wings form a triangle pattern on the back. Beak-like mouthparts usually easily visible and appears to arise from front of head, ahead of eyes. —— ***Hemiptera* (true bugs), *suborder Heteroptera***



[details page 313-7]

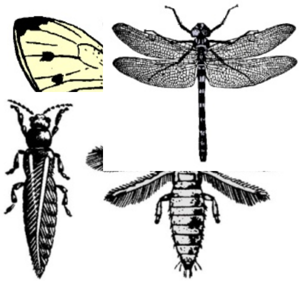
6b. Wings membranous folded tent-like at rest. Beak-like mouthparts not very visible and appear to arise from under the head or between the front pair of legs. ——***Hemiptera, suborder Auchenorrhyncha* or *Sternorrhyncha* (leafhoppers, treehoppers)**



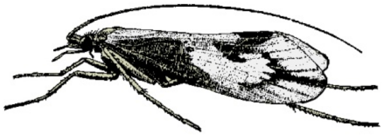
(3b) 7a. Wings membranous —— go to 8

7b. Wings usually covered with powdery-like scales. Mouthparts in the form of a coiled up tube beneath the head. —— ***Lepidoptera* (butterflies, moths)**

7c. Wings very narrow and fringed with hair. Tiny insect (less than 1/8 inch). Foot ending in balloon-like swelling. —— ***Thysanoptera* (thrips)**



7d. Wings covered with fine hairs, held roof-like over body at rest. Looks like moth with hairy wings. Long antennae extended back over body. —— ***Trichoptera* (caddisfly)**

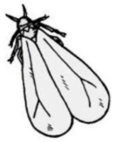


(7a) 8a. Piercing-sucking mouthparts. Beak-like mouthparts not very visible and appear to arise from under the head or between the front pair of legs. Wings generally held roof-like over body when at rest. —— ***Hemiptera, suborder Auchenrrhyncha*** or ***Sternorrhyncha* (aphids, cicadas, leafhoppers, psyllids, treehoppers, whiteflies)**

aphids

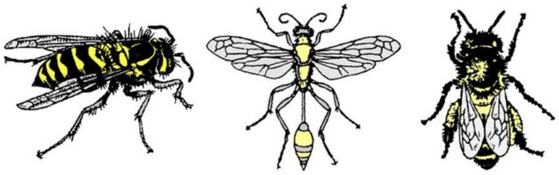
cicada

leafhopper



whitefly

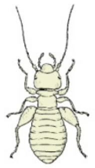
8b. Front wing usually larger than hind wing. Wings may be connected. Chewing or chewing sucking mouthparts. Bee, wasp, hornet like. —— ***Hymenoptera* (bees, wasps, hornets, wings ants)**



8c. Large wings in comparison to petite body. Wings usually with many veins and cross veins, held roof-like over body when at rest. Mouthparts chewing. No cerci (tail-like appendages). —— ***Neuroptera* (lacewing)**

8d. Wings longer than body. Body whitish, looks like a fat ant without a slim waist. Straight and beaded antennae. —— ***Isoptera* (winged termite)**

8e. Tiny (less than 1/8 inch). Wings held roof-like over body when at rest. Veins prominent. Hair-like antennae as long or longer than body. Whitish body. —— ***Psocoptera* (book lice)**

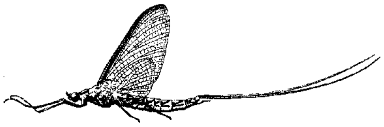


8f. Insect dominated by very large eyes. Wings elongated, highly veined. Slender, needle-like body. Chewing mouthparts used to capture and consume prey in flight. —— ***Odonata* (dragonflies and**

damselflies)

8g. Elongated wings fold flat over body when at rest. Long thread-like antennae. Two tail-like filaments. –– ***Plecoptera* (stonefly)**

8h. Front wings large and triangular shaped. Hind wings small and rounded. Held vertical over body. Two-very long tail-like filaments. –– ***Ephemeroptera* (Mayfly)**

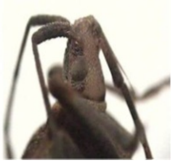


(1b) 9a. Piercing-sucking mouthparts. –– go to 10

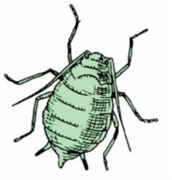
9b. Chewing mouthparts. –– go to 11

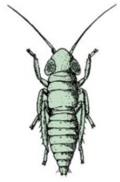
9c. Rasping-sucking mouthparts. Tiny (less than 1/8 inch), slender insects. Balloon-like swelling on end of foot. Often noticed by scarring and deformation of leaves and flowers where it feeds. –– ***Thysanoptera* (thrips)**

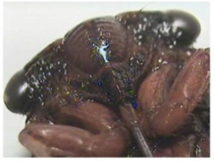
(9a) 10a. Bug-like with jointed beak. Mouthparts usually easily visible and appear to arise from front of head, in front of eyes. –– ***Hemiptera* (true bugs), *suborder Heteroptera***



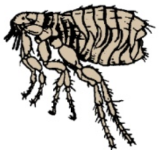
10b. Bug-like with jointed beak. Mouthparts not very visible and appear to arise from the area between the front pair of legs. –– ***Hemiptera, suborder Auchenorrhyncha*** or ***Sternorrhyncha* (aphids, cicadas. leafhoppers, etc.)**





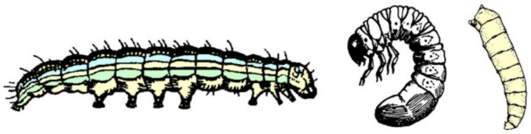


10c. Tiny, hard bodied, flattened sideways, covered with bristles that project backwards. Large hind legs designed for jumping, fast moving. –– ***Siphonaptera* (fleas)**

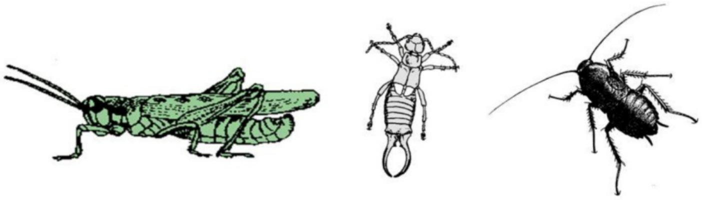


10d. Small, flattened parasites of animals and people. Forelegs with claw designed to grasp hair or feathers. Head narrower than thorax. –– ***Anoplura* (sucking lice, including head lice and body lice)**

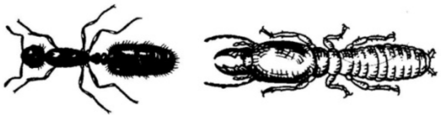
(9b) 11a. Larva-like (caterpillar-like, grub-like, maggot-like). —— go to 12



11b. Bug-like with tail-like features (cerci, filaments). —— go to 15

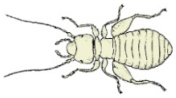


11c. Ant-like. —— go to 16

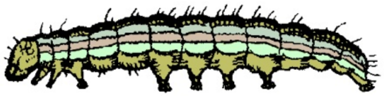


11d. Dragon-like. —— go to 17

11e. Tiny, bug-like. —— go to 18



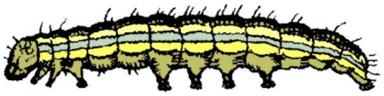
(11a) 12a. Caterpillar-like: soft bodied, three pair of legs on thorax, fleshy leg-like prolegs on abdomen. —— go to 13



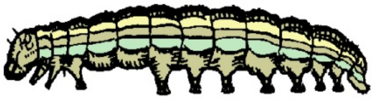
12b. Grub-like: head capsule, three pair of legs on thorax, no legs on abdomen. —— typical of ***Coleoptera* (beetle grub)**

12c. Legless —— go to 14

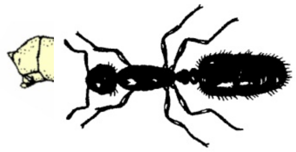
(12a) 13a. Up to five pair of prolegs on abdomen. —— ***Lepidoptera* (butterfly and moth caterpillar**)



13b. Six or more pair of prolegs on abdomen. —— ***Hymenoptera* (sawfly larva)**

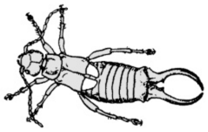


(12c) 14a. Maggot-like: no legs, no head capsule, mouth-hooks. —— **typical of *Diptera* (fly maggot)**

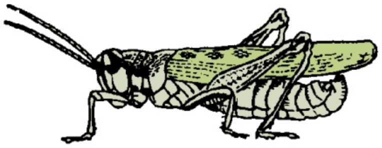


14b. Legless with enlarged head area. —— typical of ***Coleoptera* (borer larva)** [details page 313-2] and some ***Hymenoptera* larva**

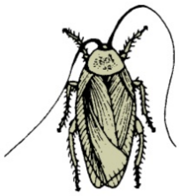
(11b) 15a. Elongated flattened body with distinct forceps-like pinchers (cerci). — – ***Dermaptera* (earwigs)**



15b. Hind legs designed for jumping. Antennae tread-like. one pair of tail-like cerci on most adults. —— ***Orthoptera* (grasshoppers, crickets, katydids)**

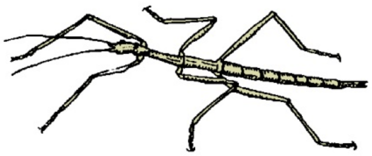


15c. Flattened body, long thread-like antennae. —— ***Blattaria* (cockroaches)**

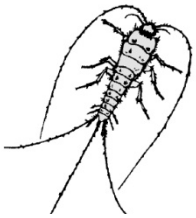


15d. Front legs designed for grasping and holding prey. Body elongated. Long, thread-like antennae. —— ***Mantodea* (mantids)**

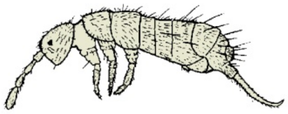
15e. Very elongated, stick-like insect. —— ***Phasmida*, (walkingstick)**



15f. Two or three long, tail-like cerci. Fast moving. Small 1/4 to 1/2 inch. —— ***Zygentomaa* (Silverfish, firebrats)**

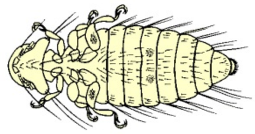


15g. Tiny (1-2 mm) soft-bodied insect. “Springtail” often present, used to jump. —— ***Collembola* (springtail)**



(11c) 16a. Three distinct body segments. Ant like with narrow ant waist. Elbowed antennae. —— ***Hymenoptera* (ant)**

16b. Looks like a fat ant with out a narrow waist. Creamy white. Straight beaded antennae. —— ***Isoptera* (termite)**



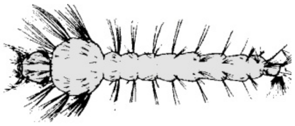
(11d) 17a. Generally dark colored with bright markings and spines. Lacking jaw as in 17b. —— ***Coleoptera* (lady beetle larva)**

17b. Forward-projecting, curved pointed jaws designed to grasp prey, which they crush and suck out the insides of their prey. —— ***Neuroptera* (antlion)**

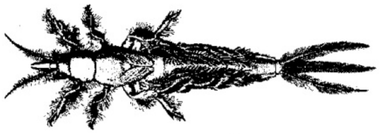
17c. Aquatic nymphs. ——

- ***Coleoptera* (aquatic beetle larva)**

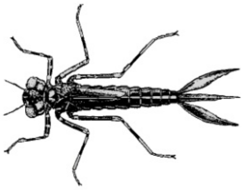
- ***Diptera* (mosquito larva)**



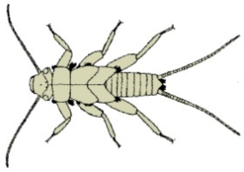
- ***Ephemeroptera* (Mayfly naiads)**



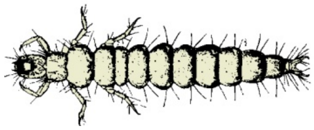
- ***Odonata* (dragonfly and damselfly naiads)**



- ***Plecoptera* (stonefly naiads)**

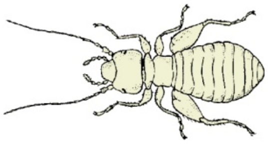


- ***Trichoptera* (caddisfly naiads)**



(11e) 18a. Tiny parasite of birds. Flattened body. Head as wide or wider than thorax. —— ***Mallophaga* (chewing or biting lice)**

18b. Tiny, less than 1/8 inch. Hair-like antennae as long or longer than body. Whitish body. —— ***Psocoptera* (book lice)**



Author: David Whiting, Consumer Horticulture Specialist (retired), Colorado State University Extension.
Line drawings from USDA. Photographs by David Whiting. Revised by Mary Small, Colorado State University Extension.

Revised July 2017

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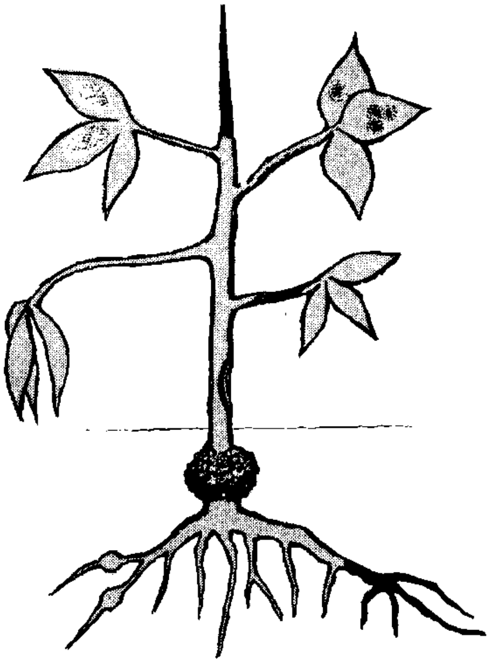

Plant Pathology

Reading / Reference Materials

CSU Extension Fact Sheets

- Aspen and poplar leaf spots – #2.920
- Backyard orchard: apples and pears [pest management] – #2.800
- Backyard orchard: stone fruits [pest management] – #2.804
- Bacterial wetwood – #2.910
- Cytospora canker – #2.937
- Diseases of roses in Colorado – #2.946
- Dollar spot disease of turfgrass – #2.933
- Dutch elm disease – #5.506
- Dwarf mistletoe management – #2.925
- Fairy ring in turfgrass – #2.908
- Fire blight – #2.907
- Forest fire – Insects and diseases associated with forest fires – #6.309
- Friendly pesticides for home gardens – #2.945
- Greenhouse plant viruses (TSWV-INSV) – #2.947
- Honeylocust diseases – #2.939
- Juniper-hawthorn rust – #2.904
- Juniper-hawthorn rust – #2.904
- Leaf spot and melting out diseases – #2.909
- Necrotic ring spot in turfgrass – #2.900
- Non-chemical disease control – #2.903
- Pesticides – Friendly pesticides for home gardens – #2.945
- Pinyon pine insects and diseases – #2.948
- Powdery mildew – #2.902
- Roses – Diseases of roses in Colorado – #2.946
- Russian olive decline and gummosis – #2.942
- Strawberry diseases – #2.931
- Sycamore anthracnose – #2.930

CSU Extension Publications

- Insects and diseases of woody plants of the central Rockies – 506A

Curriculum developed by **Mary Small**, CSU Extension, Jefferson County

Revised November 2017

Books

- ***Abiotic Disorders of Landscape Plants,*** Costello, Perry, Matheny, Henry, Geisel, University of California Agriculture and Natural Resources Publication 3420, 2003
- ***Diseases of Annuals and Perennials***, Chase, Daughtrey, Simone, Ball Publishing, 1995
- ***Diseases of Trees and Shrubs***, Sinclair, Lyon and Johnson, Comstock Publishing Associates, a division of Cornell University Press, 1987
- ***Diseases of Woody Ornamentals and Trees in Nurseries***, Jones and Benson, American Phytopathological Society (APS) Press, 2001
- ***Essential Plant Pathology***, Gail Schuman and Cleora J. D'Arcy, APS Press, 2006
- ***Landscape Plant Problems***, Byther, Foss, Antonelli, Maleike, Bobbitt, Washington State University Puyallup, 1996
- **The Disease Compendia series**, APS Press. Booklets covering diseases of various crops including apple/pear, conifers, corn, cucurbits, foliage plants, peppers, potatoes, potted plants, raspberry, rose, stone fruits, strawberries, tomatoes and turf.
- ***Tropical Foliage Disorders***, Griffith, Ball Publishing Co., 2002

Web Based

- ***A Systematic Approach to Diagnosing Plant Damage***, Green, Malloy, Capizzi, Oregon State University, 1990 http://oregonstate.edu/dept/nurserystartup/onnpdf/onn130601.pdf
- ***The 20 Questions of Plant Problem Diagnostics,*** http://ohioline.osu.edu/sc195/030.html

Learning Objectives

At the end of the training, students will be able to:

- Define disease as it relates to plants.
- Describe the difference between a sign and a symptom.
- Identify the 4 components of the plant disease pyramid.
- Identify examples of biotic and abiotic causes of disease.
- Describe how to manage common leaf spot and canker diseases using IPM techniques.
- Describe and utilize the plant diagnostic process.

Review Questions

1. Define a plant disease.

2. What four components must be present for biotic disease development?

3. Another name for a living cause of disease is_______________________________.

4. Another name for a non-living cause of disease is__________________________.

5. How are fungi dispersed? Bacteria? Phytoplasmas? Viruses?

6. Define the following terms:

    a. Chlorosis
    b. Canker
    c. Mycelium
    d. Ooze

7. List four ways to manage foliar diseases.

8. A client brings you a foot long branch of a chokecherry tree. The leaves on the branch tips are dark brown and wilted. The branch tip is bending over. Could this be fireblight? Why or why not?

9. What is the recommended pruning procedure for removal of fireblight infected branches?

10. List two management techniques for tomato spotted wilt virus.

11. List two management techniques for canker diseases.

12. How are leaf scorch and winter desiccation similar?

13. Three characteristics of healthy roots are:

14. When diagnosing plant problems, why is it important to know what a “normal” plant looks like?

15. Random patterns of injury point to a/an_________ problem; uniform patterns of injury point to a/an _____________problem.

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EXTENSION

CMG GardenNotes #331

Plant Pathology

Outline:

Introduction

A plant disease is usually defined as abnormal growth and/or dysfunction of a plant. Diseases are the result of some disturbance in the normal life process of the plant.

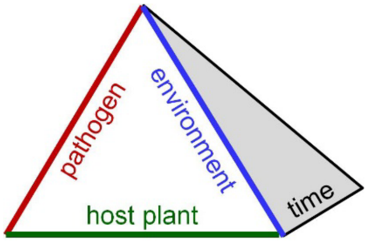
Diseases may be the result of living and/or non-living causes. ***Biotic*** diseases are caused by living organisms (e.g., fungi, bacteria, and viruses). ***Abiotic*** diseases are caused by non-living environmental conditions, (e.g., soil compaction, wind, frost, soil salt damage, and girdling roots).

Plant Disease Pyramid

Specific conditions must be present for biotic disease to develop. There must be a susceptible host plant, the pathogen (fungi, bacteria, viruses, etc.), and environmental conditions conducive to disease development; these must come together in a given point in time. These conditions make up what is called the ***Plant Disease Pyramid***. Biotic disease cannot occur if one of these pieces is missing. [Figure 1]

Environmental Conditions – Weather plays a large role in fungal disease development. Most fungi require free water or specific levels of humidity or moisture for prolonged periods of time to develop. Dry climates are not conducive to their survival. The Rocky Mountain region has fewer fungal diseases than many other parts of the United States due to climatic differences. However, gardens and other microclimates may have conditions ideal for disease development due to poor air circulation, shade, high humidity, and high moisture.

Figure 1. Plant Disease Pyramid



Symptoms

Symptoms of disease are the plant’s reaction to the causal agent. Plant symptoms include:

- **Blight** – A rapid discoloration and death of twigs, foliage, or flowers.
- **Canker** – Dead area on bark or stem, often sunken or raised.
- **Chlorosis** – Yellowing – Chlorosis is so generic that without additional details diagnosis is impossible.
- **Decline** – Progressive decrease in plant vigor.
- **Dieback** – Progressive death of shoot, branch, or root starting at the tip.
- **Distortion –** Malformed plant tissue
- **Gall** or **gall-like** – Abnormal localized swelling or enlargement of plant part. It could be caused by insects, mites, diseases, or abiotic disorders.
- **Gummosis** – Exudation of gum or sap.
- **Leaf distortion** – The leaf could be twisted, cupped, rolled, or otherwise deformed.
- **Leaf scorch** – Burning along the leaf margin and into the leaf from the margin.
- **Leaf spot** – A spot or lesion on the leaf.
- **Mosaic –** Varying patterns of light and dark plant tissue
- **Necrosis** – Dead tissue – Necrotic areas are also so generic that without additional details diagnosis is impossible.
- **Stunting –** Lack of growth
- **Wilt** – General wilting of the plant or plant part.
- **Witches broom** – Abnormal broom-like growth of many weak shoots.
- **Insect feeding injury** is also a symptom used in diagnosis, but not a symptom of disease.

Even though a plant has symptoms on a specific part, it does not necessarily mean the damaged tissue contains the organism causing the symptoms. For example, a root rot can cause chlorosis and wilting of stems and leaves, but the disease causal organism is in the roots. It is imperative to examine as much of the plant as possible to determine exactly where the problem is originating.

Signs

Signs are the actual organisms causing the disease. Signs include:

- **Conks –** Woody reproductive structures of fungi
- **Fruiting bodies** – Reproductive structures of fungi; could be in the form of mushrooms, puffballs, pycnidia, rusts, or conks.
- **Mildew–** Whitish growth produced by fungi, composed of mycelium
- **Mushrooms –** Fleshy reproductive structures of fungi
- **Mycelium –** Thread-like vegetative growth of fungi.
- **Rhizomorphs** – Shoestring-like fungal threads found under the bark of stressed and dying trees caused by the *Armillaria* fungi. They may glow!
- **Slime Flux** or **Ooze** – A bacterial discharge that oozes out of the plant tissues, may be gooey or a dried mass.
- **Spore masses –** Masses of spores, the "seeds" of a fungus
- **Insects** and/or their **frass** (excrement) are also signs, although not signs of disease.

Biotic Disease

Biotic causes of disease include fungi, bacteria, viruses, phytoplasmas, nematodes, and parasitic plants.

Fungi

Fungi are organisms that are classified in the kingdom "Fungi". They lack chlorophyll and conductive tissue. Until a few years ago, fungi were considered lower forms of plants, but today are classified as a group by themselves. Because fungi cannot manufacture their own food (due to lack of chlorophyll), they must obtain it from another source as either a **saprophyte** or **parasite**. Most fungi encountered are saprophytic (feed on decaying organic matter). The parasitic fungi, those that derive their sustenance from living plants, are the group of interest in plant health. In dry climates like Colorado, fungi are the most frequent causes of plant diseases.

A fungus "body" is a branched filamentous structure known as ***mycelium***. One single thread is called a hypha (hyphae, plural). Most fungi reproduce by spores, which are structures that contain little stored food (unlike seed). Spores are the main dispersal mechanism of fungi and can remain dormant until germination conditions are appropriate. Many fungi over-winter as fruiting structures embedded in dead plant tissue.

When a spore comes into contact with a susceptible plant, it will germinate and enter the host if the proper environmental conditions are present. Hyphae develop from the germinated spore and begin to extract nutrients from host plant cells. The hyphae secrete enzymes to aid in the breakdown of organic materials that are ultimately absorbed through their cell walls. Fungi damage plants by killing cells and/or causing plant stress.

Fungi are spread by wind, water, soil, animals, equipment, and in plant material. They enter plants through natural openings such as stomata and lenticels and through wounds from pruning, hail, and other mechanical damage. Fungi can also produce enzymes that break down the cuticle (the outer protective covering of plants).

Fungi cause a variety of symptoms including leaf spots, leaf curling, galls, rots, wilts, cankers, and stem and root rots. Fungi are responsible for “damping off” symptoms associated with seedlings.

Damping Off

Damping off is the fungal infection of seeds or seedlings that leads to death. When infected with damping off, seeds may fail to germinate. In other situations, seedlings develop but eventually fall over and die. An examination of stems at the soil line reveals a discolored, “pinched in” appearance. Most plants are susceptible to damping off because of the soft immature nature of seedling tissue that is more susceptible to infection.

The best method to manage damping off is to avoid it in the first place. For starting seeds indoors, use pasteurized soil or planting mix and ensure that plants receive optimum light, water, and heat for rapid germination and growth. In home situations, damping off frequently develops due to poor lighting and overwatering. These conditions stress plants and make conditions optimal for the development of the soil-borne organisms that cause damping off.

In the garden, plant seeds at appropriate times (correct soil temperature for rapid germination) for the crop and avoid overwatering for optimal germination and growth. A strong healthy plant is better equipped to fight off infection.

Scientists continue to study the role of hyperparasites (parasites of parasites) in disease management. Several biological pesticides have been developed from naturally occurring hyperparasitic fungi and bacteria. The organisms protect plant roots against invasion by harmful soil pathogens. These biological pesticides must be applied prior to the development of damping off so the beneficial organisms have time to grow and colonize roots. They cannot be used as “rescue” treatments.

Leaf Spots

One of the most common fungal plant symptoms is leaf spotting. Leaf spot symptoms are caused by many different fungi. Generally, fungal leaf spots possess a distinct dark brown or red margin between the interior (dead) and exterior (healthy green) tissue called a *border* or *margin*. (Figure 2).

Fungal fruiting structures (reproductive structures) are usually embedded in the dead interior. Frequently, a “halo” of yellow or red color develops around the border. A halo indicates recently killed tissue that will eventually die. Because of the cycle of killing tissue and creating a border, then killing more tissue and creating another border, many fungal leaf spots take on a target-like appearance.

To confuse matters, a series of drought events can cause damage that exhibits alternating light and dark bands. Additionally, fruiting structures may not be obvious in dry climates like Colorado. To positively identify a fungal leaf spot, it is best to either culture tissue from the sample or look for spores under a compound microscope.

Figure 2. Cedar knot gall rust is a common leaf spot with a colorful border.

Examples of common leaf spot diseases in Colorado include *Marssonia* and *Septoria* leaf spots of cottonwoods and aspen, ink spot of aspen, and early blight of tomatoes and potatoes.

Powdery Mildew

Powdery mildew is one of the most common diseases in dry climates like Colorado. General symptoms include a white or grayish powdery growth on leaves. It thrives in warm dry climates, often explodes in small yards with limited air movement, and in the fall as nighttime humidity rises. [Figure 3]

Figure 3. Powdery Mildew

There are many species of mildew fungi, each being host-specific. In Colorado, for example, it is common on ash, lilac, grapes, roses, turfgrass, vine crops (cucumbers, melons, and squash), peas, euonymus, cherry, apple, crabapple, pear, Virginia creeper, and others.

Management is centered on a variety of cultural techniques. Avoid crowding plants as the lack of air circulation favors powdery mildew. Select resistant varieties where possible. Avoid late-summer application of nitrogen fertilizer as it may push growth of tender young leaves that are more prone to mildew. Avoid overhead irrigation as it raises relative humidity. Remove and destroy infected plant parts. A variety of fungicides found in the home garden trades are effective against powdery mildew.

Cankers

Cankers are discolored, sunken areas found on plant stems, branches, and trunks. They damage plants by killing the conductive tissue and girdling the plant. Cankers may be caused by fungi, bacteria, virus, and abiotic disorders such as sunscald and hail (Figure 4).

Figure 4. Canker at base of honeylocust

Fungal cankers contain fruiting structures embedded in the discolored canker. Plants with cankers may exhibit branch dieback, leaf loss, and/or poor growth above the damaged area.

Common fungal cankers in Colorado are *Cytospora* (*Cytospora* sp.) and *Thyronectria* (*Thyronectria* sp.). Common bacterial cankers in Colorado include fireblight (*Erwinia amylovora*).

Root Rots

Root rots damage plants by stressing or killing root systems. Two common soil-inhabiting fungi that cause root rots include *Fusarium* sp. and *Rhizoctonia* sp.

Root symptoms of these (and other soil-borne) fungi include darkening, limpness, and mushiness. Rotted roots may break off easily. The cortex (the outer protective covering) of roots sloughs off, leaving behind the thread-like root core.

Leaves, stems, and entire plants may wilt, prompting one to think that the plant simply needs more water. (Unfortunately, additional water often makes the problem worse.)

Generally, the lower, interior leaves turn yellow, then brown and drop off. In addition, plants may be stunted. If enough roots are damaged, the plant eventually dies.

There are no root-rot resistant plants. Management strategies include avoiding overwatering and improving soil drainage. Roots stressed from overwatering or oxygen starvation easily succumb to root rots, because the organisms move through moist soil and water.

Sometimes, a plant with root rot may be salvaged by cutting off damaged roots and replanting in well-drained soil. Biological pesticides containing hyperparasites may help protect against root rot. These products are not designed to “rescue” plants from ongoing damage, but act as preventives.

In the Green Industry, root rots can be managed with a combination of the cultural management strategies and through use of fungicides. Because not all fungicides kill all root rot fungi, it is essential to determine which root rot organism is causing the problem through microscopic examination so the correct product can be recommended.

Bacteria

Bacteria are single-celled microorganisms. They contain no nucleus and reproduce by dividing into two equal parts (fission). As a result, they multiply and mutate rapidly. Bacteria function as either parasites or saprophytes.

Bacteria can infect all plant parts. Unlike fungi, bacteria must find a natural opening for entry. Bacterial cells can move from one plant to another in water, soil, and plant material, just as fungi do. However, bacterial pathogens are more dependent on water. Conditions must be very wet and/or humid for them to cause significant and widespread damage (Figure 5).

Figure 5. Fireblight on crabapple

Bacteria move between plant cells and secrete substances that degrade plant cell walls so the contents can be utilized. Some produce enzymes that break down plant tissue, creating soft rots or water-soaking. Like the fungi, bacteria cause symptoms such as leaf blights and spots, galls, cankers, wilts, and stem rots.

Bacterial leaf spots appear different from fungal leaf spots due to their intercellular movement. Veins often limit the development of a lesion, so they appear angular or irregular, not round.

Bacterial diseases are not common in the Rocky Mountain region due to lack of natural moisture.

It is difficult for beginners to tell fungal and bacterial plant symptoms apart. Table 1 may be used to help distinguish symptoms caused by these pathogens.

Table 1. Comparison of Fungal and Bacterial Leaf Spots

Symptom Description	Fungal	Bacterial
Water-soaked appearance	No	Yes
Texture	Dry, papery	Slimy, sticky
Smell	No	Yes
Pattern	Circular, target-like	Irregular, angular
Disintegration	No	Yes
Color changes	Red, yellow, purple halos	No
Structures of pathogen	Mycelia, spores, fruiting structures	No

Common bacterial diseases in Colorado include bacterial wetwood (slime flux), fireblight (*Erwinia amylovora*), and bacterial leaf spot (*Erwinia* sp.).

Viruses

Viruses are crystalline particles composed of nucleic acid (ribonucleic acid or deoxyribonucleic acid) and protein. They are obligate parasites, meaning they are unable to survive outside of their host. Small virus particles can be found in all plant parts and cannot be seen without an electron microscope.

To move from plant to plant, the particles must be transmitted by vectors and through a wound. The vector is typically an insect, nematode, or human. Insects and nematodes spread viruses between plants as they feed on them. The feeding injury creates the necessary wound. Usually, a plant virus is spread by only one kind of insect vector. Aphids, leafhoppers, and thrips are examples of virus vectors, but not all aphids, leafhoppers, or thrips spread virus.

Humans may spread plant viruses as they work in the garden. Mechanical abrasion from infected tools or touching and abrading plants with infected hands may be all that is needed.

Viruses overwinter in infected perennial plants or overwintering insects. A small portion of viruses can be transmitted through seeds. Some are transmitted through vegetative propagation.

Viruses cause mottling, spots, mosaic-like patterns, crinkling, and other malformations on leaves and fruits, and may stunt plants. Because viruses are systemic, infected plants must be rogued or discarded (Figure 6).

Viruses are named according to the first plant on which they were found and the type of symptom they cause (i.e., peony ringspot virus, rose mosaic virus).

For example, common virus diseases in Colorado include curly top virus of tomatoes, cucumber mosaic virus of vine crops and tomatoes, tomato spotted wilt virus of tomato, and a variety of greenhouse plant viruses.

Fig. 6. Tomato spotted wilt virus on tomato fruit

Phytoplasmas

Phytoplasmas are bacteria-like organisms; however, they lack a cell wall and can take on a variety of shapes. They are obligate parasites, meaning they can only survive within their hosts. Phytoplasmas live in the phloem of host plants and are vectored by certain phloem-feeding insects, such as leafhoppers. This pathogen causes distortion, yellowing, wilting, and “**witches’ brooms**” (a proliferation of growth). Immature leaf veins may appear clear (called “vein-clearing”). Flower parts may become vegetative and flowers that do develop produce sterile seeds.

Aster Yellows

Aster yellows damages over 300 species of broad-leafed herbaceous plants nationwide. Commonly affected flowering plants include *Echinacea* sp. (purple coneflower), cosmos, marigolds, asters, chrysanthemums, delphiniums, daisies, coreopsis, and zinnias. Vegetables affected include carrots, lettuce, and potatoes. Weeds such as dandelion, ragweed, plantain, wild lettuce, and thistles may also be infected (Figure 7).

Fig 7. Aster yellows on carrot

Aster yellows is spread by the aster (or six-spotted) leafhopper. These insects are small (one-eighth inch long), gray-green, and wedge-shaped. They are called leafhoppers because they move or fly away quickly when plants are disturbed. They feed only on plant sap (phloem tissue) and generally on leaf undersides.

Aster leafhoppers do not overwinter in Colorado due to the cold climate, but are blown in from the Gulf of Mexico in late spring or early summer. Once a leafhopper feeds on an infected plant, about 10 days to 3 weeks must elapse for the insect to become infective. Plant symptoms appear 10 to 40 days after infection. Dry weather can cause increased disease occurrence in the home garden as leafhoppers move from plants in prairies and pastures to irrigated yards. Generally, aster yellows symptoms appear in middle to late summer.

Although aster leafhoppers spread the disease, placing infected plants in the yard can also spread it. Management strategies for aster yellows include planting healthy plants, controlling weeds that may harbor the insects, and removing infected plants. Even though only one part of a plant appears infected, one must assume the phytoplasma is throughout the entire plant.

The pathogen can overwinter in plant crowns and roots. Leaves and stems that develop from this tissue will always be infected and provide a source of inoculum for other susceptible plants. Insecticidal control of aster leafhoppers is very difficult as they are constantly moving in and out of the garden, so it is not recommended.

Parasitic Plants

More than 2,500 species of higher plants are known to live parasitically on other plants. Parasitic plants produce flowers and reproduce by seeds like other plants. The main difference is they cannot produce their own chlorophyll or produce only a small amount of chlorophyll. They must obtain sustenance from a chlorophyll-producing plant to survive. Parasitic plants are spread in various ways including animals, wind, and forcible ejection of their seeds.

Dwarf mistletoe and dodder are two examples of parasitic plants encountered in Colorado. Dwarf mistletoe has chlorophyll but no roots and depends on its host for water and minerals, although it can produce carbohydrates in its green stems and leaves. Dodder cannot produce its own chlorophyll and completely depends on its host for sustenance.

Plants damaged by parasitic plants appear wilted, stunted, distorted, and chlorotic. Some plants, particularly conifers, develop witches' broom symptoms.

Nematodes

Nematodes are microscopic roundworms that live in soil, water, and plant material. They have a spear-like stylet mouthpart, require free water to move about, and reproduce by eggs. They spread in water, infected plant material, soil, and in some cases, insects.

Nematodes cause a variety of symptoms including stunting, yellowing, and wilting of plant tissue. Some infected plants simply appear unthrifty. Some develop strange, knot-like growths on their roots. Many saprophytic and parasitic species exist. Due to cold winters, nematodes as plant pathogens are uncommon problems in Colorado landscape plantings.

Pinewood nematode (*Bursaphelenchus xylophilus*) is a North American native nematode that invades exotic pines such as Austrian, black, and Scots pines.

Pinewood nematode causes pine wilt disease. The symptoms include needle necrosis, branch flagging, and eventual tree death. Trees may decline rapidly; whole tree death can occur in 2 weeks.

Pinewood nematodes are vectored two ways. The primary transmission is by maturation feeding of adult pine sawyer beetles (*Monochamus* sp.) on susceptible trees. Secondary transmission occurs when adult female pine sawyer beetles oviposit (lay eggs) into phloem of susceptible trees. If this disease is suspected as the cause of pine tree death, samples must be sent to a diagnostic laboratory to accurately diagnose pine wilt disease.

Foliar nematodes are found occasionally in irrigated Colorado landscapes. They have a broad host range and can infect many plant species but especially anemone and chrysanthemum.

General Management of Biotic Plant Disease

Plant disease is best managed through an integrated approach, which includes a combination of cultural, mechanical, biological, and chemical practices.

Cultural management includes appropriate plant selection**.** Utilize plants that perform well in the local climate. Use disease-resistant varieties when possible. Plant certified seed or seed pieces.

Place plants in the appropriate environment for optimum growth. For example, grow shade-loving plants in the shade, not hot sun. Prepare soil before planting to improve root growth, reduce compaction in clay soils, and improve water holding of sandy soils. Apply fertilizer and water according to plant needs. Prune correctly, as needed, and at the correct time of year.

Mechanical management techniques include rototilling in the fall, which exposes pathogens, insect eggs, and weed seeds to cold winter temperatures. This action also speeds the decomposition of crop residues, improving soil organic matter. Clean up or prune out infested plant materials to reduce the source of inoculum on the property.

Rotate crops when possible to starve pathogens. For example, avoid planting solanaceous crops in the same area as pathogens specific to this group may build up in soil and infect new crops.

Apply mulch in gardens. Not only does this keep soil moister and cooler (helping roots thrive), it also creates a splash barrier against soil pathogens or pathogens on plant debris in the soil. Use soil solarization to reduce soil pathogens and weed seeds. Pull weeds and volunteer seedlings that hog precious water but also serve as a reservoir for pathogens and insects. Core-aerate turf once or twice yearly.

Biological controls include the use of compost, compost teas, and hyperparasite products, which may reduce pathogens by introducing beneficial microbes. Encourage beneficial insects by planting flowering plants attractive to all stages of development. Avoid blanket applications of pesticides, which may kill beneficials in addition to harmful insects. Spot treat pest problems instead.

Chemical control refers to the use of fungicides, insecticides, and herbicides to manage a problem. Always identify the cause of a plant problem first, then select and use a product appropriate for the problem and follow label directions. Apply it at the correct time using the recommended method. Always spot treat.

Abiotic Disorders

Abiotic agents of disease are non-living factors such as soil compaction, spring frosts, hail, and lawnmower damage to tree trunks. Abiotic agents are noninfectious and non-transmissible. Plant diseases deriving from these agents have been referred to as physiological diseases or environmental diseases.

Water Management

One of the major causes of abiotic plant disorders is improper water application. Too much water can be just as damaging as not enough water, as both kill roots. Examples of abiotic disorders related to water are leaf scorch, winter desiccation, and oxygen starvation (Figure 8).

Figure 8. Water stress on trees often appears from the top down.

Leaf Scorch

Symptoms of leaf scorch include necrosis (browning) of leaf edges and/or between the veins. These are naturally the least hydrated areas of a deciduous leaf, so when moisture is lost, symptoms appear there first. Scorch symptoms on needled evergreens appear as necrosis from the needle tips downward in a uniform pattern. The initial reaction to these symptoms is to provide more water, but that may only exacerbate the situation depending on what is causing scorch in the first place (Figure 9).

Figure 9. Leaf scorch on linden caused by hardscaping over the root zone.

There are several causes of leaf scorch. There may not be enough water in the soil for root absorption. This occurs during drought periods as Colorado experienced in the early 2000s and during winters when soil water is frozen.

Water may be lost faster than it can be replaced. Warm, windy, and sunny weather during winter months causes rapid transpiration at a time when soil moisture may be frozen. During summer, sunny, hot, and windy weather causes such rapid transpiration that roots cannot physically keep up with the water loss.

Soil water may be available, but roots may not be functioning properly to absorb it. What causes roots to function poorly? Soil may be so compacted that roots cannot adequately explore soil for nutrients and moisture. Roots may be severed or otherwise damaged from construction activities or garden cultivation. Planting too deep limits oxygen availability for roots and stresses or kills them. A thick layer of mulch or black plastic covering root systems also injures them due to oxygen deprivation.

Mechanical damage on lower stems or trunks from mowing equipment, improper planting, improper staking, animal chewing, or boring insects may also prevent or slow water uptake. ***The bottom line is that more water is lost than can easily be replaced.***

Oxygen Starvation

Oxygen starvation occurs when excess water in the soil drives out oxygen, in effect “suffocating” roots. Plants respond by dropping lower leaves that are usually yellowed or necrotic. Leaf loss is most noticeable from the inside of the plant out and the bottom up. In addition, leaves may be smaller than normal, growth increments may be small, and the plant may have an overall unthrifty appearance.

While oxygen starvation causes root damage, the first clue that something is wrong appears on the canopy, stems, and branches. These parts are the furthest from the water source, so the symptoms appear there first.

To control problems caused by water management issues, identify the likely causes and correct them if possible. This will require some detective work to determine which factor or (usually) combination of factors is causing the problem.

Management strategies are based on good horticultural practices. For example, add organic matter to vegetable and flower gardens before planting to improve drainage as well as water-holding capacity. Cut back on irrigation frequency or adjust the quantity of the water applied. Core aerate turf, which will also benefit tree roots growing in it. Apply and maintain mulch at levels appropriate for the material used. Remove any black plastic in the landscape.

Weather

Winter desiccation is caused by dry winter winds that result in leaf water loss. Water cannot be replaced in the plant because the soil is too cold for root function. Symptoms of winter desiccation include necrotic leaf or needle tissue (typically from the tips inward), discoloration of needle or leaf tissue, and patchy damage distribution on individual plants in windy locations. Plants may not exhibit symptoms until the following summer when droughty summer conditions ensue (Figure 10).

Figure 10. Winter dehydration on pine appears on needle tips.

To deter winter desiccation, fall water plants after they go dormant. Roots are still active and can absorb water until soil temperatures drop below 40°F. When the ground is not frozen, additional irrigation may be helpful monthly during the winter in the absence of snow cover or sufficient snowmelt or rainfall.

Temperature

Temperatures below optimal plant growth cause plant damage. The amount and type of damage depends on how quickly temperatures drop, the lowest temperature reached, and how long cold temperatures are sustained. Freeze injury may be caused by frost crystals that form in the freezing water outside of plant tissues or by freezing water inside plant cells. Damage from the latter is much more severe and resembles herbicide phytotoxicity, bacterial blight, and branch flagging due to insect borer activity (Figure 11).

Spring freezes damage exterior buds first, as these are the first to deharden. Fall freezes affect interior buds first as these are the last to harden. Damage of tissues is uniform. For example, newly developing conifer needles may be killed completely or from the tips inward.

Temperatures above optimal growth cause plant damage as well. The most severe injury occurs on leaves that are exposed to the sun and tissue that is furthest away from water such as outer branch tips, leaf margins, and between leaf veins.

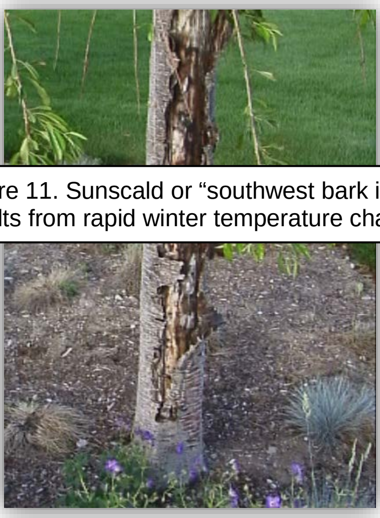


Figure 11. Sunscald or “southwest bark injury” results from rapid winter temperature changes.

Chemical Injury

Chemical injury is plant damage caused by pesticides, fertilizers, de-icing salts, and other products.

Herbicides

Herbicides (weed killers) damage plant tissues by causing symptoms such as chlorosis, necrosis, distortion, and elongated growth. Glyphosate, dicamba, and 2,4-D are examples of common herbicides that cause chemical injury to desirable plants when used incorrectly.

Herbicides that behave like plant growth regulators, such as dicamba and 2,4-D,translocate through both the xylem and phloem. They stimulate growth such as cell division, elongation, and fruit and flower production (Figure 12).

Figure 12. Damage on grapes from 2,4-D. Notice the distortion in leaf vein pattern.

Excessive concentrations of these chemicals cause twisting and curling of stems, stem swelling, weakened cell walls, rapid cell growth, and cellular and vascular damage and death. Grasses are not affected by plant growth regulators apparently due to a different arrangement of vascular bundles (xylem and phloem).

Glyphosate is an amino acid inhibitor that interferes with synthesis of certain amino acids needed to build proteins. Glyphosate moves through the phloem to the new growth of shoots and roots. Injury symptoms include chlorosis, shortened internodes (compact growth or stunting), stem proliferation, and mimics damage caused by 2,4-D and other plant growth regulators, viruses, phytoplasmas, eriophyid mites, and environmental factors.

Fertilizers

An excess or shortage of the 17 essential elements required for plant growth and development may cause plant damage. Excess amounts of fertilizers can “burn” plants due to the level of salts in fertilizers.

Symptoms of fertilizer damage include leaf margin necrosis (similar to drought stress in appearance), leaf discoloration, soft rapid growth, and vegetative growth at the expense of flower and fruit production.

Nutrient deficiencies include chlorosis, interveinal chlorosis, blossom-end rot, stunting, and purpling. Symptoms of nutrient excesses and deficiencies may be confused with disease, insect, mite, or other environmental problems. If a soil nutritional problem or salt injury is suspected, have the soil tested.

When excess fertilizer has been applied, apply water in an effort to leach salts from the root zone. Quick release fertilizers are more prone to “burn” plants. Follow label directions when applying fertilizers to avoid plant damage.

Salts

It is common practice in Colorado to use de-icing salts to remove snow and ice from roadways and sidewalks. Salts injure plants from 1) salt burn on foliage, 2) root burn of salts, or 3) soil buildup that deteriorates soil structure, interfering with drainage and root growth.

Symptoms of salt spray on leaves include stem and leaf deformities, witches' brooms, and twig dieback of deciduous plants. Conifers exhibit needle browning at the tips of branches. Salt spray damage is only noticeable on the plant side adjacent to a road.

Symptoms of salt accumulation in soils are different from salt spray and include marginal leaf scorch, stunting, and twig dieback. Leaf scorch may not appear until later in the season or in following seasons.

To reduce salt burn, avoid de-icing salts, add organic matter and charcoal to the soil, leach with water, or protect plants using a barrier that will keep salt-laden snow away from plant material.

Compost and other soil amendments can be high in salt when made with manure or biosolids. Symptoms of salt burn include marginal burning of leaves, stunting, root dieback, and death of plants. For additional information, refer to Colorado Master Gardener GardenNotes #241, *Soil Amendments* (Figure 13).

Figure 13. Salt damage on bean leaf " burns" the margin of the leaf. This was caused by using compost high in salts.

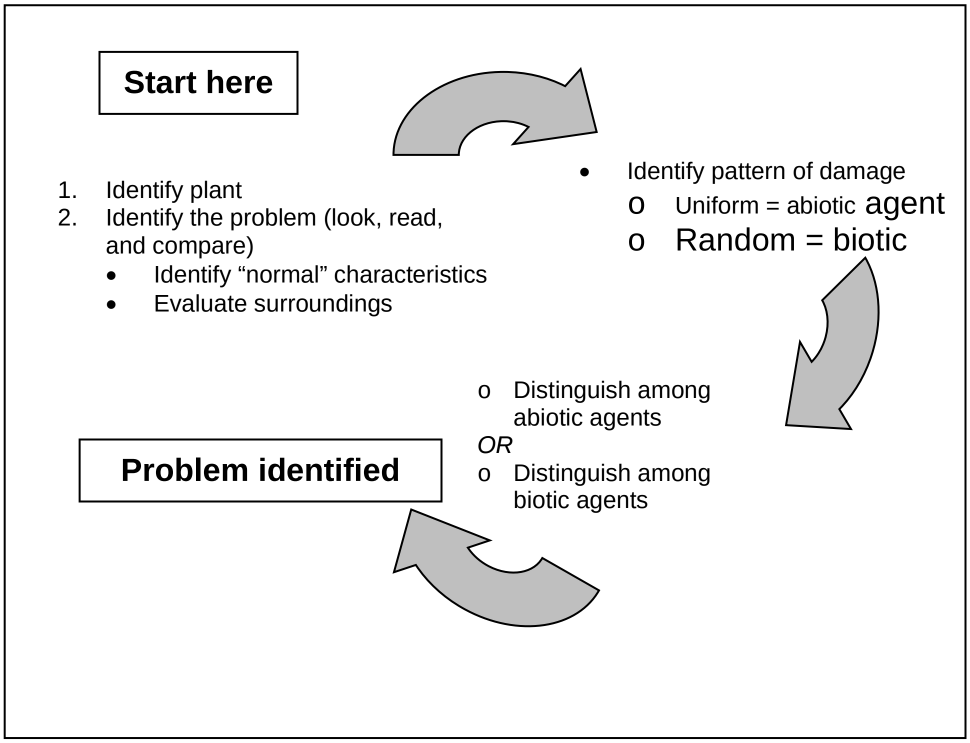
Plant Disease Diagnosis

General steps in the diagnostic process include the following:

1. Identify the plant.
2. Identify the problem(s).
    a. LOOK – Define the problem by describing the signs and symptoms.
        1) Identify "normal" characteristics of the plant
        2) A systematic evaluation of the plant helps organize questions in a methodical process.
    b. READ – Distinguish between possible causes by comparing signs and symptoms with details in reference materials.
    c. COMPARE – Determine probable cause(s) through comparison and elimination.
3. Evaluate if management efforts are warranted.
    a. What type of damage/stress does this disorder/pest cause?
    b. Under what situations would management efforts be warranted?
    c. Are management efforts warranted for this situation?
4. Evaluate management options effective for this disorder/pest and when they are applied.

Determining the causal agent of plant damage can be a tumultuous endeavor, so let us expand on content around Step 2, Identify the problem(s). Use a systematic approach when diagnosing plant damage and determination will become easier (see Chart 1). The probability of correctly diagnosing plant damage based on one or two symptoms is low. In contrast, probability of correctly diagnosing plant damage based on many symptoms and factors is high. Therefore, using investigative skills and asking many questions is imperative to arriving at a correct diagnosis. [Chart 1]

Chart 1. A flow chart displaying the systematic approach to determining causal agents of plant damage.



Sample Questions

Accurate diagnosis is absolutely dependent on accurate observation. When making observations we must ask the following questions:

1. What symptoms is the plant expressing?
2. How many plants are affected?
3. Is there a pattern associated with the problem (i.e. is the problem located in one area; such as a low area, on the north side, south side, etc.)?
4. Are there any differences in susceptibility of varieties or species (i.e. is it just the tomatoes or are other plants also affected)?
5. Ask about obvious causes first, such as animals, frost, flooding, or mechanical damage.
6. Determine which part of the plant is actually damaged. Wilts, for instance, frequently are only a response to some damage to the roots. Dieback of branches is sometimes caused by cankers or mechanical damage further down the stem.
7. Are the roots healthy appearing (not black or mushy) and moist? Note: You may not be able to diagnose the problem without roots.
8. What about the texture and wetness of the soil? Is it too heavy, sandy, or compacted? Is salt crusting evident?

9. What is the weed population? (Weeds may indicate a particular soil problem.)
10. Find out as much as possible about the previous history: fertilizer, pesticides, land leveling, cultivation methods, irrigation schedules, and climatic conditions.
11. There are many other questions that you may think to ask based on the specific sample in question. ***Remember, we can never ask enough questions. The more thorough you are, the better the diagnosis.***

Determine what the "normal" plant would look like during that time of year. Describe the damage using terms like "gall", "witches broom", and "chlorotic." Establish the location on the plant where initial damage occurred. For example, there are leaf spots with fruiting structures on the underside of leaves, but these symptoms are not what caused tree death. Cankers along the branches and trunk are what killed the tree.

Distinguishing the factor that caused plant death from other symptoms and signs can be tricky. In turfgrass, many times sclerotia, fruiting bodies, and conidia are spotted in necrotic and problematic areas. However, these disease-causing structures may not be related to turfgrass death.

Identify Pattern of Plant Damage

Uniform damage patterns on individual plants and on many different plants in a specific area are typically characteristic of nonliving or abiotic factors. Abiotic factors include mechanical, physical, or chemical factors.

Random damage patterns on individual plants or on a specific family or genus of plants typically indicates a living or biotic agent of disease. Biotic factors include fungi, bacteria, or nematodes.

> Important note: You may come to a diagnosis based on the answers a client provided, but when double-checking the diagnosis, you may realize the diagnosis does not seem quite right. Keep an open mind, go back through your questions, and take a different diagnostic avenue.

Distinguish Between Biotic and Abiotic Factors

Signs of biotic pathogen activity will always be present. It is a matter of whether the sign is observed. First, closely study plant damage. Mentally identify possible causal agents. Then look for signs that would accompany such damage. Signs of disease include fruiting structures, overwintering structures, mycelium, insect frass or carcasses, and ooze. Because some diseases are vectored by insects, signs that the vectors are present are equally as important as finding signs of the disease. In addition, some types of disease symptoms mimic symptoms of insect or vertebrate damage. It is critical, therefore, to distinguish between insect and pathogen damage using observed or unobserved signs of both insects and pathogens.

If no signs are observed, abiotic activity should be considered. Ask questions regarding mechanical, physical, and chemical factors affecting the damaged plant. Mechanical factors include string trimmer damage to tree trunks, improper pruning cuts, injury during transportation of plant material and guy wire damage. Physical factors include temperature extremes, light differentials, and extreme changes in oxygen and moisture levels. Chemical factors include pesticide damage, fertilizer damage, nutritional disorders, and pollutants.

Author: Mary Small, Colorado State University Extension. Artwork by David Whiting; used by permission. Figures 2,3, 6 and 10 by Mary Small and Figure 10 by Curtis Utley, both of Colorado State University Extension.

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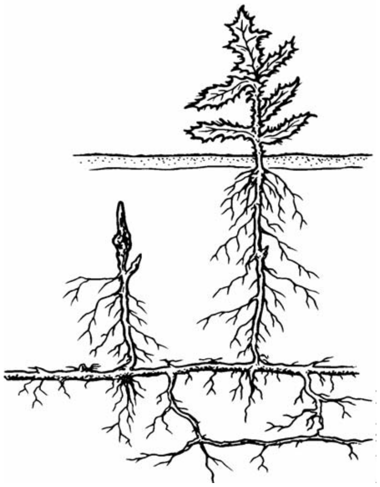

Weed Management

Class Reading / Reference

CMG GardenNotes on Weed Management

- Weed Management, #351
- Weed Identification, #352
- Weed Associations with Specific Environments and Cultural Conditions, #353
- Homework: Weed Management, #354

Learning Objectives

Students will be able to:

- Define what a “weed” is from the perspective of the home landscape
- List the problems that weeds can cause in the home landscape
- Describe why plants become weeds in the home landscape
- Understand the difference between noxious, exotic, native and invasive weeds
- Describe environmental, ecological and cultural/management factors that contribute to landscape weed problems
- Understand why weed identification is important and what resources are available to assist in weed identification
- Describe the different weed life cycles and how that knowledge is vital for developing weed control strategies
- Describe the different landscape settings in which weed problems arise, and how each of those settings each can present a unique set of weed management challenges
- Understand the principles of Integrated Pest Management (IPM) and how to apply those principles to managing specific landscape weed problems
- Describe cultural and management techniques for control of landscape weeds
- Describe the different types of herbicides and how/when each type can most effectively be used as part of a weed management program

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Weed Identification and Management Resources

CSU Extension Resources

Extension Fact Sheets

- Control of Annual Grassy Weeds in Lawns, #3.101
- Musk Thistle, #3.102
- Weed Management for Small Rural Acreages, #3.106
- Leafy Spurge, #3.107
- Canada Thistle, #3.108
- Diffuse and Spotted Knapweed, #3.110
- Russian Knapweed, #3.111
- Biology and Management of the Toadflaxes, #3.114
- Cheatgrass and Wildfire, #6.310

CSU Turf web site at www.csuturf.colostate.edu

- Turf fact sheets
- Identification and Management of Perennial Weedy Grasses in Lawns
- Broadleaf Weed Control in Home Lawns

Weed Identification Books

- ***Weeds of the West.*** 2000. T. Whitson. CSU Extension, Publication XCM-147.
- ***Weeds of Colorado***. 1997. R. Zimdahl. CSU Extension, Publication 521A.
  Weeds of California and Other Western States. 2007. DiTomaso, J. M. and E. A. Healy. Univ. Calif. Agric Nat. Res. Publ. 3488.
  Aquatic and Riparian Weeds of the West. 2003. Joseph M. DiTomaso and Evelyn Healy.
- **Color Atlas of Turfgrass Weeds**. 2008. L. B. McCarty, John W. Everest, David W. Hall, and Tim R. Murphy
- ***Weed Control in Turf Grass and Ornamentals***. 2008. A. J. Turgeon, L. B. McCarty, and Nick E. Christians

Online Weed Identification Keys

- North Carolina State University at http://www.turffiles.ncsu.edu/turfid/itemselector.aspx
- U. California Extension at http://www.ipm.ucdavis.edu/PMG/weeds_intro.html
- Michigan State University at http://www.msuturfweeds.net/

Other Weed Management Resources

- **Colorado Natural Areas -** Creating an Integrated Weed Management Plan: A Handbook for Owners and Managers of Lands with Natural Values at http://parks.state.co.us/NaturalResources/CNAP/Publications/

- **Colorado Weed Management Association** (www.cwma.org)

- **Colorado Department of Agriculture, Noxious Weed Program (Noxious Weed Lists and Photos)** http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1167928159176

- **IPM – Principles of Landscape Weed Management**
http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn7441.html

- **Solarization for Landscape Weed Management**
    - http://vric.ucdavis.edu/pdf/soil_solarization.pdf (a treatise on soil solarization)
    - http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn74145.html (solarization for gardens)
    - http://solar.uckac.edu/new_page1.htm (solarization resource website)
    - http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pni7441-tbl4.html (common garden and landscape weeds controlled by solarization)

- **Invasive Plants:** University of California – Definition of Invasive Plants
http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn74139.html

Review Questions

1. What "makes" a plant a weed, and what problems can weeds cause in the home landscape?
2. List/describe a few of the major types of landscape plantings/settings in which weed problems arise and how they might differ in terms of weed management solutions?
3. What are some plant characteristics that allow certain plants to become landscape weed problems?
4. Describe at 4 ways by which weeds may be introduced into the home landscape.
5. Explain what the "seed bank" is and how it factors into weed management decisions.
6. Give an example of a setting/location in YOUR OWN home landscape where weeds almost never occur – and explain why.
7. How do winter annuals and summer annuals differ? How does understanding this difference affect management strategies for each type?
8. For which type of weeds (life cycle, age) and in which landscape situation is the use of citric acid/acetic acid/botanical oil herbicides most effective? Least effective?
9. For which types of weeds (life cycle and age) is cultivation (hoeing) most effective? Least effective?
10. How can water/irrigation management be used to lessen weed problems in the home landscape?
11. How effective is mowing and string-trimming for weed management?
12. What is solarization? In what garden situations is it most effectively used?
13. How effective is landscape fabric for controlling weeds?
14. Why is mulch effective for weed control? Which types of mulch are 1) most and 2) least effective for weed control?
15. Why are biological control weed control products not used more often for landscape and garden weed management?
16. What is the difference between systemic and contact herbicides – and in which landscape situations (or on what types of weeds) would each be used most effectively?
17. How do preemergent herbicides work – and for which types of weeds (think life cycle) are they most effectively and commonly used?
18. What is the difference between selective and non-selective herbicides? Give examples of where each might be most effectively used.
19. What are some reasons that herbicides do not always control weeds as expected?
20. How would strategies for the management of BINDWEED and PURSLANE in a vegetable bed differ?

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CMG GardenNotes #351

Weed Management

Outline:

What Makes a Plant a “Landscape Weed”?

A weed is any plant that becomes undesirable in the landscape because of the following:

- It is growing in a place where it is unwanted (lawn grass in a flowerbed, tree seedlings in a lawn, purslane growing between patio pavers, spearmint invading a raised vegetable bed).
- It is visually unattractive (color, texture, growth habit, growth rate makes it aesthetically unappealing to the eye).
- It poses a health or safety hazard (poisonous plants, thorny plants, fuel for fires).

- It out-competes more desirable plants in the home landscape (competes for water, nutrients, light) or when it escapes into native landscapes (creating biodiversity problems).
- It acts as a host or shelter for other pests (alternate host for rust, attractive to injurious insects, food/shelter for damaging wildlife).

What Characteristics Make Weeds Successful?

Characteristics that make weeds successful where they become a problem include the following:

- Rapid growth rate.
- Prolific seed producer.
- Long longevity of seed.
- Deep roots, stolons, tubers, etc. making them tolerant of adverse growing conditions.
- More “ecologically fit” than other plants in the landscape.
- Adapted to readily spread (wind, animal manure, water, and human activities).
- Often adapted to disturbed soil/sites.
- May not have insects and diseases to keep them in check.
- May be better competitors for light, nutrients, or sun.

Seed Bank

A seed bank builds up as a weed drops seed into the soil over many years –seed can remain viable for years. Persistence and vigilance to keep weeds from going to seed are keys to depleting seed bank [Tables 1 & 2]

Weeds tend to be very competitive and are capable of taking advantage of disturbed areas. They often produce large amounts of seeds or are capable of quick reproduction. Weeds are generally a problem where the desired crop is doing poorly or the soil has been disturbed.

Table 1. Seeds per Plant

Weed	Number of Seeds Produced Per Plant
Dandelion	15,000
Canada thistle	680
Curly dock	29,500
Lamb’s quarter	72,450
Mullein	223,200
Pigweed	117,400
Purslane	52,300

Table 2. Viability of Buried Seed

Weed	Viability of Buried Seed
Black mustard	50 years
Curly dock	80 years
Foxtail	30 years
Mallow	20 years
Plantain	40 years
Shepherd’s purse	35 years

How Do Weeds Get Into Our Landscapes?

Major sources of landscape weeds include the following:

- Weeds going to seed (seed bank)
- Brought into garden in manure and soil amendments or with soils
- Disseminated from neighboring property's plants and weeds
- Deliberate introduction

Minor sources of landscape weeds include the following:

- Brought into garden with plant materials
- Brought into garden in irrigation water
- Brought into garden by humans or animals
- Using poor quality seed (weed content in seed)

Noxious Weeds

Common weeds refer to weeds commonly found in various cropping situations, such as the lawn, vegetable garden, flowerbeds, or naturalized areas.

Noxious weeds refer to weed species declared by state or local statues as a threat to agriculture and naturalized areas. Some designations require control under the law.

Legal Designations for Noxious Weeds

List A: All populations of List A species in Colorado are designated for eradication because they are not widespread (myrtle spurge, purple loosestrife)

List B: These weeds have discrete populations and will be managed to stop their continued spread, or eradicated in certain areas (Chinese clematis, oxeye daisy)

List C: These weeds are already very widespread, and not required to be controlled; however, education and research continue on these species. (downy brome, field bindweed)

For additional information on Colorado's noxious weed laws, refer to the Colorado Department of Agriculture Noxious Weed Management Program at **www.colorado.gov/ag/weeds**

Weed Life Cycle

To control weeds, the gardener needs to know their life cycles.

Annuals

Summer Annual – The seed germinates in the spring, the plant develops and produces seed during the summer, and the plant dies with killing frost in the fall. Examples include crabgrass and puncture vine.

Winter Annual – The seed germinates in late summer or fall; and lives over winter as small tufts or rosettes of leaves. It resumes growth in spring, matures seed early in the summer, and dies in summer heat. Examples include downy brome and shepherd's purse.

Keys to controlling annuals are preventing seed production, depleting the seed bank, and preventing germination.

- Timing is important.
- Winter annuals must be controlled before seed set in early summer.
- Summer annuals must be controlled before seed set in middle to late summer or early fall.
- The use of herbicides at the end of an annual's life cycle is often ineffective and does not make sense!
- Competition (from other plants and mulch) to prevent seed germination and seedling development.

Biennials

Requires two seasons to complete growth cycle. Seeds germinate in spring; the following season, the plant flowers and matures seeds in summer and fall before dying. An example is dame's rocket.

Keys to control are preventing seed production and depleting the seed bank, and preventing germination and seedling establishment.

Perennials

Simple Perennials have a root crown that produces new shoots every year. It depends upon seed production to spread. Examples include foxtail barley and dandelion.

Creeping Perennials propagate by seed, creeping above ground stems (stolons), and/or creeping underground stems (rhizomes). Examples include quackgrass and Canada thistle.

Keys to control are to prevent seed production and to kill the plant. Creeping perennials have a more extensive root system, and are harder to control.

IPM: Integrated Weed Management

“Integrated Pest Management, IPM, is a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks." - the National IPM Network

The best weed control is prevention!

- Plant weed-free seed, sod, nursery stock
- Avoid using plant species known to be invasive
- Use weed-free amendments, topdressing
- Uses mulch where appropriate
- Maintain healthy, competitive plants
- Irrigate and fertilize appropriately

Methods of Control

Cultural Methods

Irrigation

Irrigation methods and frequency have a direct influence on weeds. Infrequent, deep irrigation droughts out many shallow rooted weeds. Sprinkler irrigation (wetting the entire soil surface) encourages weeds. Drip irrigation (keeping most of the soil surface dry) discourages weeds. Keep non-irrigated areas dry to help suppress weeds.

Lawn Mowing

Many common garden weeds will not survive the frequent mowing of a lawn. However, mowing the lawn too short (less than 2 inches for Kentucky bluegrass) encourage weeds as it reduces vigor of the grass.

Mulching

If maintained at adequate depths, mulching has many benefits including preventing weed seed germination. For wood/bark chips, a depth of three inches is best for weed control. Less is ineffective. Mulching may not effectively control established perennials growing from root.

Landscape Fabrics

In landscape management, landscape fabric with wood/bark chips or rock mulch above is common. However, it prevents soil improvement by organic breakdown, decreasing plant vigor. Weed seeds that germinate above the fabric layer will be difficult to pull and must be removed with herbicides. Use of landscape fabric should be considered as a deferred maintenance technique rather than a low maintenance technique.

Crop Competition

Competition with the crops and weeds for light, water, nutrients, and growing space is an effective weed management tool. For example, mowing a cool season lawn (like Kentucky bluegrass) gives the lawn a growth advantage, shading out many weeds like crabgrass.

Block planting in the vegetable garden and close spacings in a flowerbed, with plants filling the bed space, helps suppress weeds.

Summary: Cultural Methods for Weed Management

Pros: This is the best long-term control as the gardener increases the conditions for desired plants to grow at the same time decrease the conditions for weeds.

Cons: Possibly more expensive and time-consuming; control may be slow.

Mechanical Methods

Tilling / Cultivating

Tilling or cultivating effectively controls 90% of annual and biennial weeds if done before seed set. It also brings a new set of weed seeds to the soil surface ready to germinate. When tilling for weed control, use only shallow cultivation. Deep tilling can damage crop roots. Cultivating/tilling may actually propagate most perennial weeds.

Hand Pulling

Hand pulling is quick when pulled while the weeds are small, and it is effective for small infestations. A few minutes on a weekly basis to keep the garden weed free will be more effective than a long weed pulling session as the weeds get large. For many gardeners, pulling weeds is a great way to vent stress. With hand pulling, most weed species require that they be pulled out by the roots. The weed will readily regrow if just the tops are removed. It is essential that weeds are removed before they go to seed, filling the seed bank. Some weed species, like purslane, must be removed from the garden bed. It can reroot if left in the garden.

Mowing Naturalized and Low Maintenance Areas

Mowing is a common weed management tool in natural areas and lower maintenance sections of a yard, reducing the unsightly appearance of the yard and fire hazard.

String Trimming ("Weed Whacking")

Use of a string trimmer is a form of weed management by mowing. It can be effective in preventing weeds from going to seed. However, it can sow seeds if done on weeds with seeds.

Flame (Propane Torch)

Flaming off weeds with a propane torch is a common practice in production agriculture and has limited application in landscape maintenance due to fire hazards. During the flaming process, heat from the flame is transferred to the plant tissues, increasing the thermal energy of the plant cells and resulting in coagulation of cell proteins if the temperature is above 50°C. Exposing plant tissue to a temperature of about 100°C for a split second (0.1 second) can result in cell membrane rupture, resulting in loss of water and plant death. Thus, the weeds do not need to be burned up, but rather just scorched. Flaming works best on very young weeds.

It is rather expensive and many not be cost effective in some production agriculture situations. It presents a fire and explosion hazard; use with caution. Fire prevention measures prohibit the use of flaming in many communities.

Burning

Burning of fields and ditch banks is a weed management tool in production agriculture. Generally, a permit is required. Most communities prohibit burning of weeds inside city limits.

Solarization

Solarization is a method of heating the soil to kill roots, weed seeds, and soil borne insects and diseases near the soil surface. In regions with hot summer temperatures, it is effective in open areas will full sun. However, do not solarize the soil in the rooting area of trees, shrubs, and other desired plants. Steps include the following:

1. Remove vegetation and cultivate the soil to a six inch depth.
2. Sprinkle irrigate the area.
3. Cover the area with 4 mil clear plastic. Bury the edges of the plastic all the way around the plot.
4. Leave in place for three weeks during the summer heat of July and August.
5. After removing the plastic, avoid deep cultivation what would bring up weed seeds, insects, and disease pathogens from deeper soils.

Summary: Mechanical Method

<u>Pros:</u> Mechanical methods can be quick, inexpensive, environmentally friendly, and effective on small weed seedlings.

<u>Cons:</u> Mechanical methods have limited effectiveness on many established perennials, and could be detrimental at wrong time.

Biological Methods

Biological methods include the use of carefully screened insects to attack portions of the weed (i.e., stems, seeds, flowers, etc.). Development of biological methods with insects is rather complex and must be used with caution. The introduced insects must survive and become established in the new ecosystem. The insects need to reduce the weed population, but cannot entirely eliminate it as the weeds as that would eliminate the insect's food supply. The insects must not attach beneficial plants. The insects must not become insect pest. A great example of biological methods that failed is earwigs. They were intentionally introduced into the United States as a biological control agent and have since become a pest.

Biological methods also include the grazing of sheep, cows, horses, or goats. The purposeful use of grazing animals to control weed patches can be extremely expensive.

<u>Pros:</u> Biological methods can be an inexpensive, long-term control solution. It can be environmentally friendly and require little labor.

<u>Cons:</u> Biological methods are not always effective, may require a large population of weeds to maintain insect populations (will not work in backyard setting), and does not eradicate weeds. Insects can sometimes attack non-target plants.

Herbicides (Chemical Methods)

The use of herbicides is the use of chemicals that disrupt key physiological processes in plants, leading to plant death. Among the various herbicides, many different modes of action are found.

<u>Pros</u>: Use of herbicides is generally effective (if the correct herbicide is used), cost-effective, and provides quick control.

<u>Cons</u>: Use of herbicides can be environmentally problematic when incorrectly applied. Proper use includes proper selection of the specific herbicide for the weeds and for the growing crops in the area, timing of application, correct application rates, correct application procedures, and application safety measure to protect the application and non-target plants. Some require special licensing and may not be used in a home landscape or garden setting.

Be sure to follow the label, it is the law. Components of the herbicide label include the following:

- Trade Name
- Common name
- Chemical name
- Signal Words (Danger, Warning, Caution)
- Use instructions
  - Weeds controlled
  - Plant tolerances

    - Application rate(s)
    - Application timing
    - Application technique
    - Application restrictions
- Safety
    - Applicator
    - Bystanders, pets
    - Wildlife
    - Non-target plants

How Herbicides Are Applied

- **Broadcast** application refers to a uniform application over a treatment area.
- **Spot treat** refers to application to a specific area, such as directly to individual weeds.
- **Foliar** application refer to application to the leaves
- **Soil incorporation** refers to tilling or watering the herbicide into the soil after application.

Types of Herbicides

- **Systemic or Translocated** herbicides move internally in the plant. They must be applied during period of active growth with adequate water. Systemic herbicides are especially good for many perennials. Examples include glyphosate (Round-up), and 2,4-D.

- **Contact** herbicides only desiccate the portion of the plant that is contacted. Contact herbicides are most effective on annuals. Examples include vinegar and diquat.

- **Pre-emergent** herbicides are applied to soil prior to weed seed germination, killing germinating seeds. They will not kill growing weeds. Application timing is critical. For example, to control crabgrass in lawns, pre-emergent herbicides need to be applied late April to early May before the crabgrass germinates, about the time that common lilac blooms. Most require soil incorporation by irrigation.

  Some desired crops germinating from seeds may also be killed. For example, do not apply pre-emergent herbicides prior to seeding or laying sod. Uniform application and strict adherence to application rate are essential for attaining good weed control and for preventing injury to landscape plants.

- **Post-emergent** herbicides are applied to foliage of actively growing plants. Example include 2,4-D, and glyphosate (Round-up).

- **Selective** herbicides control a limited group of plants, like monocots versus dicots.

- **Non-selective** herbicides are effective on a broad range of plants.

Examples of Common Herbicides Used in the Home Landscape

Selective Herbicides for Broadleaf Weed Control in Lawns

Examples: 2,4-D, MCPP and MCPA, Banvel (dicamba), and Confront

Caution:

- Avoid drift and ground water movement to non-target crops. Tomatoes and grapes are extremely sensitive to 2,4-D products.
- Do not use with temperatures above 85ºF.
- Do not broadcast apply under trees. Spot individual weeds.
- Banvel and Confront have higher toxicity on some shade trees including honeylocust, linden, and Japanese pagoda.
- Keep pets off treated area until lawn dries.
- Low human toxicity. Stay out of area until lawn dries.

Non-Selective Herbicides for Control of Herbaceous Plants

Example: Glyphosate (Round-up). Note: Many Round-up products in the home garden trade have a combination of other herbicides added for quicker kill or longer holding potential.

Caution:

- Requires application to leaf tissue. No soil action. Do not spray the ground.
- Neutralized up contact with soil. Mix only with drinking quality water. The dirt in non-potable water may neutralize the product.
- Effective on most herbaceous plants. May or may not be toxic on woody plants.
- Low human toxicity, but avoid skin contact.
- Extremely toxic to dogs. Keep dogs out of treated area until spray dries.

Pre-Emergent Herbicides to Check Germinating Weeds in the Lawn

Examples: Balan, Betasan (bensulfide), Dacthal (DCPA, Ronstar (oxadiazon), Tipersan (siduron), etc.

Cautions:

- Require soil incorporation by irrigation.
- Do not apply prior to seeding or sodding. (Refer to label direction.)

Approach to Clients Having Weed Problems

- The weed must be correctly identified.
- What is the landscape setting (lawn, vegetable garden, flowerbed, shrub border, hardscape)?
- What is the health of the plants where the weeds are growing?
- What is the degree of weed infestation (by numbers, area, time, nearby sources of weeds)?

- What management has been done to date?
- Cultural issues: How is the area being managed (water, mowing, etc.)?
- Indicator species: Certain weeds “indicate” overwatering, too much/too little fertilizer, etc.
- Do they use mulch, where appropriate?

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CMG GardenNotes #352

Weed Descriptions

INDEX

Summer Annuals

Common Mallow, *Malva neglecta*

- Most frequent in cultivated ground, gardens, newly seeded lawns, or stressed lawns that lack density; found at 4,500 to 7,000 feet in elevation
- Prostrate, low-spreading annual, biennial, or perennial; deep taproot; foliage similar to geranium, pinkish-white flowers, fruits look like small round wheels of cheese
- Increase turf density
- Pull plants from moist soil
- Pre-emergent herbicides are effective
- Post-emergent herbicides can be effective

Common Purslane, *Portulaca oleracea*

- Summer annual, found in newly seeded or thinning, non-vigorous lawns and also in cultivated garden sites; up to 8,500 feet in elevation
- Smooth, thick, succulent, alternate (to sub-opposite) edible leaves; small yellow flowers in leaf axils; stems are smooth and reddish; plant is sprawling, prostrate, forming dense vegetative mats from shallow fibrous root system
- Increase turf density
- Pulls easily when soil is moist; easily re-roots after cultivation—remove and dispose of plant
- Pre-emergent herbicides may be helpful
- Post-emergent herbicide use is more effective when plants are young; difficult to kill with an herbicide when larger

Crabgrass, *Digitaria sanguinalis*

- Low-growing, prostrate, summer annual grass; leaf blades wider and lighter green color than Kentucky bluegrass with leaf sheaths with long stiff hairs
- Base of stems are often reddish-purple in color; plant spreads by rooting at the lower stem nodes as well as by seed; forms seedheads below mowing height; seedheads are composed of slender, finger-like spikes
- Crabgrass is less prevalent when turf has good density; mowing too low promotes crabgrass seed germination; maintain mowing height at 2.5 to 3 inches.
- A pre-emergent herbicide applied correctly and at the proper time should provide control; do not use a pre-emergent herbicide on a newly-seeded or sodded lawn or when overseeding a lawn
- Post-emergent “crabgrass killer” sprays are not effective unless crabgrass plants are at the young seedling stage

Green Foxtail, *Setaria viridis*

- A summer annual grass with wider blades and a lighter green color than Kentucky bluegrass
- Faster growing than Kentucky bluegrass; seedheads (known as spikes) have bristles that give it a fuzzy appearance; may form a seedhead despite regular mowing
- Foxtail is much less prevalent when turf has good density; resod or reseed bare spots

- A pre-emergent herbicide applied correctly and at the proper time should provide control; do not use a pre-emergent herbicide on a newly-seeded or sodded lawn or when overseeding a lawn
- Post-emergent herbicides will kill foxtail seedlings (but not mature plants)

Kochia, *Kochia scoparia*

- Very prevalent in disturbed soils, cultivated fields, gardens
- In spring, seedlings have alternate leaves; lower leaves often wider than upper leaves; underside of leaves hairy, margins hairy
- Flowers are yellow, inconspicuous; seed production occurs from July to October
- Stems are 1 to 6 feet tall
- In fall, entire plant first becomes reddish-brown, then brown, becomes “tumbleweed”
- Germinates early; use pre-emergent herbicides before soil temps reach 38°F
- Post-emergent herbicides can be effective
- Mulch inhibits seedling development

Netseed Lambsquarters, *Chenopodium berlandieri*

- Summer annuals prevalent in disturbed soils, gardens, cultivated fields, waste areas
- Extremely variable in appearance; stems 1 to 6 feet tall, grooved, often reddish tinged; undersides of leaves whitish, mealy (mottled, granular appearance)
- Flowers inconspicuous, greenish, at tips of stems and leaf axils; seed production occurs from July to September
- Edible when plant is young and tender
- Competitive weed with rapid growth and high water use
- Can be hoed or pulled when young
- Pre-emergent herbicides applied at the right time in spring can provide good control
- Post-emergent herbicides can be effective
- Mulch inhibits seedling development

Prostrate Knotweed, *Polygonum aviculare*

- Prostrate summer annual from a thin taproot; tough, durable plant common along sidewalks, in turf that is stressed and less vigorous, and in gardens; found to 9,500 feet in elevation
- Thrives in dry, compacted soils or wherever there is excessive foot traffic
- Forms a tough, wiry mat of stems that are enlarged at each joint as well as a papery sheath at each leaf node; to differentiate from spurge, broken stem does not produce a milky sap; leaves and stems are not hairy, and leaves are alternate
- Flowers small, white, inconspicuous; found where leaf meets stem; produces many seeds
- Annual core aeration spring and/or fall will reduce knotweed infestation
- Apply pre-emergent herbicides in late fall/winter (knotweed can germinate in February or March)
- Post-emergent herbicides are mostly ineffective after plants become larger

Prostrate Spurge, ***Chamaesyce maculate***

- Prostrate summer annual forming dense mats; found in thinning, less vigorous turf
- Leaves are opposite and each leaf has a reddish-purple spot in the center; small pinkish flowers in leaf axils; stems and leaves are both hairy; sap is milky latex; some people develop a rash after skin contact with sap
- Increase turf density
- Plants can be pulled and bagged if soil is moist; wear gloves because of the sap
- Post-emergent herbicides can be effective

Redroot Pigweed, ***Amaranthus retroflexus***

- Coarse, summer annual; fast growing to 12 to 36 or more inches tall; dependent on moisture received
- Alternate leaves vary in appearance, but have prominent veins and midrib
- Lower stem reddish or red-striped; roots pink-red even down the taproot
- Flowers/seedheads at top of plant; prickly; produces many small black seeds
- Very toxic to cattle and swine
- Found in waste areas, gardens, disturbed soils, and in turf if thin and patchy in quality
- Hoe or pull from moist soil before seedheads mature; bag plants if pulled later
- Easy to kill with most herbicides, but apply according to label directions well before seedheads mature; herbicides suggested only where large numbers of plants exist or where large areas are infested

Scentless chamomile, ***Matricaria perforata***

- Noxious weed in Colorado List B
- Annual forb that can persist as a biennial or shortlived perennial
- Stems of the plant are green, erect, often branched, glabrous, or slightly pubescent, and can range in height from 6 to 20 inches tall
- Leaves are alternate, 1 to 2 inches long, slightly pubescent or glabrous, and are finely divided into several short thread-like segments
- Terminal flowers are 0.75 to 1.25 inch in diameter, with a daisy-like appearance consisting of white petals surrounding a central yellow core
- Key to control is reducing seed production; hand pulling is effective, but may not be practical in larger patches; mowing conducted early in the growing season before plants flower and prior to seed production will reduce populations
- Maintaining healthy stands of desirable vegetation can also be an effective control measure because scentless chamomile seedlings cannot tolerate intense competition
- Post-emergent herbicides can be effective

Winter Annuals

Downy Brome/Cheat Grass, ***Bromus tectorum***

- Noxious weed in Colorado (List C)
- Winter annual, extremely abundant in intermountain west; after maturity can become a fire hazard, especially when dry; found at 4,000 to 9,000 feet in elevation
- Leaf sheaths and blades are covered by dense soft hairs

- Droopy seedheads develop in spring; long awns; prolific seed producer; plants turn reddish brown in early summer (mid to late June), and then fade to a blond color
- Competes vigorously with other perennial grasses for moisture because of its winter and early spring growth habit; root growth during winter can occur until soil temperature goes below 37°F
- Hand-pulling effective for small infestations—repeat pulling over the season is necessary, as seeds will germinate irregularly; extract as much root as possible to prevent re-growth
- Infrequent in mowed turf; in the landscape, glyphosate (Round-up and others) works well in early spring prior to seedhead appearance; best when non-target species are dormant

Shepherd's Purse, *Capsella bursa-pastoris*

- Small winter annual with small white flowers early in spring; common in cultivated gardens and roadsides; common up to 9,000 feet in elevation
- Slender stems from basal rosettes; leaves are hairy below, smooth above, and often deeply lobed; seed pods are heart-shaped (or purse-shaped); seed production from April to September
- Hand-pulling or hoeing before seed set is very effective—get on it early!
- Post-emergent herbicides should be labeled for use in turf grass

Biennials

Dame's Rocket, *Hesperis matronalis*

- Noxious weed in Colorado (List B)
- Can be a short-lived perennial
- Was introduced as an ornamental
- Flowers have four petals, are purple or white, clustered in loose stalks, and fragrant
- Mature plants range from 1 to 3 feet tall
- Can be aggressive in the landscape
- Pulling or cutting flower heads before seed set will control the plant, but this will need to be repeated for several years to exhaust seed bank
- For larger infestations, post-emergent herbicides can be effective
- Do not buy seed mixes that contain this plant

Diffuse Knapweed, *Centaurea diffusa*

- Noxious weed in Colorado (List B)
- A biennial, short-lived perennial, or occasionally an annual
- The plant develops a single shoot (stem), 1 to 2 feet tall that is branched toward the top; first year rosette leaves and lower shoot leaves are finely divided; leaves become smaller toward the top of the shoot and have smooth margins
- Many solitary flowering heads occur on shoot tips; they are about one-eighth inch in diameter and 0.5 to 0.66 inch long; flowers usually are white but may be purplish; involucre bracts are divided like teeth on a comb and tipped with a slender spine that makes them sharp to the touch; sometimes the bracts are dark-tipped or spotted like spotted knapweed; the long terminal spine differentiates diffuse from spotted knapweed
- It reproduces and spreads from seed—keep from going to seed; hoeing or hand pulling before the plant goes to seed can accomplish this
- For larger areas, post-emergent herbicides can be effective

- Cultural controls include revegetating with desirable grasses
- Biological controls include the seedhead flies *Urophora affinis* and *U. quadrifasciata* and root-feeding insects such as the diffuse knapweed root beetle (*Sphenoptera jugoslavica*), the yellow-winged knapweed moth (*Agapeta zoegana*), and the knapweed root weevil (*Cyphocleonus achates*)

Musk Thistle, *Carduus nutans*

- Noxious weed in Colorado (List B)
- Musk thistle is a biennial or winter annual that can grow up to 8 feet tall
- Leaves are up to 10 inches long, dark green with a light green midrib, spiny, and deeply lobed; often have a white margin
- Solitary, lightly spiny, and nodding flower heads develop at the stem tips in midsummer and grow to a diameter of 1.5 to 3 inches and are deep rose to violet
- The key to control is not to let the plant go to seed; herbicides and hand pulling the rosette are both effective
- Applications should be made in late spring/early summer and again in the fall

Prickly Lettuce, *Lactuca serriola*

- Biennial or winter annual to 48 inches tall from a large taproot; invades disturbed garden soils
- Cut stems/leaves exude a “milky juice”; more common in areas from 4,500 to 6,000 feet
- Upper leaves lobed like oak leaves and are often twisted to lie in a vertical plane, also known as “compassplant” because leaves may “point” to north and south; lower leaves often not as lobed; leaves have prominent spines on back side of midrib
- Small yellow daisy-like flowers on elongated stems; seedheads are like those of dandelion
- Hoe or pull from moist soil before yellow flowers mature
- Easy to kill with most herbicides, especially when younger; apply according to label directions well before seedheads mature; herbicides suggested only where large numbers of plants exist or where large areas are infested

Yellow Sweet Clover, *Melilotus officinalis*

- Biennial herbaceous plants; second year plants grow 3 to 5 feet high and are bush-like; sweet clovers are very fragrant
- Leaves are alternate, divided into three finely toothed leaflets; middle leaflet grows on a short stalk
- Flowers are crowded densely at the top 4 inches along a central stem; each flower is attached by a minute stalk
- There are one or two hard small seeds per flower; they stay viable in the soil for 30 years
- Strong taproot
- Can be good forage; however, moldy hay made from yellow sweet clover (or hay made from drought stressed or frost-damaged plants) is toxic to livestock (contains coumarin which converts to dicoumarin, a blood thinner)
- The key to controlling sweet clovers is to keep them from flowering and then concentrate on depleting viable seeds in the soil
- Hoe, hand pull, or spray with post-emergent herbicide when young

Simple Perennials

Curly Dock, *Rumex crispus*

- Leaves emerge from stout taproot in spring
- Elongated leaves have wavy (curly) margins.; leaves mostly basal, with long petioles
- Stems 2 to 4 feet tall, reddish, ridged; nodes sheathed with clear membrane
- Flowers greenish, May
- Winged fruits on flowering stems, reddish-brown
- Habitat—Fields, roadsides, railroads, waste ground, disturbed sites, turf/landscape
- Dig taproot, must remove at least 75% of the taproot to control
- Post-emergent herbicides can be effective

Myrtle Spurge, *Euphorbia myrsinites*

- Noxious weed in Colorado (List A)
- Mat-forming perennial to 9 inches tall
- Escaped ornamental; formerly sold as a drought-tolerant ground cover
- Blue-green succulent leaves form a “donkey tail”; has chartreuse bracts (“flowers”)
- For small infestations, dig or pull out clumps with caution; white latex sap from stems and leaves can cause severe dermal reactions—always wear gloves if hand pulling
- For larger infestations, use an herbicide; the best time to treat myrtle spurge with herbicide is during late fall
- *Eradication of all plants is required throughout Colorado.* If you see it, contact your county weed supervisor or the state weed coordinator!

Spotted Knapweed, *Centaurea maculosa*

- Noxious weed in Colorado (List B)
- A short-lived, noncreeping perennial that reproduces from seed (primary means of spread)
- Produces one or more shoots that are branched and 1 to 3 feet tall; rosette leaves can be 6 inches long and deeply lobed
- Leaves are similar to diffuse knapweed
- Lavender to purple flowers are solitary on shoot tips and about the same size as diffuse knapweed flowers; involucre bracts are stiff and black-tipped; the tip and upper bract margin have a soft, spine-like fringe and the center spine is shorter than others
- For control measures, see diffuse knapweed

Creeping Perennials

Bouncingbet, *Saponaria officinalis*

- Noxious weed in Colorado (List B)
- An escaped ornamental, aggressive in landscapes and wild areas
- Spreads aggressively through rhizomes and seeds
- White to pink five-petaled flowers are clustered at the ends of branches
- Leaves are opposite, smooth, and have three veins from base
- Mature plants are up to 3 feet tall

- Saponins in plant are toxic to livestock
- Can be controlled by mowing or pulling several times a year—before seed production
- Post emergent herbicides can be effective

Canada Thistle, *Cirsium arvense*

- Noxious weed in Colorado (List B)
- Colony-forming creeping perennial spreading primarily by horizontal roots (can grow as much as 18 feet in one season!) and to a lesser degree by seed; found from 4,000 to 9,500 feet in elevation
- Flowers are purple and are borne in clusters; spiny foliage with variable leaf shapes; when mowed in a lawn, will not develop full height and flower
- Highly invasive species; control is difficult because of its extensive root system; pulling generally is not effective due to the tremendous reserves in the root system; *regular, persistent* pulling may gradually starve root system; shoots should be pulled as they are noticed, as all shoots (leaves) are producing food reserves
- Increase density and competitiveness of turf
- Post-emergent herbicides can be effective
- Vinegar is a contact herbicide and will only brown leaves; these will be replaced by new shoots; frequent applications may be effective
- Biocontrol insects include a seed head weevil, a stem-mining weevil, and a gall-forming fly; these may not be significantly effective alone but can provide good results when combined with other control methods; biocontrol insect releases are best suited to large acreage infestations; backyard releases are generally impractical

Common Tansy, *Tanacetum vulgare*

- Noxious weed in Colorado (List B)
- Introduced from Europe as an ornamental and medicinal herb
- Found in yards, along roadsides, stream banks, and in waste places
- Spreads by rhizomes, can reach 3 to 4 feet tall
- Flowers are button-shaped and yellow in flat-topped clusters
- Leaves are deeply divided into narrow leaflets and rank smelling
- Is toxic to livestock, although unpalatable
- Mowing before seed production can limit spread, although it may have to be repeated several times in a season to prevent regrowth from rootstocks
- Hand pulling in damp soil can remove small infestations; wear gloves; will readily regrow from fragments in soils
- For larger infestations, post-emergent herbicides can be effective

Creeping Woodsorrel/Oxalis, *Oxalis corniculata*

- Prostrate, creeping perennial from slender taproot; stems root where they touch the ground
- Leaves have a shamrock appearance; plants often mistaken for a clover; leaves may “fold up” at night or on cloudy days; leaves turn purplish with the arrival of cooler weather in fall; some plants may have purplish leaves year-round
- Small yellow flowers
- Fruits “explode” when mature, scattering seed often more than 10 feet
- More common in thin, less vigorous turf given too frequent, light irrigation; increase turf density
- Pre-emergent herbicides may be helpful

- Post emergent herbicides can be effective

Field Bindweed, *Convolvulus arvensis*

- Noxious weed in Colorado (List C)
- Creeping perennial; found as high as 10,000 feet in elevation; general range 4,000 to 8,000 feet
- Vining, sprawling, prostrate growth habit; may climb by twining around fence wire or around stems of other plants; not shade tolerant but drought tolerant due to large roots; leaves are arrowhead-shaped; attractive, white or pink bell-shaped flowers that resemble morning glory from late June until frost
- Increase density and competitiveness of turf
- Control is difficult because of its extensive root system, which can penetrate the soil profile to a depth of 20 feet; seeds also can remain viable for 20 to 50 years; pulling generally is not effective due to the tremendous reserves in the root system; *regular, persistent* pulling may gradually starve root system; shoots should be pulled as they are noticed, as all shoots (leaves) produce food reserves
- Post-emergent herbicides can be effective
- The bindweed mite has been used as a biological control with some success; initial impact is reduction of growth and limited flower and seed production; mowing moves mites around and stimulates plant growth for mites to feed on; survival is better in drier settings; excessive moisture may limit establishment; contact your local Colorado State University Extension office for information

Hoary Cress (White Top), *Cardaria draba*

- Noxious weed in Colorado (List B)
- A creeping perennial that reproduces by seed and creeping roots; one of the earliest perennial weeds to emerge in the spring
- It grows erect from 10 to 18 inches high and has a white color
- The alternate leaves clasp the stem and are oval or oblong with toothed or almost smooth margins; the leaves are often covered with very fine white hairs; each leaf is 0.5 to 2 inches long with blunt ends
- The flowers are white, one-eighth inch across, and numerous in compact flat-top clusters, which give the plant its name; each heart-shaped seed pod contains two oval, finely pitted, red-brown seeds each about one-twelfth inch long
- Due to the rhizomes of this perennial weed, mechanical control provides minimal control; diligent digging can provide control of very small infestations; hand pulling of above-ground plant parts is ineffective; successful digging requires complete plant removal within 10 days after weed emergence throughout the growing season for 2 to 4 years; cultivation 6 inches deep must be repeated within 10 days of weed emergence throughout the growing season for 2 to 4 years
- Revegetate with desirable vegetation
- Post-emergent herbicides can be effective

Leafy Spurge, *Euphorbia esula*

- Noxious weed in Colorado (List B)
- An erect plant that grows 1 to 3 feet tall
- Leaves are bluish-green with smooth margins, 0.25 inch to 0.5 inch wide, and 1 inch to 4 inches long
- Umbel flowers are surrounded by heart-shaped, showy, yellow-green bracts (an umbel looks like the stays of an umbrella if it is held upside down); flowers occur in many clusters toward the top of the plant; seeds are round to oblong, about one- twelfthinch long, gray or mottled brown with a dark line on one side
- Leafy spurge contains a white milky latex in all plant parts; latex distinguishes leafy spurge from some other weeds (e.g., yellow toadflax), particularly when plants are in a vegetative growth stage
- Leafy spurge has an extensive root system that is abundant in the top foot of soil, and it may grow 15 feet deep or more; roots contain substantial nutrient reserves that allow the weed to recover from stress, including control efforts; many vegetative buds along roots grow into new shoots
- Use a combination of methods to control leafy spurge; vigorous grass helps weaken leafy spurge through competition
- Post-emergent herbicides can be effective

Orange Hawkweed, *Hieracium aurantiacum*

- Noxious weed in Colorado (List A)
- Shallow, fibrous roots
- Leaves are hairy, spatula shaped, up to 5 inches long, and basal
- Extensive stolons create a dense mat that practically eliminates other vegetation—makes mechanical control very difficult once established
- Stems and leaves exude a milky latex when cut or broken
- Up to 30 half-inch red to orange flowers appear in late May or June
- Post-emergent herbicides can be effective
- *Eradication of all plants is required throughout Colorado.* If you see it, contact your county weed supervisor or the state weed coordinator!

Oxeye Daisy, *Chrysanthemum leucanthemum* or *Leucanthemum vulgare*

- Noxious weed in Colorado (List B)
- A perennial from rhizomes with characteristic “daisy-like” flowers
- Plants initially develop as a basal rosette; lower rosette leaves occur on petioles and are from 1.5 to 6 inches long; leaves are lobed
- Flowers are white with a yellow center and range from 1.25 to 2 inches
- Oxeye daisy should be mowed as soon as flowers appear to reduce seed production; root systems are shallow and the plant can be dug up and removed; hand removal will have to be continued for several years because seeds may remain viable in the soil for a long time
- Post-emergent herbicides can be effective
- Native daisies are a good, non-invasive garden alternative

Purple Loosestrife, ***Lythrum salicaria***

- Noxious weed in Colorado (List A)
- Escaped ornamental, aggressive in riparian areas
- Square stem, whorled leaves
- Purple-magenta flowers with five to seven petals in long racemes
- If left unchecked, a wetland may become a monoculture of loosestrife
- Control of small infestations can be managed through digging all the plants and roots—this will need to be monitored for a few years
- Large infestations should be controlled with an aquatic-labeled herbicide
- *Eradication of all plants is required throughout Colorado.* If you see it, contact your county weed supervisor or the state weed coordinator!

Quackgrass, ***Elytrigia repens***

- Noxious weed in Colorado (List B)
- Very aggressive creeping perennial grass especially in moist soils; found from 4,500 to 9,000 feet in elevation; spreads by seeds and invasive rhizomes (underground stems)
- Rhizomes are yellow-white, with brown sections; rhizome ends are sharp-pointed and can penetrate hard soils; base of leaf blade with claw-like appendage that clasps the stem
- Believed to be allelopathic (release of a chemical that inhibits growth of nearby plants)
- Mechanical control is difficult as any rhizome segment produces new plants
- A few quackgrass plants can be spot-sprayed with glyphosate, or individual blades can be painted with glyphosate; note that glyphosate will kill any bluegrass it contacts; repeat applications will likely be needed
- Renovate severely infested lawn areas—spray area with glyphosate; repeat applications will likely be needed; ensure that quackgrass is killed before areas are resodded or reseeded

Russian Knapweed, ***Centaurea maculosa***

- Noxious weed in Colorado (List B)
- Creeping perennial that reproduces from seed and vegetative root buds
- Emerges in early spring, bolts in May to June, and flowers through the summer into fall
- Shoots or stems are erect, 18 to 36 inches tall, with many branches; lower leaves are 2 to 4 inches long and deeply lobed; upper leaves are smaller, generally with smooth margins, but can be slightly lobed; shoots and leaves are covered with dense gray hairs
- The solitary, urn-shaped flower heads occur on shoot tips and generally are 0.25 to 0.5 inch in diameter with smooth papery bracts; flowers can be pink, lavender, or white
- Has vertical and horizontal roots that have a brown to black, scaly appearance, especially apparent near the crown
- Toxic to horses; allelopathic to other plants
- The key to Russian knapweed control is to stress the weed and cause it to expend nutrient stores in its root system
- An herbicide alone will usually not effectively manage Russian knapweed; combine treatment with perennial grasses sown in late fall; tillage is necessary to overcome the residual allelopathic effects of Russian knapweed

White Clover, ***Trifolium repens***

- Creeping perennial that forms runners that root at nodes

- Many people like clover in lawns, while others find white flowers and the bees they attract objectionable
- A legume that fixes nitrogen, so it is often found in lawns having low fertility
- Increase turf density with proper watering, mowing, and fertilization
- Post-emergent herbicides can be effective

Wild Violet, *Viola* spp.

- Heart-shaped leaves on long petioles, purple flowers in spring; may also spread by rhizomes
- Difficult to control due to resistance to many herbicides
- Improve light penetration to shaded areas by pruning trees and shrubs
- Mow lawn higher to increase competition from grass
- Best control may be to pull plants when ground is moist
- Post-emergent herbicides can be effective

Yellow Toadflax, *Linaria vulgaris*

- Noxious weed in Colorado (List B)
- Yellow toadflax is a perennial that spreads sideways by underground rhizomes and by seeds
- Flowers are small, yellow, look like snapdragons, and bloom mid-late summer; leaves are linear
- Some people confuse a native plant, golden banner, with toadflax, but golden banner blooms very early and has three leaves, like a clover
- Yellow toadflax is difficult to control; its extensive root system lets it recover from control attempts
- Yellow toadflax is very variable, genetically; therefore the effectiveness of herbicides is also variable
- Hand pulling can be effective on small patches, especially in gravelly soils when you can pull a large part of the root; it will need to be pulled for several years; pull *before* it goes to seed
- Post-emergent herbicides can be effective

Woody Plants

Russian Olive, *Elaeagnus angustifolia*

- Noxious weed in Colorado (List B)
- Small tree 10 to 25 feet tall originally planted as an ornamental and for windbreaks
- Leaves are narrow and appear silvery
- Branches have long thorns 1 to 2 inches in length
- Small sweet smelling yellow flowers are followed by a berry-like fruit which is spread by birds
- Has become a serious weed in low-lying pastures, meadows, and waterways
- The most effective control is to cut the tree and immediately paint the stump with a herbicide
- Silver buffalo berry is an excellent native alternative plant

Tamarisk, *Tamarix ramosissima*

- Noxious weed in Colorado (List B)
- Tamarisk was sold as an ornamental plant for gardens during the 1800 and 1900s; tamarisk has now spread to most of the western United States, displacing the native cottonwoods and other plants
- Plants can grow to 6 inches tall during the first 2 months and can grow over 18 feet tall; the taproot can reach 100 feet down with a root spread of up to 150 feet; adventitious roots can produce new trees when buried!
- Mature tamarisk trees can produce millions of pollen-size seeds dispersed through wind and water; seeds can germinate while floating and establish themselves on wet banks within 2 weeks; newly formed sand banks are particularly susceptible; trees may reproduce in the first year, but typically they reproduce during the second year
- It is very "thirsty"—one tree can use up to 300 gallons per day, and it alters hydrologic conditions in riparian areas
- Salt glands on the leaves release salt, increasing salinity of soil
- Tamarisk is difficult to control; single treatment approaches to control tamarisk have not proven feasible because no method completely eliminates tamarisk or its regeneration; use revegetation in conjunction with other methods
- The saltcedar leaf beetle, *Diorhabda elongaa*, has been released on some stands, and has shown to be fairly effective

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #353

Weed Associations with Specific Environments and Cultural Conditions

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Compacted Soils

annual bluegrass (*Poa annua*)
common chickweed (*Stellaria media*)
goosegrass (*Eleusine indica*)
knotweed (*Polygonum aviculare*)
mouse-ear chickweed (*Cerastium vulgatum*)
prostrate spurge (*Euphorbia supina*)

Dry Soil

black medic (*Medicago lupulina*)
dandelion (*Taraxacum officinale*)
bindweed (*Convolvulus spp.)*
kochia (*Kochia scoparia*)
stinkgrass (*Eragrostis cilianensis*)

Dry, Infertile Soils

black medic (*Medicago lupulina*)
yarrow (*Achillea millefolium*)

Moist or Poorly Drained Soils

annual bluegrass (*Poa annua*)
bentgrasses (*Agrostis spp.)*
common chickweed (*Stellaria media*)
crabgrasses (*Digitaria spp*.)
goosegrass (*Eleusine indica*)
ground ivy (*Glechoma hederacea*)
mouse-ear chickweed (*Cerastium vulgatum*)
violets (*Viola spp*.)
yellow nutsedge (*Cyperus esculentus*)

Moist, Fertile Soils

annual bluegrass (*Poa annua*)
curled dock (*Rumex crispus*)
henbit (*Lamium amplexicaule*)
yellow woodsorrel (*Oxalis stricta*)

Moist, Infertile (Low N) Soils

black medic (*Medicago lupulina*)
plantains (*Plantago spp*.)
white clover (*Trifolium repens*)

Low Mowing Height

annual bluegrass (*Poa annua*)
crabgrasses (*Digitaria spp.)*
yellow woodsorrel (*Oxalis stricta*)
white clover (*Trifolium repens*)

New Seedings (Spring/Summer)

annual bluegrass (*Poa annua*)
barnyardgrass (*Echinochloa crusgalli*)
crabgrasses (*Digitaria spp.)*
purslane (*Portulaca oleracea*)
foxtail (*Setaria spp.)*

New Seedings (Fall)

henbit (*Lamium amplexicaule*)
storksbill (*Erodium cicutariuim*)
shepardspurse (*Capsella bursa-pastoris*)
annual mustards (many)

Old Lawns (25-30+ years)

bentgrasses, redtop (*Agrostis spp*.)
orchardgrass (*Dactylis glomerata*)

Shady Lawns

annual bluegrass (*Poa annua*)
common chickweed (*Stellaria media*)
ground ivy (*Glechoma hederacea*)
mouse-ear chickweed (*Cerastium vulgatum*)
nimblewill (*Muhlenbergia shreberi*)
violets (*Viola spp*.)

Formerly Agricultural/Farm Land

barnyardgrass (*Echinochloa crusgalli*)
bindweed (*Convolvulus spp.)*
Canada thistle (*Cirsium arvense*)
foxtail (*Setaria spp.)*
quackgrass (E*lytrigia repens*)
smooth bromegrass (*Bromus inermis*)

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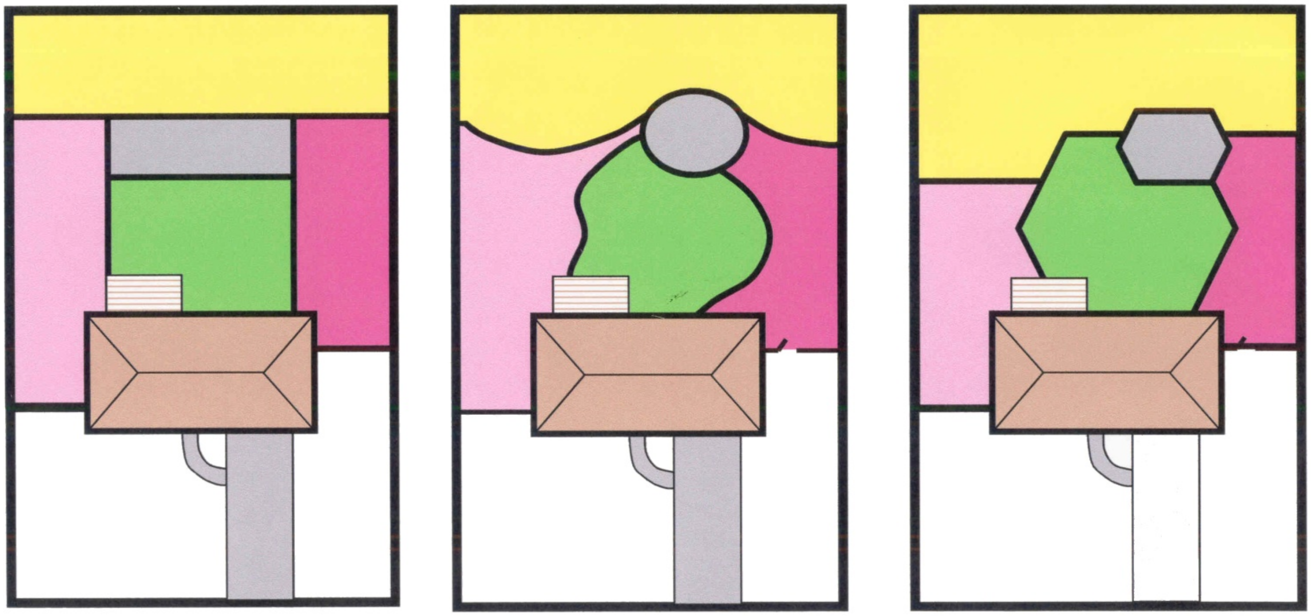

Water Wise Landscape Design

Supplemental Reference / Reading

CMG GardenNotes

- #410, *References and Study Questions: Water Wise Landscape Design*
- #411, ***Water Wise Landscape Design: Design Steps***
- #412, ***Water Wise Landscape Design: Selecting Turf Options***
- #412, ***Principles of Landscape Design: Design Principles***
- #413, *Worksheet: Water Wise Landscape Design*
- #414, *Homework: Water Wise Landscape Design*

Books

- ***Basic Elements of Landscape Architecture Design***. Norman K Booth. ISBN: 0881334782
- ***Landscaping Makes Cents: Smart Investments That Increase Your Property Value***. Frederick C Campbell and Richard L Dube. ISBN: 0882669486
- ***Landscaping Your Home***. William R. Nelson. ISBN: 0875639607
- ***Residential Landscape Architecture: Design Process for the Private Residence.*** Norman K Booth and James E Hiss. ISBN: 0131140647
- ***Xeriscape Handbook***. Gayle Weinstein. Fulcrum Publishing. 1999. ISBN 1-55591-346-6
- ***Xeriscape Plant Guide***. Denver Water, Fulcrum Publishing. 1996. ISBN 1-55591-253-2

Web

- ***Value Landscaping for Financial and Environmental Sustainability*** – Add your yard's inputs and the software calculates the cost to install and maintain the landscape. Developed by Utah State University Extension and the Central Utah Water Conservancy District – VLE.CUWCD.COM

Curriculum developed by David Whiting, Department of Horticulture & LA (retired), Colorado State University, and Jeffry de Jong, Horticulturist, Victoria, BC, Canada.. Artwork by David Whiting; used by permission.

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Learning Objectives

Working through design as a process, the student will be able to craft a water wise landscape design. At the end of this class, the student will be able to:

1. Outline the six steps in the landscape design process. Explain how the process is important to potential water savings.
2. Discuss opportunities and limitations as it relates to site analysis.
3. Explain how a garden theme defines the landscape around family values, needs and wants.
4. Describe hydrozoning and its role in potential water savings and plant selection.
5. Match lawn options with design needs and use.
6. Describe the use of rectilinear, curvilinear and angular design styles.
7. Describe how to refine a preliminary design for efficient irrigation efficiency.
8. Describe the interplay of *line, color, texture* and *form* with *scale, balance, simplicity, variety, emphasis* and *sequence* to create *unity* in the design.
9. Explain hints to mix and match plants creating pizzazz.

Review Questions

1. List the seven principles of water wise gardening. Explain the take home message of each.

2. Describe the steps in the landscape design process.

3. Describe site analysis considerations in the following areas:

    - Soil tilth
    - Grading and drainage
    - Microclimate
    - Existing vegetation
    - Extension Landscape
    - Potential for irrigation

4. Explain "opportunity or restraint" as it relates to site analysis.

5. Describe considerations in family analysis. How does potential irrigation figure into family analysis?

6. Discuss the purpose of the landscape story line (theme). What does the story line and theme bring to the design process?

7. Describe the purpose of the hydrozone bubble drawings.

8. Describe how hydrozones fit into the design process. For existing landscapes, explain why we go back to the hydrozone bubble drawings step to evolve a more water efficient landscape.

9. Describe the concept of "practical turf areas". What factors should be considered in matching a turf type for a specific site?

10. In Colorado where multi-year drought routinely occurs, how could community expectation about the lawn care change during a water shortage?

11. Discuss the following points about Kentucky bluegrass.

    - KBG makes a great low input lawn option.
    - KBG water use and growth slows as the soil begins to dry down.
    - KBG irrigation demand varies significantly between cultivars.
    - KBG goes dormant under summer water stress.

12. Discuss the following points about turf-type tall fescue lawns.

    - Tall fescue may or may not be deeper rooted.
    - Tall fescue cannot sow growth as soils dry down.
    - Tall fescue cannot go dormant under water stress.
    - Tall fescue makes a great lower input lawn option

13. Discuss the following points about turf-type Buffalo grass.
    - Summer green will be dependent on rain and irrigation.
    - Buffalo grass will be dormant fall through spring, reducing seasonal water demand

14. Describe the "feeling" of rectilinear, curvilinear and angular design. What determines which style would be appropriate?

15. Describe how to refine the preliminary design for efficient sprinkler irrigation. List criteria for efficient sprinkler layout.

16. In developing the plant potential lists for each hydrozone, explain the following concepts about water wise gardening.

    - Hydrozoning and xeriscaping is not a Phoenix style rock landscape.
    - Hydrozoning is not just purchasing and planting xeric plants around the landscape with other plants.
    - Even xeric plants require routine irrigation during establishment.
    - Hydrozoning is not against irrigated "people space" concepts.

17. Define the following design terms:

    - Balance
    - Color
    - Emphasis
    - Form
    - Line
    - Scale
    - Sequence
    - Simplicity
    - Texture
    - Unity
    - Variety

18. Describe how the following *forms* affect eye movement and emotional feelings.

    - Weeping
    - Horizontal or spreading
    - Rounded
    - Pyramidal

19. Describe how to balance *simplicity* with *variety*. Describe how to use *simplicity* to bring *unity* to the design.

20. How does distance impact texture? In a distant corner, how should textures sequence? In a kidney-shaped planting bed how should texture sequence? In a texture sequence, how should leaf size change and the proportion of plant numbers changes?

21. How do various colors speak to <u>you</u>?

22. Explain differences in warm and cool colors.

23. Describe how to sequence warm colors and cool colors.

24. In mixing colors in a bed, what is the design trick to a natural "life" to the bed?

25. Describe how to mix and match plants.

CMG GardenNotes #411

Water Wise Landscape Design: Steps

Seven Principles of Water-Wise Landscaping

- **Planning and designing for water conservation, beauty, and utility**. Water savings does not happen by accident or by just placing a few xeric plants around the landscape. – The take home message is that it requires planning.

- **Hydrozoning** – Selecting plants appropriate to our climate, grouping them according to water need, and then actually irrigating according to water need. – The take home message is actually watering the plants according to their need rather than watering the entire yard the same.

- **Watering efficiently with appropriate irrigation methods**. – Of all the principles, watering efficiently has a greatest water savings potential for the typical landscape. The average homeowner uses twice the amount of water the lawn and gardens actually need. Efficient irrigation includes attention to design, maintenance, and management.

- **Creating practical turf and non-turf areas**. – Water wise landscaping is not anti turf, but rather matching the turf type to the actual use of the site. This is a change from the typical landscape design where a high input lawn is the common ground covering.

- **Improving the soil.** – With improved soils, plants reach a larger supply of water.

- **Mulching to reduce evaporation**. – Mulch with drip irrigation can reduce water use by 50%.

- **Maintaining with good horticultural practices**. – Healthy plants are more tolerant of summer heat and wind.

What Is "Landscape Design"?

Landscape design is a **process**, rather than just plunking down plants. For existing landscapes, let the process guide the evolution of the design to become more water wise.

Landscape design **creates practical and pleasing outdoor living space**. Landscape design develops a series of outdoor rooms.

Landscape design **brings the family's wants, needs, and values into the design**. These will vary from family to family and will evolve with time for any family.

Landscape design is about **how the space will be used**. It is about the connections and "feelings" created with the space. Is the space for relaxation and healing, or for action? For many, gardening is a vehicle for spiritual and emotional connection and renewal.

- *More than anything else, a garden is a portal, a passage into another world, one of your own thoughts and your own making; it is whatever you want it to be and you are what you want to be.* – William Longgood

- *Paradise* is from the Persian word for "walled garden".

Landscape design is about the family's investment in **time** and **dollars**.

Design is more of an art. Gardening is more of a craft. The two are not the same. Being a good gardener does not make the individual a good designer. Being knowledgeable about gardening does not necessarily give knowledge about design. Most knowledgeable gardeners are rather unfamiliar with landscape design concepts.

Steps to Creating Practical and Pleasing Outdoor Living Space

1. *Site analysis* identifies opportunities and limitations of the property.

2. *Family analysis* creates a story line, bringing unity into the landscape.

3. With bold *lines*, delineate softscape and hardscape areas, creating outdoor rooms.

   a. Define macro-use of space with *hydrozone bubble drawings*.
      - Bubble drawings define *hydrozones for* efficient landscape irrigation.
      - Create practical turf and nonturf areas.

   b. Refine macro space (lawn areas, flowerbeds, vegetable garden, patio, etc) with bold *lines,* in *rectilinear, curvilinear*, or *angular* design style.

   c. Refine preliminary design for efficient irrigation.

d. Delineate micro-spaces with connecting paths, plants, and hardscape features.

4. Develop plant consideration lists based on hydrozones.

5. Fit elements into the design based on the design principles of *color, texture, form, line, unity, scale, balance, simplicity, variety, emphasis* and *sequence*.

Step 1 – *Site Analysis* Identifies Opportunities and Limitations of the Property.

Landscape maintenance professionals estimate that 90% of the landscape maintenance problems arise from issues that could/should have been addressed with the site analysis. For most, site analysis is an ongoing process. Keep a garden journal, recording concerns and success for future reference. [Figure 1]

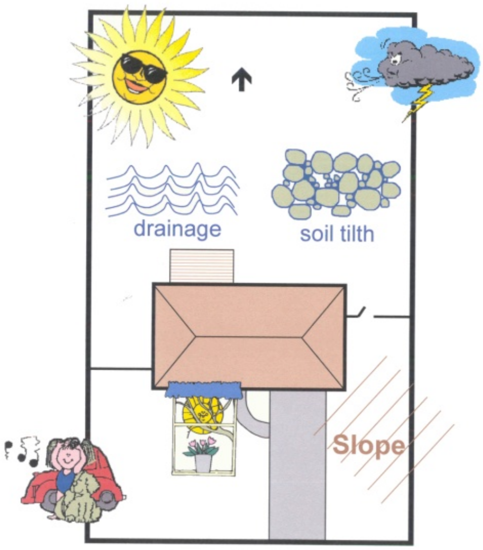


Figure 1. Site analysis looks at opportunities and limitations of the property including sun/shade patterns, wind and air drainage, soil tilth, soil drainage, slopes, views, and factors outside the property line that influence use and design of the property.

Soil Tilth – most landscape plant problems are soil related!

- Soil structure and compaction
- Sandy, clayey, or rocky
- Soil depth and profile
- Organic content
- pH and free lime
- Nutrients
- Salts

Grading and Drainage

- Slopes and land use
- Erosion potential
- Grading structures
- Drainage off the property
- Drainage onto the property
- Low spots and standing water
- Drainage down through the soil profile

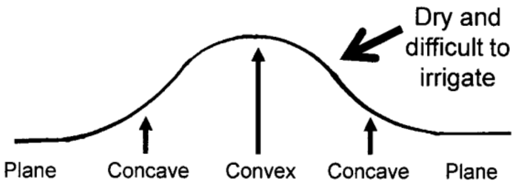


Figure 2. Although berms are popular with designers, they may be high maintenance with dry slopes

Acceptable Slope

Patio-terrace	1 to 2%
Entrance walks	1 to 4%
Ramps (with railing)	up to 15%
Steps (with railing)	up to 50%
Driveways	1 to 15%
Drainage swales	2 to 10%
Planted banks	up to 33% - Year-round plant cover to prevent erosion.

- Slopes greater than 10% are hard to walk on and require year-round plant cover to prevent erosion.

Grading Structures

- For stability, retaining walls and dry walls have specific design criteria. Contact the local city building department for details on local code requirements.
- For scale, the minimum depth of the level area below the wall should be at least one and one-half times the wall height.

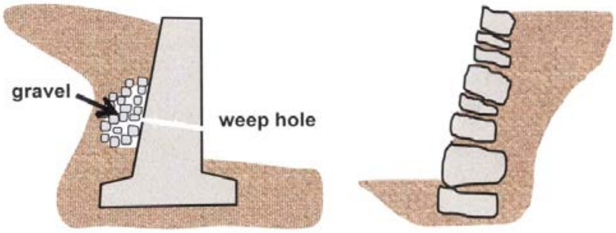


Figure 3. Retaining structures have specific design criteria. Refer to local city building codes for details. Left: retaining wall with weep hole. Right: dry wall.

Microclimate

- Orientation (north and south) and shade patterns
- Prevailing winds and air drainage
- Temperature extremes (heat sinks, cold pockets)

Existing Plant Materials

- What plants are currently in the landscape?
- What is their condition?
- Which will be kept?

Extensional Landscape

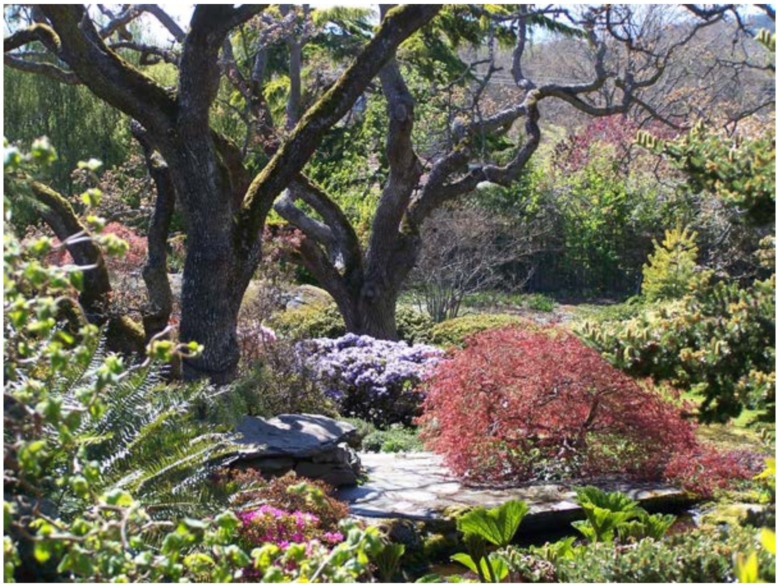
- Subdivision covenants
- Views to frame or mask
- Noise
- Neighborhood landscape style
- Privacy and security

Natural Precipitation and Irrigation Potential

- In Colorado, natural precipitation varies greatly, from below seven inches per year to above 35 inches per year. What is the natural precipitation at your site?
- Colorado communities vary greatly in water resources. Due to the planning of forefathers, some have good water resources and others are lacking for landscape irrigation. What is the situation in your community?

Opportunity or Restraint?

- Use the site analysis as an opportunity to create a unique landscape working with the limitations of the site. [Figures 4 to 6]



Figures 4 to 6. In site analysis, look at how the gardener can work with the limitations of the property to create a practical and pleasing landscape. Here at Abkhazi Garden in Victoria, BC, much of the property is covered in rock outcroppings. Working with the rock, Prince and Princess Abkhazi created an amazing garden of love and peace.

Step 2. *Family Analysis* Creates a Story Line, Bringing Unity to the Landscape.

What does the family **want and need** from the landscape? How will the family relate to the landscape? Will the space be regularly used by the family or is it simply filler space around the home?

What does the family want the landscape to **communicate**? What does the family want to "feel" from the landscape? Is it a setting of peace and relaxation, or a setting for action activities? What does the family want the landscape to communicate to others?

- *The Latin word for "sacred" gives us the word "sanctuary" denoting not only a sacred space but also a place of refuge and protection.* – Peg Streep
- *Creating Sacred Space – We transform our gardens and yards into sacred space when we understand them as places of growth, not only for plants and trees but also for our inner selves.* – Peg Streep

Irrigation: What are the family's interests and values towards irrigated and non-irrigated landscape areas? How does this match with reality of the natural precipitation and irrigation potential?

Time: What are the family's interests and values towards gardening activities?

Dollars: What financial resources will be invested in the landscape?

Rather than filling the landscape with stuff, make some choices!

1. Select the three most important elements in the design.
2. From these important elements, write a story line that reflects how you want to relate to the landscape. [Figures 7 and 8]

Figure 7. Family analysis is about what the family wants and needs in the landscape. How will the family connect to the space? How will the outdoor rooms be used? The family of this Steamboat Springs garden enjoys the sitting area with fire pit.

Figure 8. Outdoor rooms in this backyard include a dining room, a fountain garden room, and vegetable garden room, creating a pleasant, relaxing space.

Writing a Story Line

The story line creates a more congruent message bringing unity into the design.

The story line clarifies how the family wants to relate to and use the space. It reflects the family's personal tastes. It clarifies the "feeling" or mood the family desires from the landscape. It clarifies what the family want to communicate to others.

- This is the **most important design step**. Without a story line, most landscapes are not really designs, but rather collections of plant materials.

- This is the **most difficult design step** in the design process. It takes some careful evaluation about what the family really wants and needs in the design.

Step 3. With Bold Lines, Delineate Softscape and Hardscape Areas, Creating Outdoor Rooms.

Note: *Softscape features* of the landscape include all the plants (trees, shrubs, flowers, turf, vegetables, fruits, etc.) *Hardscape features* of the landscape include the non-living elements of the design (patio, deck, fences, water features, and lighting.)

Three Areas in the Landscape

Public area (front yard) is the portion of the yard openly viewed by others. Homeowners associations and cities often regulate what can/cannot be done in the public area. [Figures 9 to 11]

- Driveway and path to front door
- Lawn, trees, shrubs and flowers
- Community standards – Following community standards for the front yard helps create the feeling that the community is friendly and welcoming, increasing property values.
- What does the family want to communicate to the neighborhood?

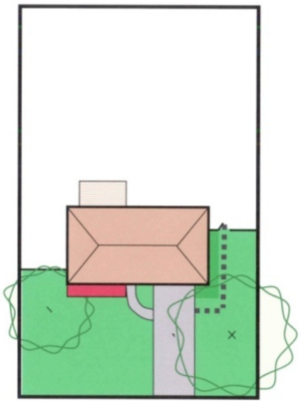


Figure 9. The *public area* is the portion of the yard in open view by others. It may have HOA or community standards that influence the design

Figures 10 and 11. When the public area reflects community landscape standards it builds a welcoming and friendly feeling for the community and enhances neighborhood property values. The public area communicates about the family.

What does your front yard communicate about your family?

Private area (back yard) is the portion of the yard not openly viewed by others. Being the family's private space, it is designed with rooms to support the family's activities and interests. [Figure 12]

- Cooking and eating rooms
- Sitting rooms, play room
- Fruit, vegetable, and flower garden room
- Water features

- How does the family want to relate to the space?
- How will the family use the space?

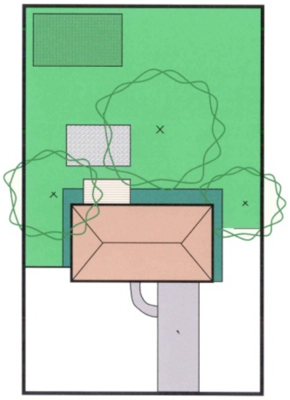


Figure 12. The *private area* is typically the family's primary outdoor living space.

Utility areas serve specific nonlandscape functions such as the dog run and parking. They need to fit into the function of the landscape design.

- Garden shed, potting area, work area, compost bins
- Storage, dog runs, additional parking for cars, boats, RVs
- How does this fit into the landscape?

Think of Design as Creating an Assortment of Outdoor Rooms. [Figure 13]

- What makes up the floor?
- What makes up the wall?
- What makes up the ceiling?
- *Lines* connect and defines space (rooms)

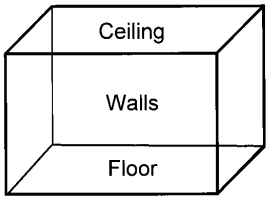


Figure 13. The landscape is an assortment of outdoor rooms with various activities. In design, pay attention to the floor coverings, wall features, and what makes up the ceiling.

Step 3a. Define Macro-Use of Space with *Hydrozone Bubble Drawings*.

Bubble Drawings

Bubble drawings brainstorm the macro-use of space. It the first and primary opportunity in the design process to be creative.

Bubble drawings are ovals that identify space allocation and use. For example, a circle represents the location and approximate size of the patio. Other circles identify the location and approximate size of lawn areas, the vegetable garden area, flower beds, etc. [Figure 14]

Bubble drawings do not identify actual lines, beds, path, or individual plants. These will come in future steps in the design process. [Figure 15]

The bubble drawing step also defines hydrozones, areas with various levels of irrigation. [Figure 16]

Landscape elements that will not change (like an existing deck or large tree) should be on the plan before starting this step.

Do not move on too fast. Breaking out of the box, look at a variety of options. Try lots of options before selecting the one to use as the base for the design

To become the design base, select a bubble drawing that best serves the design needs, best communicates "feelings," and gives the best connection with the space.

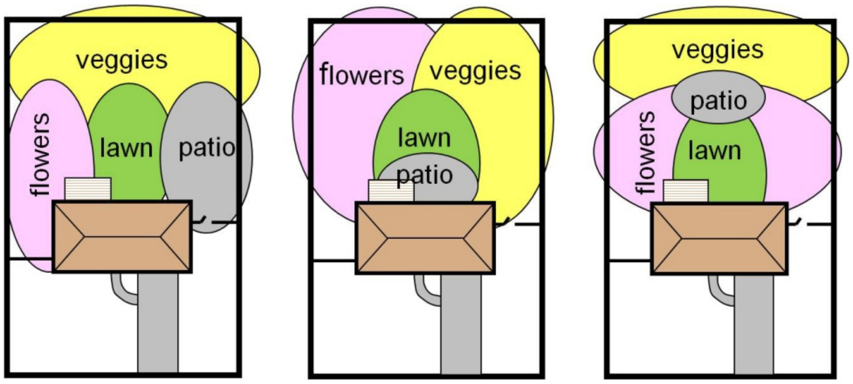
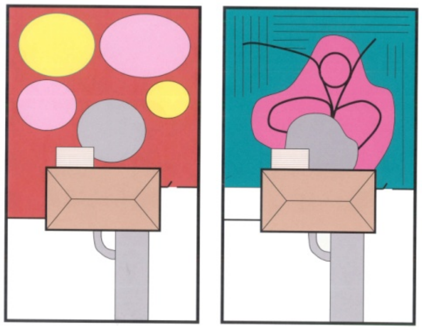


Figure 14. Examples of bubble drawings for a back yard with people space (patio and lawn rooms), vegetable room, and flower room.

Figure 15. Bubble drawings are ovals that depict various uses and irrigation levels of the space. Left: They need to fill the space, rather than leave large areas unidentified (red in the drawing). Right: Bubble drawings do not identify the actual shape and line of the area; this will come in the next step.



Hydrozoning – Selecting plants appropriate for the climate, grouping plants according to water needs, and actually watering them according to need.

In irrigation management, individual plants are not watered plant by plant. Rather the irrigation system waters all plants in an area (call ***zone***). With sprinkler irrigation this is easy to understand.

With drip irrigation, we apply water to individual plants, but all plants in the zone receive the same run time and frequency of irrigation. As a point of clarification, some gardener mistakenly think that using half, one, and two gallon per hour drippers is an effective method to manage the differing water needs. Although this works to a small degree, the concept is basically flawed. The two gallon per hour drippers will have significantly larger wetting zones than the half gallon per hour dripper. However, plants with the higher water need (two gallon/hour drippers) do not necessarily have a larger root spread. Likewise, plants with the lower water need (half gallon/hour dripper) will not necessarily have a smaller root spread. (In fact, a large root spread is what makes some plants more xeric). The factor missing here is irrigation frequency to match the water needs.

In simple terms irrigation is done by areas not plant by plant. ***Hydrozoning*** groups plants with similar water needs, and then actually irrigates each group in the landscape to match the water needs of the grouping.

In developing bubble drawing, factor in the irrigation needs (hydrozones). [Figure 16]

- Areas of routine irrigation – watered every 2 to 4 days.
- Areas of reduced irrigation – watered every 4 to 14 days.
- Areas of limited irrigation – watered during dry spells once plants are established.
- Nonirrigated areas

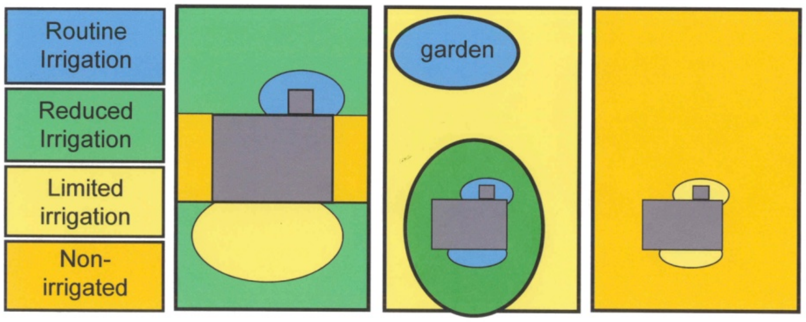
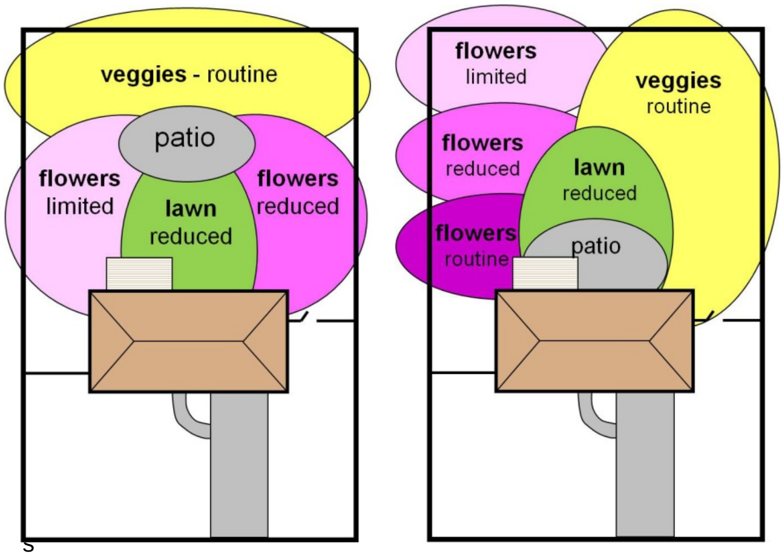


Figure 16. Examples of yards with various styles of hydrozones – Left: yard with reduced irrigated lawn in front and back, limited irrigation shrub and flower bed in front yard, routine irrigation flower bed around patio in back yard and non-irrigated side yards. Center: larger property with a patch of lawn in the front and back yard while much of the property has limited irrigation. Right: Yard is basically nonirrigated with small limited irrigation flowerbeds near house in front and back.

Hydrozones Base on Irrigation Need [Figure 17]

- Lawns—Routine irrigation
- Lawns—Reduced irrigation
- Lawns—Limited irrigation or non-irrigated

- Mixed flower and shrub beds—Routine irrigation
- Mixed flower and shrub beds—Reduced irrigation
- Mixed flower and shrub beds—Limited irrigation
- Vegetables – routine irrigation
- Tree fruits – reduced irrigation
- Small fruits – routine irrigation
- Nonirrigated areas



s
of hydrozone bubble drawings. Note the multiple hydrozone zones for flowers.

Note: A common incorrect belief is that lawns are high water user and shrubs and flowers are low water users. Actually, the water demand of Kentucky bluegrass is lower middle class when placed in an ordered list of water demands for landscape plants. The typical lawn receives twice the amount of water that it actually needs.

Creating Practical Turf and Nonturf Areas

Water wise gardening is not anti-turf, but about selecting the turf type to match the use of the property. This is a change from the typical western landscape where most of the property is covered with high-input lawn.

What turf type matches the design objectives and use of the site?

- **Routine irrigation** with high performance Kentucky bluegrass and turf-type tall fescue – For high traffic areas with lots of wear and tear, like ball fields. While most home lawns are managed this way, few actually have the wear and tear to justify the high inputs.

- **Reduced irrigation** with Kentucky bluegrass and turf-type tall fescue – This reduced water use actually matches the need of most home lawns, keeping it summer green.

- **Minimal irrigation** with summer dormant Kentucky bluegrass or Buffalograss – Quality of the lawn depends on the amount of rain and irrigation the grass actually receives.

- **Non-irrigates** sites with Buffalograss or blue grama grass – quality of the lawn depends on the amount of rain the grass actually receives.

For additional information on turf options in Water Wise Design, refer to *CMG GardenNotes* #412, **Selecting Turf for Water Wise Landscapes.**

What turf type matches the community's water supply?

Some communities lack the water resources for routine landscape irrigation. Here limited or non-irrigation may be the only practical options.

Other communities have good water resources to support landscape irrigation needs. However, even these communities may lack the water resources during western drought cycles. In dry years, the community may need to accept lower levels of inputs and drier lawns.

Step 3b. Refine Macro Space (lawn areas, mixed shrub and flowerbeds, vegetable gardens, patio, etc.) with Bold *Lines* in *Rectilinear*, *Curvilinear*, or *Angular* Design Style.

Which design style fits the theme?

- **Rectilinear** style has straight lines and right angles in square and rectangular shapes. It is described as bold, orderly, organized, and stately; or stuffy, uncreative, and controlling. [Figures 18 & 19]

- **Curvilinear** style replaces the straight line and right angles with bold sweeping curves. (Avoid wavy lines as this does not create the bold line for a strong design.) It is described as natural, free flowing, and friendly; or lacking form and structure. [Figure 18 & 19]

- **Angular** style uses the straight lines but with a variety of angles and directions. It is described as modern, action oriented, and bold; or hectic, chaotic, and disorganized. [Figures 18 & 19]

Most people have a love/hate relationship to the three styles. Select the style that created the feeling or mood desired from the story line. A common question is "May styles be mixed?"

- Basically no, as it weakens the feelings created by the style and destroys unity.
- However, a front yard could be one style and the back yard another style. In large properties, various areas may have different styles.
- The property line and the home style do not dictate the landscape style.
- It is recognized that a rectilinear deck and raised bed garden boxes may be found in an otherwise curvilinear design.

Figure 18. Examples of styles for a backyard with patio (gray), flower beds (pink), and vegetable garden (yellow).

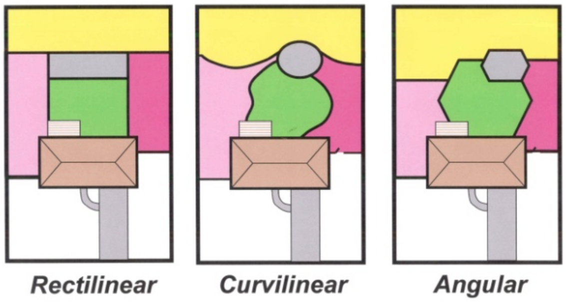
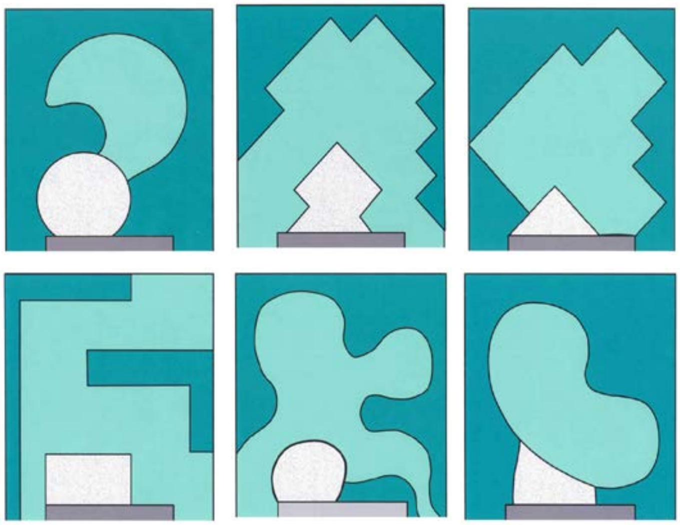


Figure 19. Notice how lines connect and define space. The different styles bring various feelings to the site. Some are calming and relaxing whereas others stimulate action. Which design style fits the story line?



Step 3c. Refine Preliminary Design for Efficient Irrigation

Of all the principle of water wise landscaping, irrigation efficiency has the greatest water saving potential for most home gardeners. On a community basis, gardeners apply twice the amount of water that plants actually need. This is due to poor irrigation system design, management, and maintenance.

Efficiency in irrigation is based on uniformity of water delivery. In any irrigation zone, spots that receive more water will be overwatered to keep spots that receive less water green.

Drip irrigation systems are great for mixed flower and shrub beds, perennials, small fruits, and vegetables. Drip irrigation is not an install and forget it type of system. Like any irrigation system, maintenance is required. Sprinkler irrigation is more suited for large trees and lawn areas.

Sprinkler Irrigation: Design Criteria for Uniform Water Delivery

- Uniformity of water delivery = water savings

1. **Head-to-head coverage** [Figure 20]

   - Spray from each head must reach neighboring heads.
   - A 10 to 20% overlap may give better uniformity.
   - Less than head to head coverage (while popular to reduce installation costs) significantly increases water use for the life of the system.

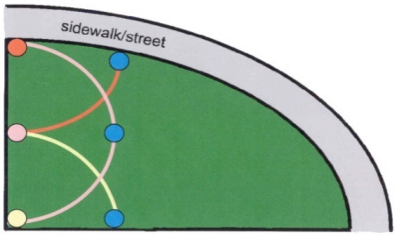


Figure 20. Head- to-head coverage is a minimum standard for water savings. Water from each head reaches the neighboring heads. A 10 to 20% overlap may give even better uniformity.

2. **Line-out along nonirrigated areas.** [Figure 21]

   - Another standard for water savings is to water from the outside in.
   - Do not water from the center out onto nonirrigation areas. The nonirrigated area will be watered or a dry edge will be found along the edge of the lawn.
   - Although lining out requires more sprinkler heads with higher installation costs, it is a primary water saving technique, reducing water use.

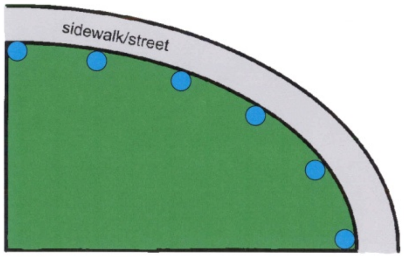


Figure 21. Another water saving standard is to ***line out*** the irrigated area from the non-irrigated area by watering from the outside inward.

3. **Fill in with heads in square and triangle patterns.** [Figures 22 & 23]

   - For uniform water distribution, fill in heads in square or triangle patterns. The overlap gives the most uniform delivery.
   - Avoid pentagons (five- sided) patters and this creates a dry spot.

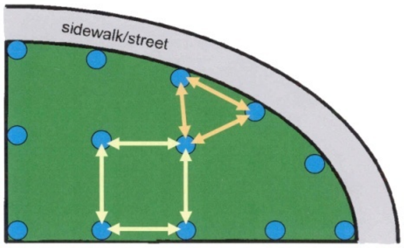


Figure 22. For uniform water delivery, fill in heads in square or triangle patterns.

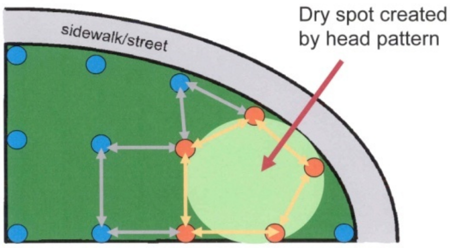


Figure 23. Avoid placing heads in pentagon shaped patterns, it creates dry spots and the entire lawn will be overwatered to compensate. Pentagon-shaped patters frequently pop up in irregular shaped areas.

4. **Use uniform type, brand, and style of heads in each irrigation zone.**

   - Spray heads apply water a 1 to 2½ inches per hour.
   - Rotor heads apply water at ¼ to ¾ inches per hour.

5. **Avoid sprinkler irrigation of small irregular shaped areas.**

   - To walk the talk of being water wise, avoid sprinkler irrigation on small irregular shaped areas.
   - Minimum width of sprinklers is generally is five to ten feet wide.
   - In design, avoid sprinkler irrigation on smaller areas. Design these for drip irrigation, hand watering, or nonirrigation areas. Or avoid creating small irregular shape areas all together in the design process.

6. **Use recommended water pressure.**

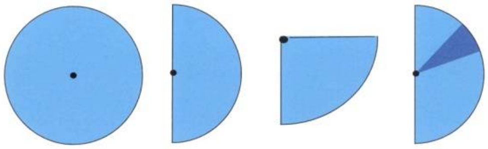
   - A mist cloud around a sprinkler head indicates excessive pressure, increasing evaporation and total water usage.
   - A pressure regular is standard on newer homes. This is typically located were the water line enters the home, just beyond the shut-off valve. It can be retrofitted into the water line in older home.
   - Most sprinkler heads in the home garden trade are designed to work at 30 to 40 psi, and generally do not have internal pressure regulators.
   - Heads use on commercial/industrial properties may work with much higher pressures and these more expensive heads generally have a pressure regular built into the head.

   - Many cities deliver water at 30 to 40 psi. However much higher pressures are common. With pressure above 80 psi, automatic values may have trouble closing.

<u>Typical sprinkler patterns</u> [Figure 24]

- Full circles
- Half circles giving a straight line.
- Quarter circles giving a right angle for square corners
- Adjustable arc (the angle can be manually set); however, these are less uniform in delivery.
- Other patterns (like strip head) lack good uniformity in water distribution.

Figure 24. Sprinkler heads come in full circle, half circle, quarter circles, and adjustable arc.



Fitting sprinkler patters into the design

Pop-up spray heads are spaced at eighth to fifteen-foot intervals (depending on interchangeable nozzle installed). They have a high water deliver rate, around two inches per hour, often leading to surface run-off. They are used for small areas.

Rotor heads are spaced at 15 to 45 or more foot intervals (depending on the head). They have a lower delivery rate, around half-inch per hour, causing less surface run-off. These are use for large open areas.

For example, a 30-foot by 45-foot area would have pop-up spray heads at 15-foot intervals, with quarter heads in the corners, half heads along the sides and full circles in the center. [Figure 25]

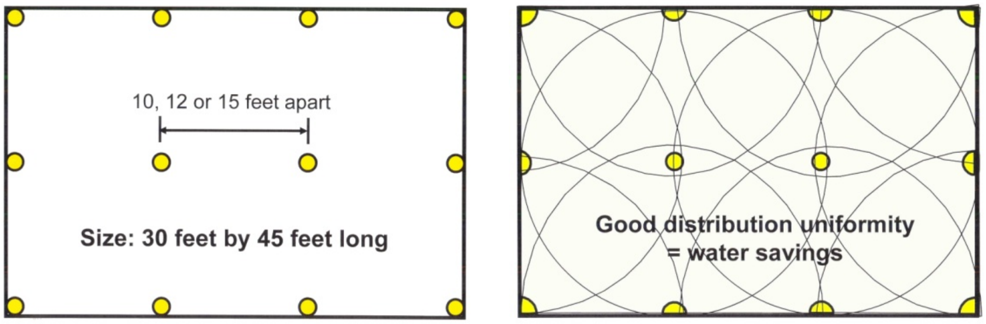


Figure 25. Left: For this 30-foot wide by 45-foot long area, pop-up spray heads could be used at 15 foot centers. Right: quarter head would be place in the corners, half heads along the sides and full circle heads in the center. With head to head coverage, this would give a good efficiency for water delivery.

If a flowerbed was added to the area, blocked spray creates a dry area around the bed and a very wet planting bed from the intercept water. In water wise design, AVOID blocking sprinkler delivery with flowers and shrubs. [Figure 26]

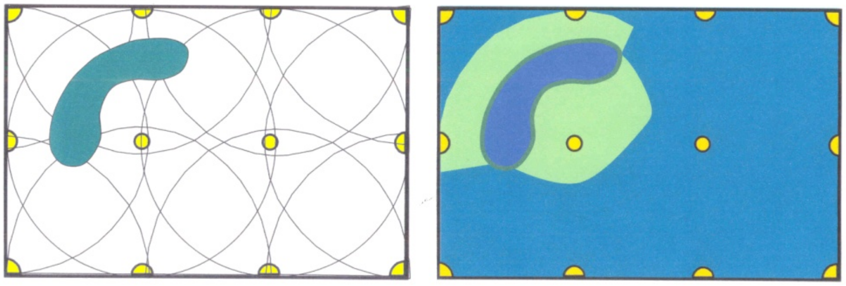


Figure 26. If a flower/shrub bed was added to this sprinkler layout, it will interfere with water distribution. The lawn areas around the bed will be dry, and the rest of the lawn will be over watered to compensate. The flower/shrub bed will be rather wet from the intercepted water.

In water wise landscaping design, overlay the sprinkler layout onto the design. **Then adjust the lines of the design for efficient irrigation layout.** [Figure 27]

Remember

- Head-to-head coverage with up to 20% overlap
- Line out nonirrigated areas
- Place heads in square and triangle patters
- For small areas, use pop-up spray heads at 15-foot centers. For open large areas, use rotor type heads spaced at 15-45+ foot centers depending on the site and heads used.
- Avoid sprinkler irrigation on spaces less than five to ten feet wide.

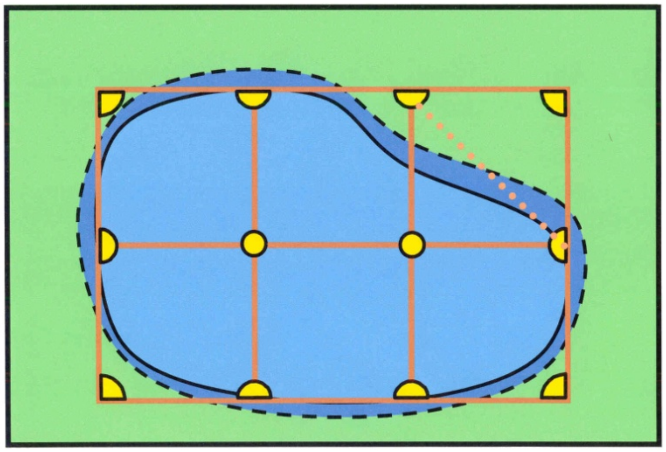


Figure 27. To walk the talk of being water wise, adjust the line in the preliminary design for improved irrigation efficiency. In the drawing the blue area represents a lawn that will be sprinkler irrigated surrounded by a mixed flower shrub beds with drip irrigation. The original line is indicated with the dotted line. Then the sprinkler grid pattern was over-laid. With head-to-head coverage, note that some lawn areas are outside of the water delivery zone. Sliding the heads out to compensate will significantly increase water use with the lack of head-to-head coverage. A better solution is to move the line inside the sprinkler delivery pattern. As redrawn, this minor adjustment could reduce water use by 30 to 50%!

In small areas, sprinkler heads cannot follow the curves. Instead, they stay on the grid lines. In water wise design, draw primary lines, and then overlay the sprinkler system looking at patterns. Adjust the head placement (staying on the grid) and redraw lines for maximum water savings. [Figures 28-30]

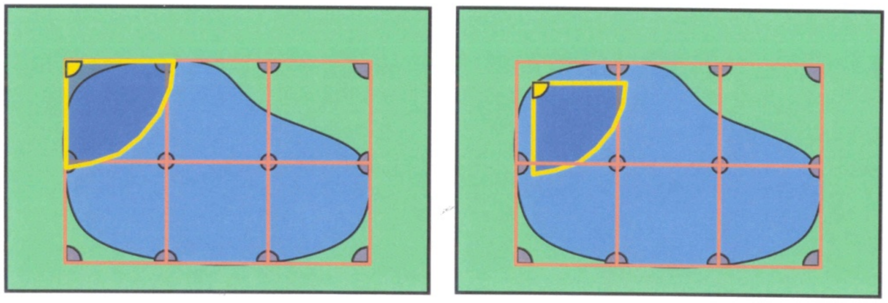


Figure 28. In small areas, notice how the sprinkler heads must stay on the grid lines. Plant materials along the edge of the lawn area must be kept short to allow for water delivery and must be tolerant of the water levels given the lawn. Right: If the head is moved in to the edge of the lawn (blue area), it creates coverage problems along the edge. As drawn, the final head placement is given in Figure 28 left.

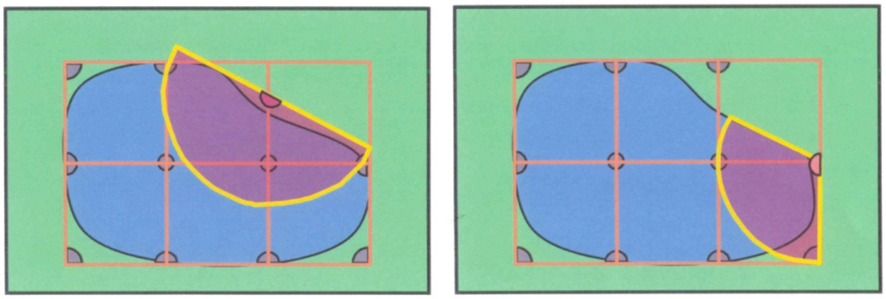


Figure 29. As drawn, the sprinkler head in the upper right hand corner could be eliminated. Drawing left and right show adjustments in placement and arc of adjacent heads. Note: for head to head coverage in this small area, all heads stay on the grid line. As drawn, the final head placement is given in Figure 23 left.

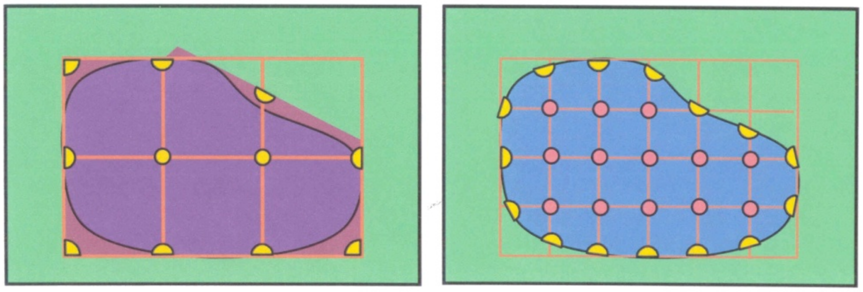


Figure 30. Left: Illustration of sprinkler layout for a lawn area 30 by 45 feet with pop-up spray heads at 15-foot intervals. Notice how heads stay on the grid line. The head in the upper right corner was eliminated with adjustments made in placement and arc of neighboring heads. Notice the overspray of the sprinkler system on the edges of the flower/shrub bed. Any plant materials in this area would be low ground cover types and acceptable to the watering level of the lawn.
Right: Illustration of sprinkler layout for a 60 by 90 foot lawn area with pop-up spray heads at 15-foot centers.
Rotor heads: In the large 60 by 90-foot lawn area, rotor heads could be used at 30-foot spacings. With rotor heads the layout would be like the illustration on the left.

Step 3d. Delineate Micro-Spaces with Connecting Paths, Plants, and Hardscape Features

With the primary lines refined for efficient landscape irrigation, we are now ready to continue developing the design plan with secondary lines defining beds, paths and other features.

How do people move through the garden rooms?

- Paths direct people around a garden and are an effective way to deal with soil compaction from foot traffic.
- Paths also eliminate self discovery of the garden.
- A threshold or peak-hole is also an invitation to enter and explore.

Step 4. Develop Plant Consideration List Based on Hydrozones

Create a Potential Plant List for Each Hydrozone

Why a potential list? Plant materials need to be identified by hydrozone so they can grouped by water need. Flexibility in the design process at this point in time allow for exciting new plants, not previous on the list, that one finds at the nursery. Flexibility may also be needed when the desired plants are not available or are in poor quality.

Information sources on plant water needs include the following:

- CSU Extension Fact Sheets and *CMG GardenNotes*
- ***Xeriscape Plant Guide*** by Denver Water, Fulcrum Publishing
- X-rated plant lists at www.gardencentersofcolorado.org

Water Wise Landscaping in Colorado's Semi-Arid Climate

- On sites where landscape irrigation is not desirable or possible, focus on natural growth.
- Xeriscaping is not a rock pile. A rocked over landscape is environmentally unfriendly, creating heat sinks and limiting carbon dioxide conversion into oxygen.! [Figure 31]

Figure 31. Xeriscaping does not need to be a rock pile.

- Even xeric plants need rain and/or irrigation during establishment.
- Gardens with limited to no irrigation will thrive in years with heavy rainfall and decline in dry years.
- Water wise concepts support irrigation for "people space".

Step 5. Fit Elements into the Design Based on the Design Principles of *Line, Color, Texture, Form, Unity, Scale, Balance, Simplicity, Variety, Emphasis and Sequence.*

With the primary lines on the page, defining outdoor rooms, it is now time to decorate the rooms with various plants and hardscape features. This discussion on landscape design continues in *CMG GardenNotes* #412, **Principles of Landscape Design**.

Additional Information – *CMG GardenNotes* on Water Wise Landscape Design

#410	References and Review Questions: Water Wise Landscape Design
#411	Water Wise Landscape Design
#412	Water Wise Landscape Design: Selecting Turf Options
#413	Water Wise Landscape Design: Principles of Landscape Design
#414	Worksheet: Water Wise Landscape Design
#415	Homework: Water Wise Landscape Design

Authors: **David Whiting**, Extension Consumer Horticulture Specialist (retired), Dept. of Horticulture and LA, Colorado State University; and **Jeffry de Jong**, Horticulturist, Victoria, BC, Canada. Artwork by David Whiting; used by permission.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

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CMG GardenNotes #412

Water Wise Landscape Design:
Selecting Turf Options

For additional information on turf selection, refer to Dr. Tony Koski's website at http://csuturf.colostate.edu and the following *CMG GardenNotes*:

#561,	Turfgrass Species Selection Guidelines
#562,	Best Turf Varieties: Variety Recommendations for Bluegrass, Ryegrass, Tall Fescue, Fine Fescue, Buffalograss and Bermudagrass
#563	Hybrid (Kentucky X Texas) Bluegrass for Turf Use in Colorado
#564,	Fine Fescues for Lawns
#565,	Buffalograss Lawns
#566,	Sources of Grass Seed, Sod, and Plugs for Colorado Lawns

Water-wise landscaping is not anti-turf, but about matching turf selection to the design needs and use of the site.

With Colorado's continued population growth, water use becomes a critical issue. Water conservation helps 1) reduce total water demand, and 2) reduce the extensive cost of expanding a community's water infrastructure.

In a typical community, water use more than doubles during the summer irrigation season. On a statewide perspective, landscape irrigation accounts for 7 to 10% of Colorado's total water use.

Benefits of Grass

Healthy grass is an aesthetic asset and a factor in property value. It provides a backdrop for other landscape elements pulling the landscape design together.

The growing body of evidence points to the positive health and environmental contributions made by lawns and other grassy areas. A healthy, vigorous lawn with high plant density provides the following benefits:

- **Conversion of CO_2 to O_2** – Twenty-five square feet of actively growing grass produces enough oxygen for one person per day.

  On a global basis, grasslands of the northern hemisphere are second to the tropical rain forests in the CO_2 to O_2 conversion.
- **Pollution breakdown** – Microorganisms found in the soil of actively growing turf, breakdown organic pollutants, including air contaminates, pollen, and pesticides.

- **Wind erosion –** Grass cover prevents wind erosion of soil, trapping dust and pollen.

- **Water quality** – Turfgrass areas play a significant role in reducing surface water runoff, a key factor in *non-point-source* pollution in the landscape setting.

  - An average golf course of 150 acres can absorb 12 million gallons of water during a 3-inch rainfall.
  - A thick turfgrass allows 15 times less runoff than does a lower quality lawn.
  - A healthy, dense stand of turfgrass can reduce runoff to almost zero.
  - Compared to a garden or field planted to row crops, grassy areas reduce soil erosion by 84 to 668 times.
  - To protect surface water quality, direct surface runoff onto grassy areas allowing for natural filtering in the biologically active turf soil.

- **Soil structure –** Actively growing grass supports soil organism activity that improves soil structure.

- **People space** – Turf is basic “people space” with a cool, dirt-free activity space for children and adults.

- **Element of landscape design** – Turf brings unity to a landscape design and provides a neutral background to set off flowers and shrubs.

- **Property values** – Turf quality influences property appeal and marketability.

- **Fire defense zone** – Irrigated mowed lawns is an important aspect of fire management in communities. Dry, unmoved grass/weeds become a major fire hazard.

Turf Selection: Creating Practical Turf Areas

High input lawns are a habit in American and European landscapes since the days of King Louis of France. However, does the property use require the perfect green lawn with high inputs or would a moderate quality lawn with reduced inputs or a low input lawn be acceptable for the site?

Many lawn care problems arise from management differences between high, moderate and low input lawns. For many gardeners, there is a conflict between expectations and inputs. Table 1 summarizes difference in high, moderate, and low input lawns.

Table 1.
Comparison of High, Moderate, and Low Input Lawns

	High Input	**Moderate Input**	**Low Input**
Wear tolerance	best	good	limited
Appearance	best	good	limited
Water	high	moderate	limited
Exposure	sun	sun to partial shade	sun
Fertilization	spring and fall	primarily fall	fall
Species	o Select KBG cultivars o Perennial rye o Turf-type tall fescue	o Select KBG cultivars o Turf-type tall fescue o Buffalo grass	o Select KBG cultivars o Blue grama o Buffalo grass

Grass and Water Use

Contrary to popular belief, there is no magic lawn type that delivers top quality with minimal inputs. The quality of any turf is directly dependent on the amount of summer rainfall and supplemental irrigation it receives.

A lawn's tolerance or resistance to drought is a complex situation. A "drought tolerant" specie may or may not use and/or require less water depending on many factors. Factors contributing to drought tolerance include:

- Species (including its actual water use, rooting depth, and ability to go dormant)
- Soil tilth and soil oxygen levels (rooting depth)
- Wind and sun exposure (actual water use)
- Mowing height (high mowing leads to deeper roots).
- Traffic, (any lawn is intolerant of traffic when dry).
- Salt levels in soil and irrigation water.
- Previous irrigation pattern (frequency and watering depth).

The bottom line is that species selection is secondary to irrigation management in water savings. A more drought tolerant lawn species will not use less water if managed like a high input lawn!

Since Kentucky bluegrass, turf-type tall fescue, and Buffalograss make up 99% of home lawns in Colorado, this *CMG GardenNotes* only looks at these options. For additional information on turf species, refer to *CMG GardenNotes #561*, **Turfgrass Species Selection Guide**.

If A Turf Is Deeper Rooting

If a turf is deeper rooting:

- It requires less frequent irrigation (i.e., stays greener longer between irrigations).
- However, it will also require a heavier/deeper irrigation to recharge the rooting zone, so actual water use is not necessarily reduced.
- Deeper rooting may or may not be an irrigation savings technique depending on the frequency of soaking summer rains and the irrigation pattern. If the area can depend on frequent soaking summer rains, the deeper rooting cultivars can be an advantage to keep the grass green between rain events. If the lawn is automatically watered two or three times a week, potential rooting depth is a moot point. [Figure 1]
- Many gardeners mistakenly assume that deep rooting is a water savings because irrigation is needed less often. However, the frequency of irrigation is not the primary factor to consider. The issue is total water consumption.

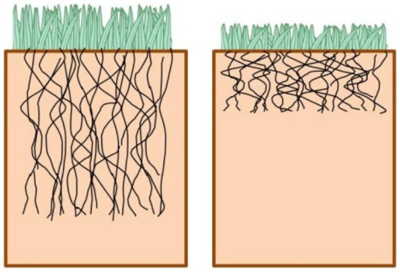


Figure 1. Deeper rooting means less frequent irrigation, but heavier irrigation to replenish the rooting zone. It should not be interpreted as a water savings.

<u>Kentucky Bluegrass Makes a Great Lower-Input Turf Option.</u>

- Kentucky bluegrass, KBG, is the standard for home lawns due to the rich blue-green color and its high tolerance for wear.
- Water use primarily depends on the gardener’s irrigation management. On a community wide basis, we use twice the amount of water that the KGB lawns actually need. Research studies show that the most gardeners actually do a good job of irrigation management. However, in any neighbourhood, some gardeners apply four to ten times the amount of actually needed by the lawn.
- With KBG, water use and growth actually slows when the soil begins to dry down. However, to capitalize on this dry down requires careful irrigation management rather than automatic irrigation on fixed days of the week.
- Irrigation demand varies significantly between cultivars. Some deeper rooting cultivars require less frequent irrigations. Some cultivars demand 25% less total water.

- KBG goes dormant with water stress. Summer dormant KBG is a standard in many parts of the eastern United States. Just not in the arid west! Will summer dormant with green lawns in the spring and fall work for the site?
- Bottom line: It is not the KBG that demands the heavy irrigation but rather the gardener's management style.

    - High input KBG makes a great "people space" for high use areas like a ball field with lots wear and tear. Few home lawns have this high traffic situation demanding high inputs.
    - Moderate input KBG (irrigated at 80% ET) fits the need for most home lawns where a beautiful green lawn is desired.
    - When irrigated at 60% ET, KBG makes a thinner carpet. This may be well suited for lower use areas.
    - Where summer dormant is acceptable, KBG makes a great minimal input lawn. It needs to be greened up in the cooler weather of spring and fall with rainfall and supplemental irrigation. [Figure 2]
    - The public objection to summer dormant lawns is that so many are found in un-kept yards that become the neighborhood weed patch.

Note: the term "ET" stands for *evapotranspiration* which is an actual measurement of the water use of the lawn (or crop) based on crop growth, temperature, wind, humidity, and solar radiation.

Figure 2. A weed free, summer dormant KBG lawn. Public objection to summer dormant KBG is that so many are simply no maintenance yards becoming the neighborhood weed patch.

Turf-Type Tall Fescue Makes A Great Lower Input Turf Option.

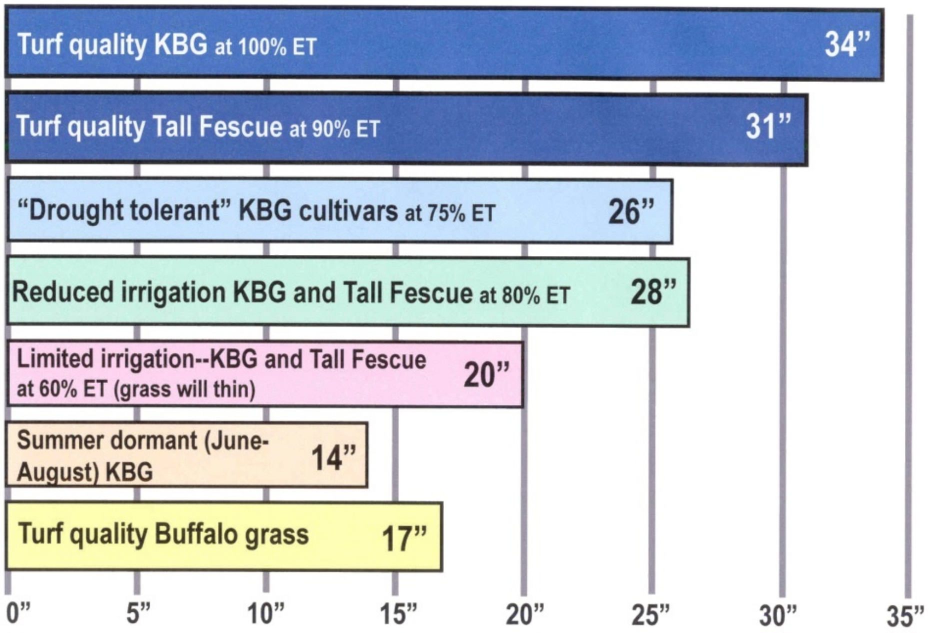
- Turf type tall fescue <u>may</u> be deeper rooted than KGB, depending on soil tilth (oxygen levels), cultivars, and irrigation pattern. This means it may go longer between irrigation, but should not be mistaken as water savings.
- Tall fescue cannot slow growth and water use as the soil dries down. Actual water use may be significantly higher than KBG.
- Tall fescue cannot go dormant. In summer dry spells, it requires irrigation.
- Based on ET, actual water use of turf-quality tall fescue is only 10% less than the ET for KBG. Irrigation management plays a larger role in water use than species selection. Switching from a KBG to a turf-type tall fescue lawn will not save water! Water savings comes in the management of the irrigation.
- Tall fescue makes a great reduced-input turfgrass for site where top quality turf is not essential for the landscape design.

Buffalograss Quality Is Dependent on the Amount of Summer Rain and Irrigation It Receives.

- Being a warm season grass, Buffalograss will be dormant brown from early fall (first frost) to late spring in Colorado.
- To be green in the summer, water use for Buffalograss is about 1 inch of rain and irrigation per week. To remain green in Colorado summers, Buffalograss generally requires irrigation to supplement natural rainfall.
- Turf-quality Buffalograss requires 50% less rain and irrigation per season than KBG. This reduction is due, in part, from being dormant in the spring and fall.

Comparative Seasonal Water Requirement

Figure 3 illustrates the comparative season water requirement (including summer rainfall and irrigation) of lawn options. The typical lawn receives twice the amount of irrigation required for high input KBG. [Figure 3]



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CMG GardenNotes #413

Water Wise Landscape Design:
Principles of Landscape Design

Outline:

The principles of landscape design include the elements of *unity*, *scale*, *balance*, *simplicity*, *variety*, *emphasis*, and *sequence* as they apply to *line*, *form*, *texture*, and *color*. These elements are interconnected.

Landscape design is a process of developing practical and pleasing outdoor living space. For additional information on the process, refer to *CMG GardenNotes* #411, **Water Wise Landscape Design Steps**.

Unity is the Quality of Oneness.

Unity attracts and holds attention. It organizes view into orderly groups with emphasis. Unity starts with the ***story line*** developed in the *family analysis*, step 2, in the design process. For additional details on Family Analysis, refer *to CMG GardenNotes* #411, **Water Wise Landscape Design Steps**.

Figures 1 and 2. Unity develops from the story line. Here in Jeff de Jong's garden a story line around "sacred space gardening" creates unity with the feeling of peace and tranquility.

Line Connects and Defines the Space, Creating Outdoor Rooms

Lines are a powerful design element that define rooms and connect people to the landscape. For a professional touch, use sweeping bold lines and curves rather than small zigzags and small wavy curves. Lines develop through Step 3 in the design process, *With Lines, Delineate Softscape and Hardscape Area Creating Outdoor Room*. For additional details on Step 3, refer to *CMG GardenNotes* #411, **Water Wise Landscape Design Steps**.

Figure 3. Notice the strong use of "line" here in the Japanese Garden at Butchart Gardens, Victoria BC. The path (primary line) invites you into the garden. Secondary lines form the beds.

Figure 4. In this private garden, the "line" formed by the edge of the pond creates an amazing space as the plants reflect in the water. The line defines the space and pulls you into the landscape.

Form Includes the Three-Dimensional Mass.

Form is determined by the line, direction, and arrangement of branches and twigs. The resulting mass influences the scale. For unity, repeat the topography form in plant forms. [Figure 5]

- **Horizontal and spreading** forms emphasis the lateral extent and breath of space. They are comfortable because it corresponds with the natural direction of eye movement.

- **Rounded** forms are most common in plant materials. They allow for easy eye movement and create a pleasant undulation that leads itself to plant groupings.

- **Vase-shaped** trees define a comfortable “people space” beneath the canopy.

- **Weeping forms** lead the eye back to the ground. What is below the weeping form often becomes a focal point.

- **Pyramidal** forms direct the eyes upward, so use sparingly. Grouping pyramidals will soften the upward influence. They will look more natural in the surroundings with foliage to the ground.

Figure 5. Forms (left to right) columnar, oval, vase, weeping, pyramidal, rounded

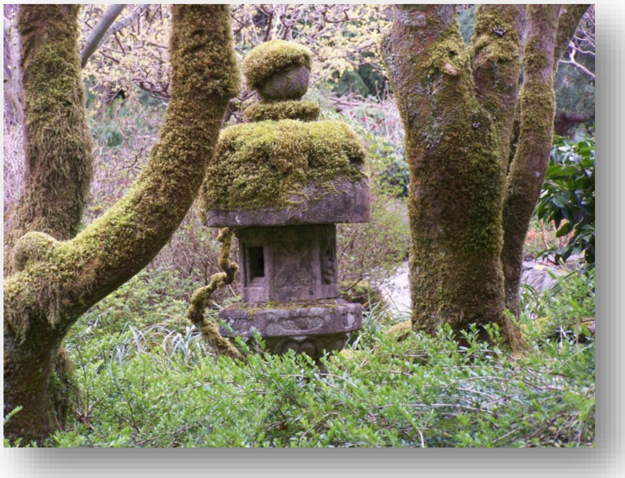
Texture is Fine/Coarse, Heavy/Light, Thin/Dense, and Light/Shade.

Texture can be defined as the relationship between the foliage and twig size, and the mass of the plants. Closeup, texture comes from the size and shape of the leaves, the size of twigs, spacing of leaves and twigs, the colors and shading, the gloss or dullness of leaves. At a distance, texture comes from the entire mass effect of plants and the qualities of light and shadows. [Figure 6]

Figure 6. Texture changes with distance. Up close, texture comes from the size and shape of leaves and twigs, plus the coloring and shading. At a distance, it comes the mass and play of light.

Figure 7. Four season gardening is all about texture gardening. Without the summer color, texture becomes the primary design element.

Figure 8. Texture rules here in the Japanese Garden at Butchart Gardens, Victoria, BC. Notice how the fine texture created by the moss plays with the coarse texture of the tree trunks and lantern. In Japanese gardening, the lantern is a symbol that this is sacred space, leave your cares and worries behind.



Color Gives Greatest Appeal, and Evokes the Greatest Response.

<u>How does color speak to you? What colors work for the landscape story line?</u>

Color is powerful in creating mood and feeling. *Color therapy* is a popular topic in our rapid paced modern world. What moods and feeling do various color create for you? What colors work for the landscape story line? What moods and feeling do you want in the garden? Is it a room for relaxation and healing or a room for action activities? Examples of common color feelings include the following:

Red	**Yellow**	**Blue**	**Green**
Passion	Joy	Imagination	Harmony
Courage	Happiness	Calm	Beginnings
Power	Communication	Serenity	Prosperity
Wealth	Inspiration	Relaxation	Nature
Motivation	Sunshine	Compassion	Growth
Fame	Optimism	Reflection	Healing

Orange	**Purple**	**White**	**Pink**
Enthusiasm	Intuition	Purity	Love
Joy	Devotion	Innocence	Sweetness
Exuberance	Respect	Faith	Uplifting
Interaction	Peace	Benevolence	Happiness
Fun	Spirituality	Honesty	Tenderness
Captivation	Awareness	Grace	Enticement
Sex	Deity		
	Royalty		

What color schemes work for the landscape story line? [Figure 9]

Cool colors	**Warm colors**
Less conspicuous	Conspicuous
Restful	Cheerful
Recede	Stimulating
Suggest distance	Come forward
Low scale	High scale

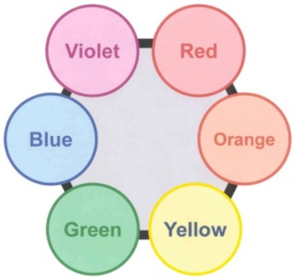


Figure 9. Color is the most powerful of the design elements. Choose colors carefully to create the mood desired in the story line.

Scale Evokes Emotional Connection and is Closely Related to Color.

Absolute scale relates to the comparative value of landscape elements to a fixed structure (house). [Figure 10]

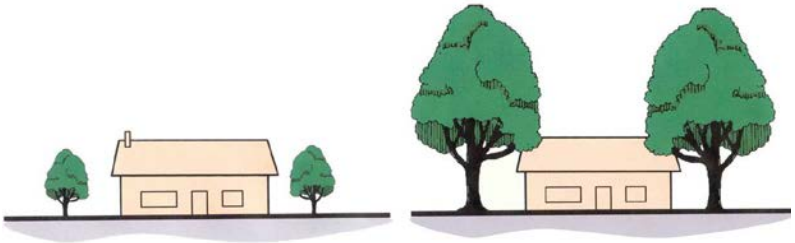
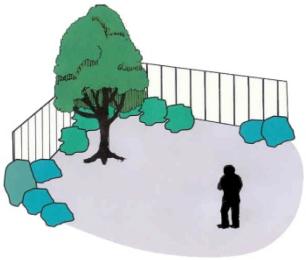


Figure 10. In absolute scale, the small trees on the left drawing give the feeling that the house is large. On the right drawing, the large trees give the feeling that the house is small. Both houses are the same size.

Relative scale relates to comparative sizes or “values” of objects in the landscape. Relative scale is very emotionally charged and closely linked to color. It may create a feeling of relaxation and peacefulness or one of energy and action. [Figures 11-13]

Figure 11. Relative scale compares the size or "value" of the landscape elements. Perception of tree size is based on the relative size of the person. Being emotionally charged, relative scale can create feelings of action or relaxation.

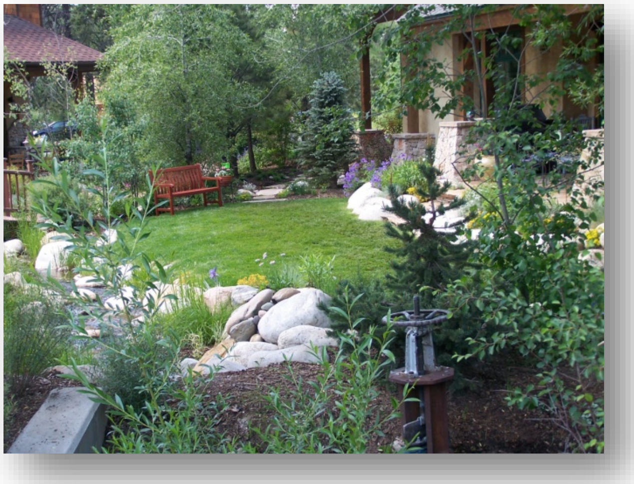


- **High scale** promotes action. It is used around large buildings and in large spaces to fill the space. Use of high scale in small spaces makes the space feel smaller. [Figure 12]

Figure 13. Here in the fountain area at Butchart Gardens, scale is high with the brightly colored flowers. The action feeling of high scale helps move people through.

- **Low scale** is relaxing and calming. It is used in the home landscape to give a feeling of peace and relaxation. [Figure 13]

Figure 13. In this private garden in Steamboat Springs, CO, the low scale creates a relaxing, renewing atmosphere.



Balance is Equilibrium on Left and Right Sides.

Formal balance repeats the same left and right, giving stability, stateliness, and dignity. [Figures 14 and 16]

Figure 14. Formal Balance

Informal balance differs from left to right giving curiosity, movement, and feels alive. [Figures 15 and 17]

Figure 15. Informal Balance

Which gives the “feeling” desired by the story line and design?

Figure 16. The stately Italian Garden at Hatley Park, Victoria, BC, is a great example of formal balance.

Figure 17. The Herb Garden at Government House, Victoria, BC, is an excellent example of informal balance being relaxing and free flowing.

Simplicity and *Variety*

Simplicity and variety work together to balance each other. ***Simplicity*** is a degree of repetition rather than constant change, creating unity. ***Variety*** is diversity and contrast in form, texture, and color preventing monotony. [Figures 18-22]

- For simplicity, repeat some plant materials in sweeps and groupings.
- For variety, fill in with other plants.
- Avoid creating a horticultural zoo (one of this, two of that)!
- Zipper plantings (like red-white-red-white) lack simplicity and variety.

Figure 18. In this simple drawing, *simplicity* is gained with the shrub row repeating the same plant materials. *Variety* is added with the tree.

Figure 19. For simplicity, repeat some plant materials in sweeps and groupings. Fill in with other plants for variety.

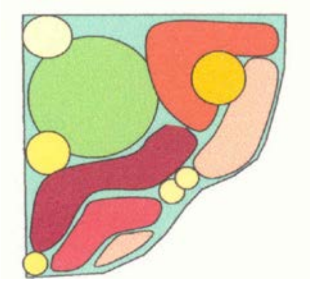


Figure 20. Simplicity is created by several hundred Hosta in this large bed. Variety is created by placing some in clusters of pots. - Innis Gardens, Columbus, Ohio

Figure 21. At Abkhazi Garden, Victoria, BC, simplicity is created with the row of purple heather and the lawn (the "Yangtze River"). Variety is created with an assortment of plant materials on the rocky hillside.

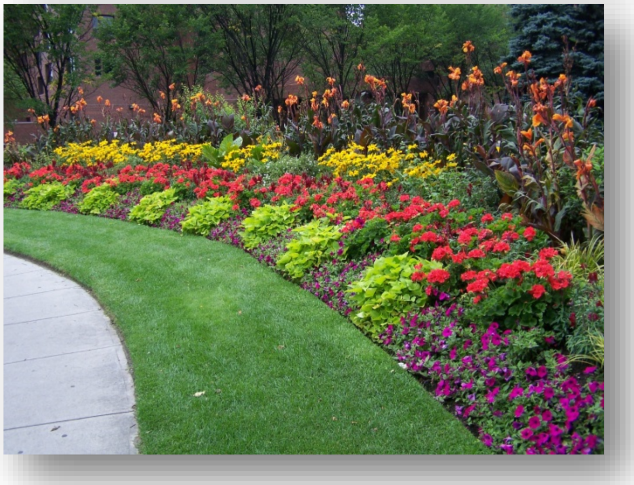


Figure 22. In this park, people enjoyed taking pictures of the various flowerbeds. However, they did not take pictures of this zipper planting (same elements repeated over and over again) finding it monotonous.

Emphasis is Dominance and Subordination of Elements.

The human mind looks for dominance and subordination in life. As we look at a landscape from any direction, we need to see dominance and subordination of various elements. If we do not find it, we withdraw from the landscape. Some gardens lack the dominant element. Others suffer with too many dominate elements screaming to be the focal point. [Figure 23-25]

Emphasis can be achieved through different sizes, bold shapes, groupings, and the unusual or unexpected. What is the focal point?

Figure 23. Emphasis is achieved with the tree being dominant and the shrub grouping being subordinate.

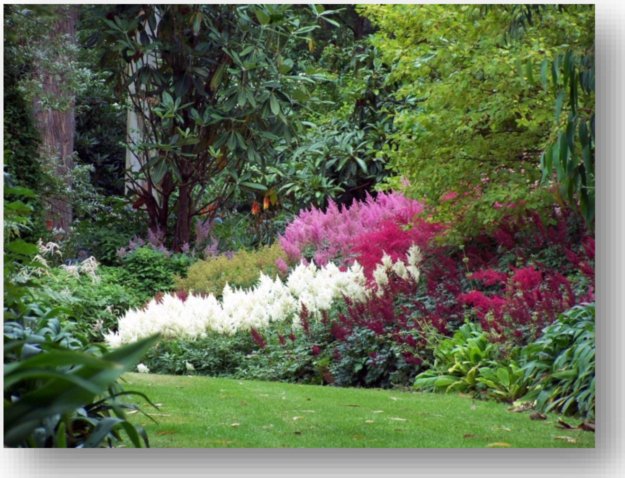


Figure 24. In this private garden, emphasis is added with the blooming Astelbe.

Figure 25. Ornamental grass often adds emphasis to a garden spot.

Sequence is the Change or Flow in Form, Color, Texture, and Size Giving Movement or Life.

Sequence with Texture

Change leaf size of adjacent different plants by at least one-half. Use proportionally larger numbers of fine textured plants. [Figure 26]

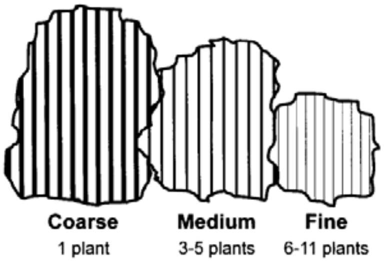
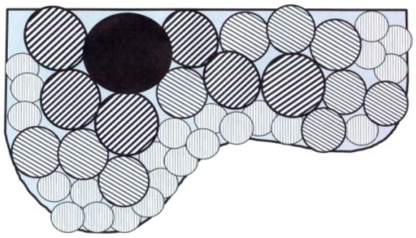


Figure 26. In texture sequence, change leaf size of adjacent different types of plants by at least one-half. Use more of the finer textured plant.

In a flower/shrub bed, use coarser texture, larger plants in the back; sequencing to finer textured, smaller plants in the front inside-curve. [Figure 27]

Figure 27. In texture sequence, place the fine texture plants in the inside curve and the coarse texture plants opposite. This is the way Mother Nature would do it. Look at the river. The sand bank is on the inside curve and the cliff opposite.



- Texture and distance – Texture becomes finer with distance. In a distant corner, place finer textures in the corner, sequencing to coarser textures on the arms. [Figure 28]

Figure 28. Textures get finer with distance. Place the fine textured plants in the distant corner with coarser textured plants toward the viewer.

Sequence with Color

There are few basic rules on how much warm and cool colors to use. However, watch that the scale does not become too commanding. More is NOT better. As a rule-of-thumb, the designs needs 90% green to set off the 10% color.

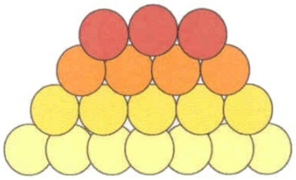
Darkest shades and the purest intensity dominate and should be used at the focal point. Using cool colors in contrast is more effective than sequences. Warm color work best in sequence.

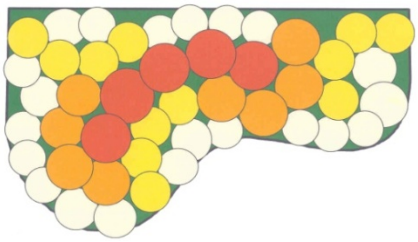
Color Sequence

1. Decide what color(s) will be used.
2. Decide if light or dark will dominate. – The darker or more intense (pure) the color, the more it will show up and dominate the scene.

3. Calculate the number of plants of each color using this rule-of-thumb.
    a. Establish the largest amount of dark/dominant color that will be used.
    b. Select the next lighter shade and increase the number of plants by 1/3.
    c. Select the next lighter shade and increase the number of plants by 1/3.
    d. Continue the ratio to the lightest color. [Figure 29]

Figure 29. In color sequence, increase the number of plants by 1/3 as the design moves from the dominant color to subordinate colors.

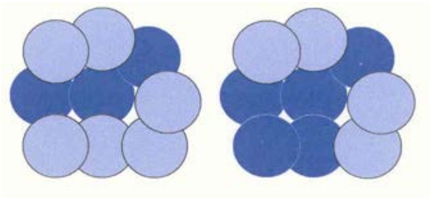




- Grouping for best effect – Kidney or crescent shaped groupings create a natural flowing design. [Figure 30]

Figure 30. In color sequence, crescent shapes of colors give a natural flow.

Color Contrasts



- **Monochrome light/dark color contrasts** – Use 1/3 one shade and 2/3 the other shade. [Figure 31]
- **Complementary color contrasts** – Use 1/3 one color and 2/3 the complementary color.

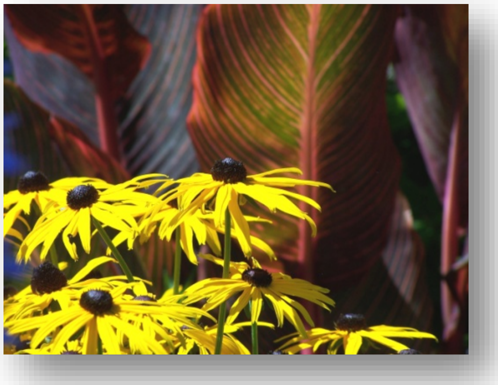
Figure 31. In color contrasts, use 2/3 of one color for dominance and 1/3 of the other color for subordination. Not half and half.

Create effective plant combinations by paring opposites

To create plant combinations with pizzazz, pair opposites. [Figures 32 to 35]

- ○ Fine/Course
- ○ Round/Upright
- ○ Small/Large
- ○ Short/Tall
- ○ Thugs/Dainty
- ○ Color contrasts

Figure 32 to 35. Examples of great pairing.



Additional Information – *CMG GardenNotes* on Water Wise Landscape Design

#410	References and Review Questions: Water Wise Landscape Design
#411	Water Wise Landscape Design Steps
#412	Water Wise Landscape Design: Selecting Turf Options
#413	Water Wise Landscape Design: Principles of Landscape Design
#414	Worksheet: Water Wise Landscape Design
#415	Homework: Water Wise Landscape Design

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- *CMG GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

Herbaceous Plants

Learning Objectives

At the end of this unit, the student will be able to:

- Select plants for different garden situations.
- Describe Colorado Eco-regions found in their area.
- Describe factors that influence microclimates.
- Describe methods to create and exploit microclimates.
- Interpret catalog and plant label descriptions, as they relate to
    - Life cycles.
    - Exposure.
    - Irrigation requirements.
    - Drought tolerance.
    - Soil requirements.
- List other selection considerations related to *Right Plant, Right Place.*
- Describe clues to overly well-adapted plants in relation to Colorado noxious weeds.

Curriculum developed by Irene Shonle, PhD, and Linda McMulkin with Laurel Potts, Darrin Parmenter, and David Whiting, CSU Extension.

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- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

Revised January 2012

Reading / Reference

Books

- ***Annuals for Connoisseurs***, Wayne Winterrowd, Prentice Hall, 1992
- ***Best Perennials for the Rocky Mountains & High Plains***, Celia Tannehill and James E. Klett, Word Press, 2002
- ***Encyclopedia of Perennials: A Gardener's Guide***, Christopher Woods, Facts on File, 1992
- ***Gardening in the Mountain West,*** Barbara Hyde, Johnson Printing, 1999
- ***Hardy Herbaceous Perennials***, Leo Jelitto and William Schacht, Timber Press, 1990
- ***Illustrated Encyclopedia of Perennials***, Ellen Phillips and C. Colston Burrell, Rodale Press, 2004
- ***Rodale's Flower Garden Problem Solver***, Jeff Ball, Rodale Press, 1995
- ***Sunset Western Garden Book***, 7th Edition, Sunset Publishing. 2001
- ***The Perennial Garden : Color Harmonies Through the Seasons***, Jeff and Marilyn Cox, Rodale Press, 1985
- ***Tough Plants for Tough Places***, Peter Loewer, Rodale Press, 1992
- ***Waterwise Landscaping***, Jim Knopf, Chamisa Books. 1999
- ***Well-Tended Perennial Garden: Planting and Pruning Techniques,*** Tracy Disabato-Aust and Steven M. Still, Timber Press Inc., 1998
- ***Xeriscape Colorado,*** Connie Ellefson and David Winger, Westcliffe Publishers. 2004
- ***Xeriscape Plant Guide,*** Denver Water, Fulcrum Publishing. 1996

Web Based

CMG GardenNotes (available at www.cmg.colostate.edu)

- Herbaceous Plants: References and Study Questions, #510
- Colorado Plant Ecosystem, #511
- Herbaceous Plants: Right Plant, Right Place, #512
- Herbaceous Plants: Worksheet, #513
- Herbaceous Plants: Homework, #514

- Managing Soil Tilth, #213
- Mulching with Wood/Bark Chips, Grass Clippings, and Rock, #216
- Native Grasses For Colorado Landscapes, #571
- Native Plant References, #572
- Soil Amendments, #213

CSU Extension Fact Sheets (available at www.cmg.colostate.edu)

- Choosing a Soil Amendment, #7.235
- Fall and Winter Watering, #7.211
- Fall-Planted Bulbs and Corms, #7.410
- Flowers for Mountain Communities, #7.406
- Ground Cover Plants, #7.400
- Ground Covers for Mountain Communities, #7.413
- Herbaceous Perennials, #7.405
- Mulches for Home Grounds, #7.214
- Native Herbaceous Perennials for Colorado Landscapes, #7.242
- Ornamental Grasses, #7.232
- Perennial Gardening, #7.402

- Rock Garden Plants, #7.401
- Soil, Water and Plant Testing, #0.507
- Soil: The Key to Successful Gardening, #7.222
- Spring-Planted Bulbs, Corms and Roots, #7.411
- Wildflowers in Colorado, #7.233
- Xeriscaping: Garden Flowers, #7.231
- Xeriscaping: Ground Cover Plants, #7.230
- Xeriscaping: Retrofit Your Yard, #7.234
- Xeriscaping: Creative Landscaping, #7.228

Colorado Garden Show, Inc at www.gardeningcolorado.com/plants/

PlantTalk® Colorado scripts at www.ext.colostate.edu/ptlk/index.html

Review Questions

Climate and Microclimate

1. Describe Colorado Ecoregions found in your area of the state.

2. What parameters is the USDA Hardiness Zone based on?
3. What is the hardiness zone of your region? How well does it describe your own garden situation? Why may it be different?

4. List six factors that can influence hardiness.

5. Describe a situation in the landscape where you may have a “heat-tolerant” location.

6. Define microclimate.

7. Describe how microclimates can be influenced by the following situations.

   a. Elevation
   b. Aspect
   c. Hills and valleys
   d. Rocks
   e. Structures
   f. Bodies of water

8. Describe techniques to create and exploit microclimates.

9. What are the advantages and disadvantages of gardening at higher elevations?

10. You have four sides of your house – north, south, east, and west – describe what types of plants or the type of growing conditions that would work best on each side:

11. Describe how a windbreak in your location could work to your advantage or disadvantage.

12. Describe the microclimates around your home landscape.

Interpreting Plant Descriptions

13. Describe what makes a well-defined (complete) plant description in a catalog and a poorly-defined (incomplete) plant description.

14. What attributes define the four different life cycles?

    a. Annual
    b. Biennial
    c. Perennial
    d. Bulbs, corms, and tubers

15. What are the benefits of having annuals, biennials, and perennials in your garden? Give one example for each life cycle.

16. List the five different exposure situations and discuss challenges associated with growing plants in each situation.

17. Describe different hydrozones associated with residential landscapes?

18. Explain common mis-understandings related to xeriscaping.

19. What makes a plant "drought tolerant"?

20. Plants that can be defined as xeric may have adaptations to their leaf structure that make them more drought tolerant. After each adaptation, describe why it would assist the plant in its drought tolerance:

    a. Thick
    b. Waxy
    c. Fleshy
    d. Hairy
    e. Light-colored
    f. Small and narrow

21. What defines a "woodsy or woodland soil"?

22. What ecosystems/climates/locations in Colorado could fit in the description of having a soil that would have a "woodsy or woodland soil"?

23. Define "ordinary soils".

24. Given your preference for time of year flowering, what type of plants (annuals, biennials, perennials, and bulbs, corms, and tubers) would be your primary choice of plants in your garden?

25. Horticulturally speaking, what is resistance?

26. What are the parameters that define wildlife <u>resistant</u> plants?

27. Give three examples of plants that you believe have attractive or contrasting foliage.

Ecological Adaptation

29. What are characteristics of the "ideal" Colorado plant? Which of these characteristics are applicable in your area?

30. Give five attributes that make a plant adaptable to many of Colorado's growing areas.

31. Of these five attributes, can any of them also be attributes that could make the plants aggressive or invasive?

32. Define the following terms in regard to plant populations:

    a. Aggressive
    b. Invasive
    c. Native
    d. Alien

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #511

Colorado Plant Ecosystems

Plant Zone Ecosystems

Colorado is defined by its topography and climate Natural settings are described in terms of ecosystems, which are localized areas where non-living and living components interact. These interactions result in communities of organisms influenced by variations in the factors needed for survival. In the case of plant communities, factors such as light, temperature, soil, slope and exposure influence which species are found in particular locations. The study of natural plant communities can offer hints to gardeners about local conditions and the plant species that may thrive in landscapes with characteristics similar to the natural setting.

Ecosystems in Colorado are named for the region, soil type and plant species of an area. Broad ecosystem descriptions include grassland, shrubland, coniferous forest and alpine, defined by elevation and plant type. These broad categories can be further defined by the specific location and dominant plant type; examples include Subalpine Engelmann spruce forest, Colorado Plateau Pinyon-Juniper woodland and Foothill grassland. Within each ecosystem, microclimates are created by variations in site conditions. The plant community on a south facing slope will differ from that found on a north facing slope, even when elevation and soil conditions are similar.

The details of Colorado ecosystems and plant communities change as more is learned about how species interact and how communities react to natural processes. The Colorado landscape is most often divided into five vegetation zones, based primarily on elevation. Within these distinct vegetation zones, the overall climate is relatively uniform. Microclimates result in plant communities that may be unique or a variation on the overall theme.

The five vegetation zones of Colorado are grassland/semidesert shrubland, foothills, montane, subalpine and alpine. Each vegetation zone is named for the dominant woody species (grasslands are the exception), but each zone has herbaceous plants that thrive under the same conditions as the woody backbone of the landscape.

Grasslands/Semi-desert Shrublands

The lowest elevations in Colorado are found on the eastern plains, the western slope and in the San Luis Valley. But elevation alone cannon define these areas, since the variation in soil and weather patterns result in different vegetative communities. The plains of the eastern third of Colorado are dominated by grass species while the western slope and the San Luis Valley are more commonly dominated by native shrub species.

Plains grasslands cover the eastern third of Colorado (up to 6,000 feet) and are made up of primarily short-grass species. The climate is hot in the summer and highly variable in winter. Summer thunderstorms and winter blizzards, which provide up to 16 inches of moisture annually, can be sudden and violent. Wind driven fires played a role in development of this ecosystem. Agriculture and urban sprawl have impacted the health of prairies and few areas in Colorado retain a truly native ecosystem.

Semi-desert shrublands extend to 7,000 feet on the western slope, to 8,000 feet in the San Luis valley, and east of the Continental Divide from the Arkansas River basin to New Mexico. Plants here are low growing, drought tolerant, deciduous shrubs. Diversity tends to be low in comparison with grasslands, due primarily to lower annual precipitation and colder winters. Soils are variable but are often alkaline with poor water infiltration and high runoff.

Foothills

The foothills zone is the transition from the grassland/semi-desert shrublands of the lower elevations to the coniferous forests found in the montane zone. This ecosystem is dominated by deciduous shrub communities and Piñon-Juniper woodlands. Shrublands are dominated by Gambel oak, Mountain mahogany and Sagebrush. The species that make up the Piñon-juniper community are conifers that can grow at low elevation under similar conditions to those found in mountain shrublands.

Plant species native to this ecosystem generally have extensive lateral root systems to maximize water uptake and leaves with waxy coatings or hairs to reduce water loss during the growing season. The deciduous growth habit found in the shrublands helps reduce winter water loss.

Foothills plant communities thrive on south facing slopes, which are hot in summer and have winter conditions are moderated by solar heating. Competition between plant species in the shrublands is high, primarily due to intermittent precipitation.

This ecosystem is most commonly found from 5,500 feet to 8,000 feet, but some plant communities may reach as high as 10,000 feet on the western slope. Gambel oak dominates many south facing slopes but is most common south of I-70 on the Front Range. Mountain mahogany, which appears to tolerate slightly colder temperature than Gambel oak, is more dominant north of I-70. On the western slope, Gambel oak and sagebrush species dominate the shrublands.

Piñon-Juniper woodlands are found throughout western and southern Colorado. The proportion of Piñon pine to junipers changes according to the elevation and climate conditions of a site. Populations range from almost exclusively one species of juniper to a mix of pine and one or more juniper species.

Montane

The montane ecosystem ranges from 8,000 to 10,000 feet and is dominated by pines, Douglas-fir and aspen. Ponderosa pine, which can be found growing in the adjoining Foothills ecosystem as low as 5,600 feet, is more common on dry, south facing slopes east of the Continental Divide and in the southwestern portion of Colorado. On north facing slopes, moist areas and in northwest Colorado, Douglas-fir is the dominant plant. Lodgepole pine and aspen are common at the upper elevations of the montane.

Ponderosa pine and Douglas-fir are tolerant of mid-elevation conditions, including a longer growing season than at higher elevation, warm summers, cold winters, and intermittent summer moisture. The understory community is dependent on the amount of light and moisture available. Ponderosa pine forests tend to be more open than Doulas-fir and have greater understory diversity. Douglas-fir tends to naturally grow closer together, which restricts the growth of most other plants. Aspen are found throughout the montane ecosystem in microclimates that receive 25 or more inches of moisture annually and are cooler than sites in lower elevation ecosystems.

Subalpine

Englemann spruce, subalpine fir, limber pine and bristlecone pine are common inhabitants of the subalpine ecosystem. The zone ranges from 9,500 to 11,400 feet and is characterized by a short growing season, high snowfall and cold temperatures, and locally strong winds.

Alpine

The alpine zone exists at elevations above treeline throughout the Rocky Mountains. Treeline ranges from 11,200 feet in northern Colorado to around 12,000 feet in southern Colorado. Herbaceous plants and low growing woody shrubs frequent this harsh environment. Successful species must complete growth and reproduction in the short growing season available and withstand strong winds and intense sunlight.

Special considerations

The ecosystem that a particular plant species inhabits is a function of the many environmental conditions of a site. Plants thrive in specific areas because conditions allow them to outcompete or coexist with other species. Plant communities are adapted to specific conditions, including sun or shade, wet or day and long or short growing season. Many plant species are adapted to survive drought, wind or fire. In addition, plants must be able to reproduce successfully; each species has specific conditions for germination and seedling growth.

There are rarely clear dividing lines between ecosystems. The edges of individual ecosystems intermingle in transition zones, with grassland species growing among Ponderosa pines and stands of subalpine fir surrounded by alpine wildflowers.

In any of the above ecosystems, areas exist that are dominated by herbaceous species. These can be small openings in the forest, large meadows or areas where fire has destroyed the woody plants and the process of ecological succession has begun. These areas will contain plant species that favor conditions of that site and will vary according to soil, moisture, sun and length of growing season.

All ecosystems have areas into which water drains. The edges of lakes, ponds, streams and rivers are referred to generally as riparian areas and are further defined by the ecosystem where they are found. The plant species found within these narrow bands differ by elevation, but are dominated by plants that prefer high moisture levels or tolerate being partially submerged during high runoff. Cottonwoods, willows, alders, plums, poison ivy, cattails and tall-grass species are common in these moist areas.

Riparian areas tend to have high levels of plant diversity and are often home to plant species more common to the eastern plains or to adjoining ecosystems. Water courses are heavily used by native animals, agriculture and for recreation and are impacted by seasonal flooding and drought as well as human activities.

Colorado gardeners can use published information about local native plant communities to plan successful landscapes. Conditions in an individual yard have much in common with the surrounding natural setting, sharing similar soil, precipitation, length of growing season and light intensity. By studying the characteristics of plants that thrive in a specific area, gardeners can make wise choices for their personal landscape.

Authors: Linda McMulkin, with Laurel Potts, Darrin Parmenter, Irene Shonle, and David Whiting, Colorado State University Extension

Revised August 2010

CMG GardenNotes #512

Herbaceous Plants: Right Plant, Right Place

<u>Outline</u>:

Climate and Microclimate

<u>Temperature</u>

Plants generally have a specific range of temperatures in which they thrive. This information is usually listed in terms of hardiness or hardiness zones, although maximum daily temperature, minimum daily temperature, difference between day and night temperatures, average daytime temperature, and average nighttime temperature all have an effect.

Hardiness and Hardiness Zones

Hardiness refers to a plant's tolerance to low temperatures. Factors that influence hardiness include minimum temperature, recent temperature patterns, water supply, wind and sun exposure, snow cover, genetic makeup, and carbohydrate reserves.

Because of these complex interactions, gardeners may want to experiment with hardiness, or take the zones with a grain of salt. Depending on the microclimate and the year, Colorado gardeners often find that they can grow plants that are supposedly not hardy here. At other times, a plant that “should be” hardy will not be.

Hardiness zone maps indicate the average annual minimum temperature expected for geographic areas. While this is a factor in plant selection, it is only one of many factors influencing plant hardiness.

In 2012, the U.S. Department of Agriculture released a new USDA Hardiness Zone Map. It can be found at http://planthardiness.ars.usda.gov/PHZMWeb/. The revised map has a large database correcting inherent problems with the 2003 version. It documents a climate zone creep, that is zones moving northwards in recent years. Zones are based on a 10°F difference in average annual minimum temperature.

Average Annual Minimum Temperature

Zone 4	-20°F to –30°F
Zone 5	-10°F to –20°F
Zone 6	0°F to –10°F

The Sunset Climate Zones claim to take into account the total climate, including length of growing season, timing and amount of rainfall, winter lows, summer highs, and humidity. This is a good concept, but there are not enough zones for Colorado—for example- Vail and Denver are shown in the same climate zone.

Figure 1. Hardy perennials, like tulips, are tolerant of the snow.

Heat Tolerance

This is the opposite extreme; how much heat a plant can tolerate during the growing season. For example, Colorado summers can be very hot and dry. In planting near stone, a south-facing wall, a driveway, or some other heat sink, the gardener might want to look for plants that “tolerate” or “thrive” in heat and drought. Keep in mind that this is not often listed in descriptions. If you live in an area with a cooler summer (such as higher elevations), heat-loving plants are not necessarily a good choice. Phrases such as "*not a good choice for Desert Southwest*" suggests that the plant does poorly in dry heat. [Figure 2]

Figure 2. Begonias are generally considered shade plants. They are intolerant of heat and can be found in full sun in cool climates.

Microclimate

A microclimate is a variation of the climate within a localized area, usually influenced by hills, hollows, structures, or proximity to bodies of water. A microclimate differs significantly from the general climate of a region. These can be exploited to grow plants that would otherwise not be hardy (i.e., in garden beds against a facing south stonewall). Similarly, plants that prefer cooler seasons might benefit from being placed in areas that get dappled shade or only morning sun. [Figure 3]

Mountains and valleys create some rather complex microclimates. The bottom of a valley is cooler than hillsides due to cool air draining to low spots. Valley floors may be over 10°F cooler than surrounding gardens on hillsides. Air drainage and aspect (direction the slope faces) may change a growing season by one to two zones and blooming by two to six weeks.

A gardener can expand what is possible to grow by learning to create and exploit microclimates. For example, a south facing slope may be one or more hardiness zones warmer. In hot areas of the region, avoid plants that prefer cool temperatures. In cool areas of the region, grow tender plants or ones that need more heat to bloom on the south and west.

Gardeners can also note and take advantage of the microclimates on different sides of their houses. Sunny south and west sides will be warmer. The east side of a house is typically cooler than south or west, and it may be more protected from wind. Because of this, it is perhaps the most temperate side in which to garden. The north side of a house is the shadiest, coolest, and generally moist. Grow plants that are not heat or drought tolerant here.

Figure 3. This alpine garden features plants from the harsh microclimate of the high alpine meadows. Plants are small and quick to bloom, being tolerant of wind, cool temperatures, and short growing seasons.

Many places in Colorado are very windy, with gusts up to 100 mph. Wind desiccates plants, increasing mortality. It can also blow away mulch. Gardeners in windy places can either grow plants that are tolerant to wind, or create or take advantage of existing windbreaks. The ideal windbreak will be semi-porous, with a density of 40% to 60%. This will provide the greatest downwind area of protection. Snow also will build up on the lee side of windbreaks, so this can be a good spot to plant more tender plants.

Plant Evaluation

Gardeners have a wide range of plant material available to them. Garden centers, plant catalogs, and the internet provide exciting new choices. However, not all plants will perform equally well in a given area or in a specific garden bed. To evaluate a specific plant, gardeners must ask questions to determine whether it is a good choice for a site. This includes interpreting catalog, garden tag, and seed packet descriptions.

Developing this skill is critical to making the best choices because few garden catalogs are written for Western climates. Many gardeners did not learn to garden in the climate where they currently reside. The ability to evaluate plants helps gardeners plant the “right plant in the right place.”

Plant Descriptions

There are many pieces of information in a complete plant description that helps gardeners make good decisions. These include the scientific name, life cycle, preferred sun exposure, hardiness, mature size, soil preference, moisture preference and bloom period.

Catalogs, plant tags and seed packets generally include at least sun exposure and hardiness, but these are often not enough. Even if the description is more complete, interpreting what exactly is meant by these descriptions is often fairly tricky. This chapter helps the gardener to “read between the lines” of plant descriptions.

Scientific Name

Although the scientific name of a plant can be intimidating, it can be an important piece of information. Plants often have many different common names, and there is no way of ensuring you have a specific plant unless the scientific name is given. The name is also important if the plant description is not complete and the gardener needs to do more research.

Life Cycles

One of the most fundamental pieces of information about a plant is its life cycle. Because of this, nurseries and plant catalogs often divide plants into categories based on life cycle or life form. Categories often used include bulbs (including rhizomes and corms), annuals, perennials, shrubs, and trees.

Annuals complete their life cycle (from seedling to setting seed) within a single year. In other words, they will not come back next year, although some may self-seed. Annuals are useful in flowerbeds where gardeners prefer yearly change as well as in containers and as cut flowers. Annuals can also be planted in perennial beds to fill gaps in the succession of bloom. Summer blooming annuals typically bloom all summer long.

Biennials complete their life cycle within two growing seasons, germinating and growing vegetatively the first season and flowering the second season. The individual plant will not come back after flowering second year (although it may self-seed). Biennials can provide quicker color than perennials and are often more architectural than annuals.

Perennials live through multiple growing seasons. Most have a short blooming period of two to six weeks. Perennials readily add structure to the garden. While individual plants may be more expensive than annuals, the one-time investment may last for years.

Bulbs, corms, and tubers – Many herbaceous ornamentals fall into the category of bulbs, corms, and tubers. These plants are perennial in their native climate, but in regions with cool winter soils, some require fall digging and winter storage indoors.

Notes on Annuals, Biennials, and Perennials

> Many of our annuals are actually perennials in warmer climates. Some of our more hardy annuals may live as short-lived perennials in protected areas.
>
> Some plants are described as either being biennials *or* short-lived perennials. In a good spot, such a plant might last for three or more years – on the other hand, if it blooms extravagantly, and produces many seeds, it may “bloom itself to death” in only two seasons. Some factors to consider in choosing one of these plants for the garden would be does the plant self-seed? If so, is this a desirable trait? Self-seeding plants can be invasive.

Exposure

The amount of sun a plant needs to thrive is a critical factor in choosing a plant to fit a particular garden situation. The following are catalog terms used to describe the plant’s preference for sun exposure.

Full sun – Due to the strong sunlight in sunny, high elevations like Colorado, a garden that receives at least six hours of sun each day is generally considered to be full sun. Frequently, eastern catalogs (from areas with more cloud cover) will describe full sun as being eight to twelve hours per day.

Part sun – In Colorado, a garden site that receives six hours of dappled shade from trees or approximately four hours of direct sun with shade either in the morning or afternoon is considered part sun. Frequently Eastern catalogs may say six to eight hours is part sun.

Part shade is used interchangeably with the term part sun.

Light shade is the shade produced from a one-story building or tree and is characterized by bright, indirect light. [Figure 4]

Figure 4. Hosta and ferns create a good textural combination for a north- side shade garden.

Medium shade is the shade under deciduous trees, unless the tree is large and dense. If the tree is very large, the shade may be considered deep shade. Thinning tree branches will not adequately improve sun levels for sun loving plants.

Dark shade is very dense and dark, and is found under evergreens and very large deciduous trees. The plant palette for these areas is limited.

Irrigation Requirements

Hydrozones – Plants should be grouped into areas requiring the same irrigation amounts. For example:

- **Routine irrigation** – Watered every 2-4 days
- **Reduced irrigation** – Watered every 5-14 days
- **Limited irrigation** – Watered during dry spells
- **Non-irrigated** – In sites where landscape irrigation is not desirable or possible, focus on natural growth.

Based on differences in annual precipitation, gardens with limited to no irrigation will thrive some years and decline other years.

In a semi-arid state such as Colorado, the amount of water a plant needs is a very important factor, although it is not always listed in catalogs. If this information is given, it is often through the use of symbols. Because the meaning of this varies, refer to the catalog or plant tag key for interpretation. If there is no mention of moisture requirements, and the plant or catalog is not from the west, assume that the plant in question cannot tolerate extremely dry soils.

Drought Tolerance

This is a relative term. Consider where the information is coming from. It will mean very different things if coming from New Mexico or Maine. This distinction is illustrated by the following catalog description “Thick roots drive down deeply, making it drought tolerant; struggles in the desert southwest”. [Figure 5]

Figure 5. “Drought tolerant” does not mean just cacti and desert -type plants.

What is a “Xeric Plant”?

“Xeric” is a relative term. Some sources consider a plant that needs no supplemental irrigation as xeric; others consider plants needing up to one-inch of water per week as xeric. Xeric plants tolerate conditions of low water, bright light, and warm temperatures. Adaptations include thick, waxy, fleshy, hairy, or light-colored leaves, small narrow leaves, and taproots. [Figure 6]

For additional information on xeric plants, refer the following Colorado State University Extension fact sheets available online at www.cmg.colostate.edu.

- Xeriscaping: Perennial and Annual Flowers, #7.231
- Xeriscaping: Ground Cover Plant, #7.230
- Xeriscaping: Creative Landscaping, #7.228
- Xeriscaping: Retrofit Your Yard, #7.234

Figure 6. A cacti and succulent garden can be a fun specialty garden.

Soil Requirements

Eastern catalogs will often describe soil needs of plants as being ***woodsy*** or ***woodland soils***. Colorado soils seldom match that description. Woodland soils usually refer to moist, acidic soils that are high in humus. Plants needing a woodsy soil often do poorly in western soils even if they area hardy.

Similarly, woodland plants are usually adapted to a low light condition and soils rich in organic matter. They typically have large leaves and small flowers, and are often adapted to humid air. Again, they usually do poorly in much of the arid west.

Other soil requirement ‘red flags’ to watch for are “needs ordinary soil” or “good soil”. What is “ordinary”? Catalog writers are probably not referring to the typical western soils. In general, Colorado soils are either clayey, sandy, or gravelly, and are almost always low in organic matter and high in pH (alkaline)

If a catalog states the plant grows best in sweet soils, there should not be a problem, because ‘sweet’ means alkaline. If a catalog states a plant “needs well drained soil,” it may or may not be a good choice for gravelly soils. It depends on how well drained the soil really needs to be. For example, in an eastern catalog, a plant description reads “needs well-drained, evenly dry soil; struggles in desert southwest.” This indicates that western ‘well-drained and dry’ is probably more well drained and dry than in the east. [Figure 7]

Figure 7. Iris is an example of a flower tolerant of a variety of soil types as long as it well drained.

Bloom Period

Another factor often listed on plant descriptions is the bloom period. This becomes of greater importance when planning a garden from catalogs in January, as opposed to going to a garden center where merely seeing what is in bloom at the time of purchase can be a guide. Consider when you want your plants to bloom. Does the whole garden area flower only in June or is there color throughout the growing season?

Usually plants are described as blooming in spring, late spring, early summer, summer, late summer, or fall. Gardeners living at higher elevations or elsewhere with a short growing season may find the term misleading. Here, the seasons are more compressed and most late summer or fall blooming plants never get a chance to flower before frost. [Figure 8]

Figure 8. Tulips and other spring flowering bulbs are popular, easy to grow, spring bloomers.

Length of Bloom

The number of days a plant bears flowers is generally not listed in catalogs, but this can make a big difference in the garden. Perennials bloom for a period of a short-but-showy one week to six weeks or more. These long-blooming perennials can become the "backbone" of a perennial bed, unifying plants that bloom around it. Annuals can help increase the amount of color in a garden, as they tend to bloom all summer, reaching their peak at the end of summer.

Consider whether you want a changing palette of plants, or fewer, longer-blooming plants. Keep in mind that the former will be hard to accomplish in a small garden, and a small number of plants in bloom at one time may end up looking "spotty" in the garden. [Figure 9]

Figure 9. Daylilies are a popular perennial with a long bloom period.

Mature Size

An important consideration in choosing plants is the overall size it will reach at maturity. Often, catalogs only give information on height, which can determine whether it is better for the front or back of the border. Width is less frequently listed, but should be given as much consideration as height. Because the final size of the plant is hard to visualize, it is easy to plant too closely, especially when starting with smaller plants. The bed should be measured and planted to take into account the ultimate size of each plant. Annuals can be used to fill in the empty space in the first season.

Growth Form

Frequently, catalogs will describe something about the growth form of a plant. These terms include the following:

- **Clumping** – Individual plants form clumps rather than spreading evenly to fill the bed.

- **Creeping, underground runners** – These usually refer to rhizomes. Plants with this growth form can be aggressive, and may need to be divided or contained (such as mints or yarrows).

- **Trailing or climbing** – These are usually vining or semi-vining plants, and are usually used as a groundcover or hanging basket. [Figure 10]

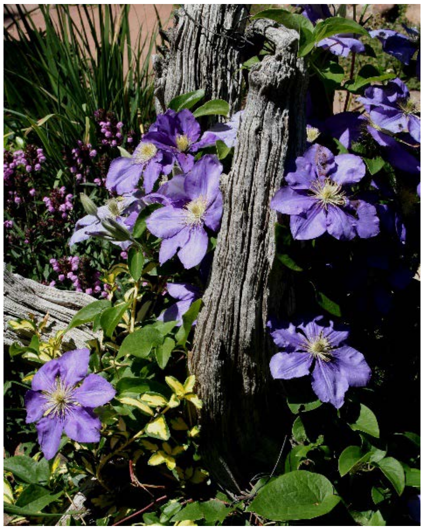

Figure 10. Clematis is a popular flowering vine in shades of blues, purples, pinks, and whites

Other Important Considerations That May or May Not Be Listed in a Catalog

Fragrance

Gardeners may be interested in having fragrant plants near paths, patios, windows, or doors. Even if the species as a whole is considered to be fragrant (i.e., roses), bear in mind that not all cultivars *within* a species are fragrant. Check individual listings to see whether "fragrant" is in the description. If not, it is probably not fragrant. [Figure 11]

Figure 11. When it comes to fragrance, not all roses are created equally. Some were bred for fragrance, while color patterns were the attractive features of others.

Wildlife Resistant Plants

Wildlife can make gardening difficult. Everything from deer to chipmunks eat cultivated plants. While there are no guarantees on what a very hungry animal will avoid, in general, most wildlife will avoid plants that are very aromatic, have prickles and spines, tough leathery leaves, milky sap, or are toxic. Further, some catalogs will actually include a little symbol or statement if, in their experience, the plant is wildlife resistant. These are only tendencies, however, and are not foolproof.

Wildlife Attracting Plants

Many gardeners select plants to attract wildlife, such as butterflies and birds. A large variety of pollen and nectar bearing flowers attract butterflies. In butterfly gardening, give attention to plants for the adults and plants to feed the caterpillars (larval stage of the butterfly). [Figure 12]

Figure 12. A wide variety of pollen and nectar producing flowers attracts butterflies and hummingbirds.

Insect and Disease Resistance

Certain species are prone to insects or diseases, which has led to the development of resistant cultivars. Sometimes you only will notice a problem if you read through description of *all* of the cultivars. For example, bee balm (*Monarda)* is known to be susceptible to powdery mildew. However, in one catalog, the species description of bee balm says nothing of this susceptibility, nor do two of the cultivar descriptions. However, the cultivar ‘Red Shades’ is listed as “very resistant to powdery mildew.” You must read between the lines to discover that the genus *Monarda* is susceptible to powdery mildew.

Hail Resistance

Big or soft leaved plants such as hosta are very vulnerable to hail. In areas with frequent hailstorms, choose narrow and tougher leaved plants, as they are more resilient. [Figure 13]

Figure 13. Hail can be destructive to large-leaved plants, like Hosta.

Need for Staking

Many places are very windy, which means that top-heavy and tall plants may need staking. If gardening in a windy location, consider looking for shorter or lighter cultivars. For example, "a mid-size delphinium that never needs staking… the choice for smaller gardens."

Need for Division

Some plants need to be divided more frequently than others. For example, ornamental grasses like blue fescue requires frequent division as the center dies out. Peonies can go many years without the need for division. Plants needing frequent division would be considered "high maintenance". On the other hand, plants that need division frequently are good sources of plants to share with others.

Information on plant division will rarely be found in catalogs, but may be looked up in other reference materials. [Figure 14]

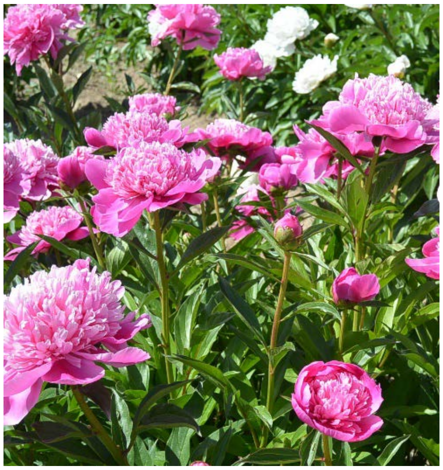

Figure 14. Peony is an example of a plant that rarely needs division.

Attractive or Contrasting Foliage

Consider how the plant will look out of bloom; will the foliage still look attractive? Using a range of colors, sizes, and shapes of leaves will help add interest in the garden even when nothing is blooming. Choosing plants that have colorful fall foliage will add an extra season of interest to the garden. Planting for foliage over blooms is a new design trend. (Figure 15)

Figure 15. Caladiums (right) and coleus (left) are two examples of plants used for foliage color. A trend in landscape design is to replace short blooming flowers with plants that have attractive foliage.

Plant Evaluation Programs

There are many different ways that new plants are tested. One example is the Annual Trial Garden on the Colorado State University campus in Fort Collins (the Annual Trial Gardens and PERC Trial Gardens). [Figure 16]

Plant Select®, (a collaboration between Colorado State University, Denver Botanic Gardens and the Green Industries of Colorado) is a program to designed to seek and distribute the very best plants for gardens of the high plains and intermountain region (refer to www.plantselect.org).

All America Selections is a national program evaluating new cultivars (refer to

https://all-americaselections.org/

Figure 16. Annual Trial Gardens at Colorado State University

Ecological Adaptation

The goal is to plant “the right plant in the right place.” For example, the ideal perennial for Colorado will require low water, prefer the local clayey, sandy, or rocky soils, be hardy, be long-lived, and will self-sow before dying. However, there is a fine line between choosing plants that are well adapted and plants that are so well adapted that they become invasive. Invasive plants can become noxious weeds, escaping from gardens and taking over native vegetation. [Figure 17]

Clues to Overly Well-Adapted Plants

Plants that are aggressive in one region may not be a problem in another. These words should give clues that a plant may become a problem in some regions.

- “Naturalizes readily”
- “Quickly spreads to give blanket of color”
- “Resist the temptation to crowd plants too closely. They will spread of their own accord soon enough”
- “Vigorous spreader, but that's no vice with looks like these.”
- “Give this plant lots of room”
- “Plants are typically short-lived but they seed themselves quite freely, so you’ll always have plenty around”

How Aggressive Plants Spread

Aggressive plants spread by runners or seeds. They can just be aggressive within a landscape (such as a garden), spread into neighboring gardens/natural areas, or could be a Colorado Noxious Weed.

It is important to note that not all plants are aggressive in all climates. What is aggressive in New England may not be aggressive Colorado, and vice versa. For example, *Euphorbia myrsinites* (donkey-tail spurge) is a plant on the Colorado Noxious Weed List A. It has many ornamental and xeric qualities and was even recently promoted in Colorado as a rock garden plant. Its invasive qualities only became apparent afterwards. Because it is not a problem in the east, it is still offered for sale in many catalogs.

Similarly, in Colorado’s climate, blackberries have marginal hardiness, and will be killed in winters with lots of temperature swings. However, on Vancouver Island in Canada, blackberries thrive and have invaded thousands of acres of roadsides and native lands.

Not all catalogs will bother to find out where a plant is illegal to sell in various states. Therefore, the responsibility is on the consumer to find out which plants are illegal to grow in their state or region.

Weed Terminology

Alien is a plant that is not native to the country or state. This term is synonymous with non-native.

Aggressive usually means that it will spread widely in a garden. These plants can take over a garden, or might escape into wild areas.

Invasive is loosely used, but generally means that a plant escapes into native habitat, crowding out native plants. However, it can also mean invasive within a garden only.

Noxious weed is defined by state law. Noxious weeds are always aliens, and have proven to escape into native habitats or agricultural lands. Plants with this designation must not be sold or grown in Colorado. For information on Colorado Noxious Weeds, Google the Colorado Department of Agriculture. Examples of escaped ornamentals on Colorado Noxious Weed Lists include:

- Bouncing bet
- Oxeye daisy
- Yellow toadflax and dalmation toadflax
- Chicory
- Common tansy
- Dame’s rocket/sweet rocket
- Purple loosestrife
- Scentless chamomile
- Donkey tail spurge (myrtle spurge)
- Orange hawkweed
- Russian olive trees

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

Turfgrass Management

Learning Objectives

At the end of class, the student will be able to:

- Describe how lawn management practices influence turf quality and why incorrect management decisions lead to common lawn care problems.
- Describe which grass species are best-adapted for lawn use, and the most important factors to consider when choosing a species for a new lawn (or when renovating an existing lawn)
- Describe how mowing height and frequency affect the aesthetic quality and stress tolerance of turfgrass; why grass clippings should be recycled back to the lawn during mowing.
- Describe why nitrogen is the most important nutrient in a lawn fertilization program, how and when to fertilize a lawn, and how to select the appropriate lawn fertilizer.
- Describe the environmental factors affecting turf water use and how to use that knowledge to most effectively irrigate a lawn (how MUCH water to apply, and how OFTEN?).
- Describe thatch, understand why it forms in the lawn, what common problems its accumulation may cause, and how thatch is most effectively managed.
- Describe the negative effects of soil compaction on turf health and how to improve soil physical conditions by using common cultivation practices.
- Describe how to establish a new lawn, using seed, sod or plugs. What is meant by lawn renovation and how this process can be used to improve the quality of an existing lawn.
- Describe the most common lawn weeds, why weeds occur in the lawn, and how to most effectively manage weeds using cultural practices and, if necessary, herbicides.
- Describe the process of diagnosing common lawn problems and know where to find the most useful resources (books, websites) to assist in the diagnostic process

- CMG volunteers approach diagnostic situations as a process. Students will be able to:
  - Describe concepts of *Plant Health Care* (PHC; IPM as it applies to lawn care)
  - Outline the life cycle of a lawn and describe how lawn/turf needs change with the age of the lawn
  - List steps in the diagnostic process
  - Using the diagnostic process, diagnose routine lawn pest problems

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Turfgrass Management curriculum developed by Tony Koski, Extension Turf Specialist, Department of Horticulture and Landscape Architecture, Colorado State University

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References

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Grass Species Selection for the Home Lawn

CMG GardenNotes

- Best Turf Varieties: Variety Recommendations for Bluegrasses, Tall Fescues, Fine Fescues Ryegrasses, and Buffalograss – #562
- Buffalograss Lawns – #565
- Fine Fescue Lawns – #564
- Hybrid (Kentucky X Texas) Bluegrasses for Turf Use in Colorado – #563
- Native Grass Lawns – #567
- Sources of Grass Seed, Sod and Plugs for Colorado Lawns – #566
- Turfgrass Species Selection Guidelines – #561

Mowing

Extension Fact Sheets

- Lawn Care - #7.202
- Eliminate Grass Clipping Collection - #7.007

Lawn Fertilization

Extension Fact Sheets

- Lawn Care - #7.202
- Nitrogen Sources and Transformations – #0.550
- Organic Materials as Nitrogen Fertilizers – #0.546
- Soil Testing – #0.501
- Soil Testing – Selecting an Analytical Laboratory – #0.520
- Soil Testing – Soil Test Explanation – #0.502
- Soil Testing – Soil, water and plant testing – #0.507

Lawn Irrigation

Extension Fact Sheets

- Lawn Care - #7.202
- Irrigation: Inspecting and Correcting Turf Irrigation Systems - #4.722
- Watering Established Lawns - #7.199
- Operating and Maintaining a Home Irrigation System - #7.239

Thatch and Compaction Management

- Lawn Care - #7.202

Lawn Establishment and Renovation

Extension Fact Sheets

- Lawn Care - #7.202

- Renovating the Home Lawn - #7.241

CSU TurfNotes

- Lawn Renovation: Terminology and Guidelines - #820

Turf Weed Management

Extension Fact Sheets

- Lawn Care – #7.202
- Control of Weedy Grasses in Home Lawns – #3.101

Books

- ***Integrated Turfgrass Management for the Northern Great Plains***. 1997. Baxendale, F.P. and Gaussoin, R.E. (eds.) University of Nebraska. Publication EC97-1557. 236 pages.
- ***Fundamentals of Turfgrass Management***. 2003. Christians, N.E. John Wiley & Sons. 368 pages. 2nd edition.
- ***Identifying Turf and Weedy Grasses of the Northern United States***. 2005. Pederson, D. and Voigt, T. University of Illinois Extension. 63 pages. Publication C1393. http://www.pubsplus.uiuc.edu
- ***Lawns: Your Guide to a Beautiful Yard.*** (2002 and 2007). Christians, N., Ritchie, A. and Mellor, D. Meredith Publishing. 1st edition ISBN 0696212706; 2nd edition ISBN 9780696229695.
- ***Weeds of the West***. 1991. The University of Wyoming. 630 pages.

Review Questions

Turfgrass Species/Variety Selection

1. What is the best grass to plant in Colorado lawns?
2. What is the best grass to plant if you don't want to water a lawn?
3. What grass can grow with only a "little" irrigation?
4. Can zoysiagrass grow in Colorado? What will happen if I plant it anyway?
5. What is the best grass for a shady lawn?
6. Which grass grows best in salty soil?
7. What is the best grass to plant over my septic leach field?
8. What grass can I plant if I don't want to mow my lawn very often?
9. I would like to have a backyard putting green. What kind of grass is used?

Mowing the Lawn

1. What is the best mowing height for lawns?
2. My neighbor mows their lawn 2 or 3 times a week. I mow only on Saturday morning. Who is right?
3. Should I mow higher or lower during the summer?
4. Will I have less turf disease if I mow my lawn shorter in the fall, just before winter?

5. Shouldn't grass clippings be collected because they create thatch in lawns?

6. My lawn gets a brownish cast after I mow. What is the problem?

7. I see wheel marks in my lawn after it is mowed. What causes this to happen?

8. How should I mow my lawn when it gets very tall?

9. Do I have to buy a mulching mower to return my grass clippings?

10. What is the best mower? Rotary or reel?

11. Can I compost my grass clippings, or use them as mulch, in my gardens?

Lawn Fertilization

1. What is the best fertilizer for my lawn?

2. How often should I fertilize my lawn?

3. How important is it to use a "complete" lawn fertilizer?

4. Is liquid lawn care better (or worse?) than dry/granular lawn care?

5. How do I know if I am applying the correct amount of fertilizer to my lawn?

6. Should I "winterize" my lawn? What does that mean, and what does it do for my lawn?

7. Is it OK to fertilize after aerifying my lawn?

8. Isn't organic fertilizer better for my lawn than synthetic fertilizer?

9. Will I have to fertilize more or less if I leave my grass clippings on the lawn?

10. Should the fertilizer that I use have iron in it?

11. Should sulfur be used to lower a lawn's pH?

Lawn Irrigation

1. Doesn't Kentucky bluegrass need more water than all other lawn grasses?
2. For how long should I run my sprinkler system?
3. Is it OK to water my lawn every 3-5 days, even though my neighbors water their lawns every day?
4. Is it bad to water my lawn every day?
5. Will I get "fungus" if I water at night?
6. At what time of the day is it best to water my lawn?
7. Should I water my lawn in the winter?
8. I have brown spots in my lawn, even though I water every other day. What is causing these dry spots?
9. My new tall fescue lawn (which is supposed to save water) seems to need as much water as my old bluegrass lawn. What is the problem?
10. How should I water my newly seeded/sodded lawn?
11. Should I water my lawn after I fertilize it?
12. Should I ever water my buffalograss lawn?

Thatch and Compaction Management

1. What is thatch?
2. Why do my neighbors' lawns NEVER seem to get thatchy, while mine always seems to be that way?
3. Can I topdress my lawn to get rid of thatch?
4. Do power rakes (dethatchers) work well?
5. Are there any liquid or granular "dethatching" products that work? How about ones which claim to relieve soil compaction?
6. What are some symptoms of soil compaction in a lawn?
7. What is the best time of the year to aerate a lawn?
8. How many times per year should a lawn be aerified?
9. How deep should the aeration core holes be?
10. What should I do with all of those plugs that the aerifier pulls out?
11. Should I topdress the lawn with something to fill in the aerification holes?
12. Does wearing golf spikes aerify my lawn? What about "lawn aeration sandals"?

Lawn Establishment and Renovation

1. Is it better to seed or sod a new lawn?
2. What time of the year can lawns be sodded?
3. When is the best time to seed a lawn?
4. Does soil really need to be tilled before planting a new lawn?
5. Should I bring in topsoil before I plant my new lawn?
6. Before planting my new lawn, how much sand should I add to my soil to loosen it up and improve its drainage?
7. How important is it to amend soil before planting a lawn?
8. What is the best soil amendment?
9. Is hydroseeding a good way to start a lawn?
10. Is "plugging" a good way to start a buffalograss lawn? How does it work?
11. Does "overseeding" help a lawn in any way?
12. When is the best time to overseed a lawn?
13. Is there a way to start a new lawn without going through the process of removing old sod and tilling the soil?

14. How does lawn renovation differ from starting a new lawn from scratch?

Weed Management in Lawns

1. Where do lawn weeds come from? How do they get into a lawn?
2. How do I get rid of the crabgrass in my lawn?
3. Is it important to identify lawn weeds before spraying them with a herbicide? Why?
4. I used a preemergence herbicide this spring and I still have weeds. What went wrong?
5. Can I aerify or dethatch my lawn after I apply my preemergence herbicide?
6. What is the best way to get rid of dandelions? Can I use a preemergence herbicide for dandelions?
7. Is it OK to pull weeds?
8. Do “weed-and-feed” products work well?
9. Are there any “organic” or “natural” weed control products that work?
10. What is the best way to control weeds in my newly seeded lawn?
11. Weeds have come up in the “seams” in my new lawn. Should the sod company replace the sod?
12. What is the best time of the year to spray for weeds?
13. What is the best herbicide to spray for dandelions and other broadleaf weeds?
14. Is it better to spray the entire lawn, or just spot-treat individual weeds? Won’t I miss some weeds if I spot-treat?
15. Is it OK to spray lawn weeds growing under my trees? Will the trees be OK?

Miscellaneous Lawn Questions

1. How do I take care of “dog spots” in my lawn?
2. I have high and low spots in my lawn. How can I level them out?
3. Will my lawn care companies mowers and aerifiers bring diseases into my lawn from other lawns?
4. When should I do soil testing on my lawn?
5. If I want to expand my garden areas, what is the best way to kill off areas of my lawn?
6. Is it OK to flood a part of my lawn to make a skating/hockey rink for my children?
7. Can I empty the water from my swimming pool onto my lawn without killing the grass?
8. How long can grass seed last if I don’t use all of it?
9. What kind of grass do I have growing in my lawn? How can I find out?
10. My lawn is “lumpy”, but my neighbor’s is not. What causes the lumps, and why do I have them?

Plant Health Care and the Diagnostic Process

1. Define IPM and PHC.
2. Describe concepts central to PHC?
3. Give examples of common PHC tools used in home lawn care.
4. What is the PIC cycle? What does it explain about lawn problems?
5. In diagnosing *contributing* disorders, why is it important to also identify the *predisposing* and *inciting* factors to the extent possible?
6. List the four steps in the diagnostic process.
7. Give examples of BIOTIC (living) factors that cause turf problems.
8. Give examples of non-living (abiotic) factors that cause lawn problems.
9. Why is it important to correctly identify the turf species in a lawn that is having problems?

10. Define *symptom* and *sign*. Give examples of each.

11. Explain why it is important to understand what is normal versus abnormal when dealing with lawn problems?

12. Why is it important to know the AGE of a lawn as part of the diagnostic process?

13. Why is it important to "start from scratch" with every diagnostic situation?

Diagnosing Abiotic Lawn Disorders

1. Explain how knowing the context of the situation helps in diagnosing the disorder.

2. Explain how painting a mental picture of a lawn problem helps in diagnosing a disorder.

3. Explain how repeating back the details in your own words helps in diagnosing a disorder.

4. Explain how to tactfully change directions with a client when the evidence for the cause of a lawn problem leads down another road.

5. Why is it important to discuss management options ONLY after the problems have been diagnosed?

6. In the landscape setting, what is the universal limiting factor for root growth?

7. What percentage of lawn problems are related to root/soil/water issues?

8. Describe techniques to evaluate soil/root disorders and soil compaction.

9. Why is it important to know if a client uses a professional lawn care company, or is a do-it-yourselfer?

10. Why is it important to look at the ENTIRE landscape (trees, flowers) when diagnosing a lawn problem?

11. Why look to see if the problem is occurring in the back yard/front yard as well – or in neighboring lawns? What can that tell you?

12. What kind of tests can be done to determine whether or not chemical injury has occurred on a lawn?

Diagnosing Biotic Pest Problems on Lawns

1. List the four steps in the diagnostic process.

2. What is the "disease triangle" and how does it apply to diagnosing lawn disease problems?

3. What percentage of summer lawn problems in Colorado are related to irrigation amount/frequency, or other aspects of lawn irrigation?

4. If a client tells you that they get the SAME problem every year, in the same part of the lawn, what are some potential causes of the lawn problem?

5. What is the proper way to obtain a sample of turf for diagnostic purposes? How should it be stored and transported?

6. What do you tell a client who believes that "fungus" has been tracked onto their lawn by a lawn care company's mowing or aeration equipment?

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CMG GardenNotes #551

Basic Turf Management

Outline:

Reasons for Lawn Problems…

Although there are many specific reasons to which one could attribute lawn problems, the most common general reasons include:

- Poor management decisions (soil compaction, improper mowing, irrigation, fertilization, pest management)
- Using poorly adapted species or cultivars. Limitations in resources (water, time/labor, dollars)

Mowing

The two most important facets of mowing are mowing **height** and **frequency**. The **preferred height** for all species in a lawn is two and half to three inches. Mowing to less than two inches can result in decreased drought and heat tolerance (due to shallow rooting and reduced photosynthesis) and encouraged weed invasion. Higher encourages insects, diseases, and weeds. Mow the lawn at the same height all year. There is no reason to mow the turf shorter in late summer or in the fall.

Mow the turf often enough so no more than one-third of the grass height is removed at any single mowing. This may mean mowing a bluegrass or fescue lawn every three to four days during the active spring growth period, but only once every seven to 10 days at other times of the year when growth is slowed by heat, drought or cold. If weather or another factor prevents mowing at the proper time, raise the height of the mower temporarily to avoid cutting too much at one time. Cut the grass again a few days later at the normal mowing height. [Figure 1]

Figure 1. Mow often enough that no more than 1/3 of the grass height is removed in any single mowing.

Let **grass clippings** fall back onto the lawn while mowing, unless they are to be used for mulching elsewhere in the landscape. Grass clippings decompose quickly and provide a source of recycled nutrients (equivalent to 1 to 1½ fertilizations per year) and organic matter for the lawn. Although a mulching or recycling mower makes this easier to do, clippings can be recycled into the lawn using any mower (as long as the 1/3 rule of mowing frequency is used). Grass clippings do not contribute to thatch accumulation.

Lawn Clippings and Surface Water Pollution

Lawn clippings and leaves mowed, swept, or blown onto the street are the major source of phosphorus pollution in urban lakes and streams. With side discharge lawnmowers, mow in a direction to prevent clippings from being blown onto the street, driveway, and other hard surfaces. Do not sweep or blow lawn clippings into the gutter and street. [Figures 2 and 3]

Figure 2. In a Minnesota study, 60 to 80% of the phosphate loading of surface water in an urban setting came from lawn clippings and leaves that were mowed or blown into the streets.

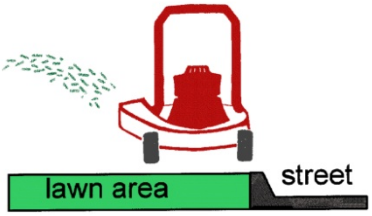

Figure 3. When mowing the lawn, mow in a direction to prevent clippings from being blown into the street.

Also, leave an unmowed grass buffer strip edging any lakes, streams, ponds, and wetlands. [Figure 4]

Figure 4. To reduce surface water pollution, leave an unmowed buffer strip around lakes, streams and ponds.

In a natural setting, rain and snowmelt absorbs mostly into the soil. Air-borne pollutants and pollen washed out of the air are broken down by soil microorganism activity. The nitrogen and phosphorus released from the decay of grass, leaves, and other organic matter recycle back into the soil.

However, in the landscape setting, the water cycle is greatly changed by large areas covered by hard surfaces (streets, driveways, walks, parking lots, compacted soils, and buildings). In a typical landscape setting 55% of a rainfall moves as surface runoff, compared to only 10% in a naturalized setting. Nutrients from grass and leaves (along with fertilizers, pesticides, and other water-soluble pollutants) readily wash off the hard surfaces into the storm sewer system. Here the pollutants end up in local streams, ponds, and lakes.

Fertilization

Selecting a Lawn Fertilizer

Nitrogen (N) is the most important nutrient for promoting good turf color and growth. However, do not over-stimulate the turf with excess nitrogen, especially during the spring and summer. Over-fertilization can contribute to thatch buildup with some species, as well as increased mowing and irrigation requirements. Under-fertilization of some species (bluegrass and ryegrass, for example) can result in poor turf color and turf thinning, which can encourage weed and disease problems. Turf species differ in both the amount of nitrogen required to keep them healthy, as well as the best time of the year to fertilize them.

Balanced or complete fertilizers contain various amounts of phosphorus, potassium, iron, and sulfur. They are a good safeguard against a potential nutrient deficiency and there is no harm in using a “complete” fertilizer. However, if you leave clippings on the lawn, these nutrients are recycled back into the lawn, so there is little likelihood of seeing these deficiencies. Besides nitrogen, the most commonly deficient nutrient in lawns is iron (Fe).

Organic fertilizers will work as effectively as synthetic types. However, it is important to understand the release characteristics of the different fertilizers so that they can be used at the correct times of the year. Organic fertilizers typically release nutrients more effectively when soils are warm and moist. Many synthetic types work well when soils are cooler, but some synthetic types work like the natural organic sources.

Better lawn fertilizers include a quick release form of nitrogen for quick green-up, plus slow-release forms of nitrogen for sustained greening. Examples are listed in Table 1.

Table 1. Example of Quick and Slow Release Fertilizers

Quick-Release Nitrogen for fast green-up	**Slow-Release Nitrogen** for sustained green
Ammonium sulfate	Resin-coated urea
Ammonium nitrate	Sulfur-coated urea
Potassium nitrate	Isobutylidene diurea (IBDU)
Urea	Methylene urea
	Urea formaldehyde
	Compost and manure
	Poultry waste
	Poultry feathers

When to Fertilize and How Much to Apply

The natural grass growth cycle influences proper fertilization time for lawns. Figure 5 illustrates typical root and shoot growth patterns of cool season turfgrass species. [Figure 5]

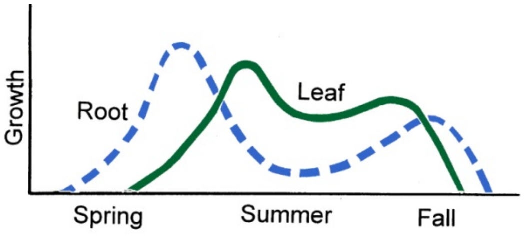

Figure 5. Growth cycle of roots and shoots for cool season turf.

Figure 6 on the right illustrates the influence on shoot growth when nitrogen fertilizer is applied. Heavy spring fertilization promotes shoot growth, reducing carbohydrate energy reserves and stress tolerance. [Figure 6]

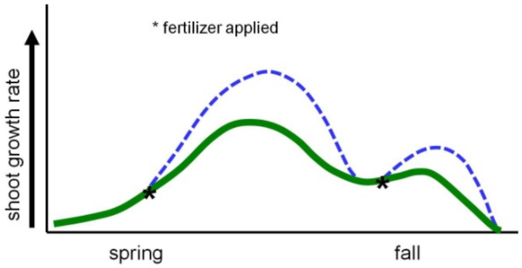

Figure 6. Influence on shoot growth for nitrogen fertilization.

Benefits of Fall Fertilization on Cool Season Home Lawns

- Enhances storage of carbohydrate energy reserves
- Strengthens root system
- Increases shoot density
- Increases stress tolerance
- Better fall and winter color
- Earlier green-up in spring

Timing and Application Rate

Timing and application rates are given in Table 2. If lawn clippings are returned to the lawn, reduce application rate by ¼ to 1/3.

Table 2. Fertilizer Application Schedule for Established Colorado Lawns[1, 2]

Turfgrass species		**Mid-March to April[3]**	**May to mid-June**	**July to early August**	**Mid-August to mid-September**	**Early October to early November[4]**
(Nitrogen application rates are in pounds of nitrogen per 1,000 square feet of lawn area.)						
Cool Season Species	High maintenance Bluegrass and Ryegrass	½ to 1	1	Not required	1	1-(2)
	Low Maintenance Bluegrass	½	½-1	Not required	1	(1)
	Turf-Type Tall Fescue	½	½-1	Not required	1	(1)
	Turf-Type Fine Fescue	½	½-1	Not required	½-1	Not required
Warm Season Species	Buffalograss, Blue Grams, and Bermudagrass	Apply no N	½-1	½-1	Apply no N	Apply no N

1 Nitrogen applications can often be reduced by 1/4/ to 1/3 when grass clipping are returned to the lawn during mowing. Nitrogen and other nutrients contained in the clippings are recycled to the lawn as they decompose. **Grass clippings do not contribute to thatch accumulations in lawns.**

2 On sandy soils, use slow-release nitrogen fertilizers (sulfur-coated ureas, IBDU, and natural orgainic-based fertilizers) throughout the year to reduce the potential for leaching loss. On very sandy soils, do not fertilizer turf after late September. Nitrogen can leach into ground water during the winter months.

3 The March-April nitrogen application may not be needed if fertilized in late fall (September to November) the previous years. If spring green-up and growth is satisfactory, delay fertilizing until May or June.

4 Make the final fall nitrogen application (October-November) while the grass is still green and at least two to three weeks before the ground begins to freeze. Optional N applications shown in (). Use extra nitrogen applications where a higher quality turf is desired or on a heavily used turf.

Fertilizers and Water Pollution

Home lawn management techniques play a significant role in protecting or polluting surface water. Popular press has incorrectly labeled lawns as a major contributor to water pollution. It is not the lawn, but rather the management style of the gardener that become the problem.

Fertilizers and pesticides (herbicides, insecticides, and fungicides) spread onto hard surfaces (driveways, sidewalks, streets, and compacted soils) will move with surface water into neighboring lakes, streams, and ponds. (Surface water running down the street gutter is not treated before release into local lakes, streams, and ponds.)

However, phosphate fertilizer applied to a lawn or garden soil is bound to the soil and does NOT leach into ground water. The phosphate could move into surface water with soil erosion.

Organic fertilizers are not necessarily safer for the environment. The pollution potential is based on where the fertilizer is applied and application rates. Any fertilizer becomes a potential pollution problem when over-spread into hard surfaces. Over application of both manufacture and organic fertilizers have been linked to ground water contamination.

Potential pollution problems arise from the careless application rather than the type of fertilizer applied. In most Western soils, lawns do not need phosphate fertilizers.

Irrigation

Many factors influence lawn water requirements, and no two lawns will have exactly the same needs. Table 3 gives the typical water requirement (rain plus irrigation) per week. A healthy, high-quality bluegrass or ryegrass lawn may require up to 2 to 2.25 inches of water per week under hot, dry, windy summer conditions; but may require much less when the weather is cool or cloudy. Turf-type tall fescue may perform well with less irrigation than a bluegrass lawn, if it can grow a deep root system and the soil in which it is growing is holding usable water. In many cases, however, a tall fescue may require as much water as bluegrass to look good. [Table 1]

Table 3.
Typical Water Requirement (Rain Plus Irrigation) for Colorado Lawns

	Late April	May & June	July & August	September	Early October
Inches of water per week (irrigation plus rain)	0.75”	1.0”	1.5”	1.0”	0.75”

Buffalograss and blue grama lawns can remain green for weeks without watering, even during the hottest summer weather, with rainfall.

Shady lawns (not in the rooting zone of large trees) and areas protected from the wind require less water over the growing season than more exposed turf. However, the roots of mature trees and shrubs also need water. You may have to water more in mature landscapes where the roots of many plants compete for water. Healthy turf encouraged by proper mowing, fertilizing, and cultivation, uses water more efficiently.

How Much Water?

Each time you water the lawn, apply enough water to moisten as much of the root zone as possible. Use a soil probe or shovel to determine what the average rooting depth is in your lawn. If the roots grow down 6 inches deep, water so the soil is moistened to that depth. It is important to know not only how deep the turf roots grow, but also how deep your irrigation water penetrates. Watering too deeply, especially on sandy soils, wastes water and allows it to percolate past the root zone. [Figure 7]

Figure 7. Typical water (rain plus irrigation) is given in Table 5. However, actual water use jumps around from day to day based on temperature, wind, humidity, and solar radiation (sunny or cloudy).

How Often Should a Lawn be Watered?

Grass growing on a sandy soil must be watered more often than the same grass growing on clay or loam soils. Even after a thorough watering, sandy soils hold little plant-available moisture. They require more frequent irrigation with smaller amounts of water.

Conversely, turf growing on clayey soils can be irrigated less frequently, with larger quantities of water. Watering less often means more efficient water use because of less loss to evaporation. It can also reduce the number of weeds that appear in the lawn. With most soils, do not apply all of the water in a short period of time. If applied too quickly, water will run off of thatchy turf, from sloped areas, or from turf growing on heavy clay or compacted soils. In these cases, it is more effective to apply only a portion of the water and move the sprinkler or switch to another station to water another section of the lawn. Cycling through irrigation stations (“soak cycles”) will promote infiltration and reduce runoff and puddling in low spots. This allows water to soak into the soil rather than run off.

Core cultivation (aeration) can resolve some infiltration problems by reducing thatch and compaction. Wetting agents may enhance water movement into the soil, but they should not be considered a cure-all, especially when compaction and thatch are problems.

What are Some Signs that Turf Needs to be Watered?

A sure sign that turf requires irrigation is a wilted appearance. One symptom is “footprinting,” where footprints on the lawn that do not disappear within an hour or so following traffic. This symptom is soon followed by actual wilting, where the turf takes on a grayish or purple-to-blue cast. If only a few such spots regularly appear in the same general location, spot water them to delay watering the entire lawn for another day or so. These indicator spots help predict that the entire lawn will soon need watering.

A hardened or toughened lawn, attained through less frequent, deep irrigation, often withstands minor drought and generally has fewer disease problems. It is important, however, that the turf not be allowed to become overly drought-stressed between waterings. This weakens the turf and makes it more susceptible to insect and disease damage and to weed invasion.

During extended dry periods from late fall to spring, it may be necessary to "**winter water**" every four to six weeks if the ground is thawed and will accept water. Pay particular attention to exposed slopes, sites with shallow soil, and south- or west-facing exposures, where winter mites may infest and kill drought-stressed turf during the winter and early spring.

The most efficient **time of day** to water is late evening and early morning (between 9 p.m. and 9 a,m.). It generally is less windy, cooler, and more humid at this time, resulting in less evaporation and more efficient use of water. Water pressure is generally better, optimizing sprinkler distribution patterns. Contrary to popular belief, watering at night (after 9 p.m.) does not encourage disease development in turf.

Thatch

Thatch is a tight, brown, spongy, organic layer of both living and dead grass roots and stems that accumulates above the soil surface. Factors that lead to thatch problems include the following: [Figure 8]

- **Sod over compacted soil** – When sod is laid over compacted soils, a thatch problem will develop in a couple of years.
- **Soil compaction** is a common contributor to thatch build-up as it slows the activity of soil microorganisms.
- **Over fertilization** is a common contributor to thatch build-up as the lawn may be growing faster than the microorganism can break it down.
- **Grass species** – Thatch tends to be a problem on Kentucky bluegrass, bentgrass, and fine fescue lawns. It is rarely a problem with tall fescue or buffalograss.
- **Frequent heavy irrigation** may contribute to thatch as lower soil oxygen levels slow the activity of soil microorganisms.
- **Pesticides** – Excessive use of some pesticides may also slow soil organism activity.

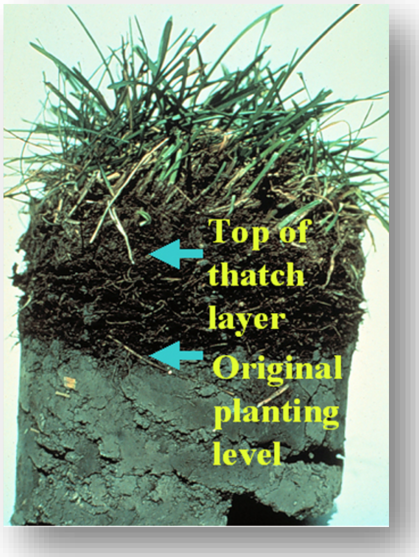

Figure 8. Thatch is a tight, brown, spongy, organic layer of both living and dead grass roots and stems that accumulates above the soil surface.

Grass clippings do not contribute to thatch accumulation and should be returned to the lawn during mowing to recycle the nutrients they contain.

Measure thatch depth by removing a small piece of turf, including the underlying soil. Up to ½ or ¾ inch of thatch is acceptable and will enhance traffic tolerance. The thatch depth can increase quickly beyond this point, making it difficult to control later. As the thatch layer thickens, it becomes the main rooting medium for the grass. This predisposes the turf to drought stress or winterkill and increases the possibility for insect, disease and weed problems. In addition, fertilizers and pesticides applied to a thatchy lawn work less effectively.

Power Raking for Thatch Management

This method of thatch removal has been used for years. Light (shallow) power raking may be beneficial if done often. Deep power raking of a thatch lawn can be damaging, and often removes a substantial portion of the living turf. Used properly, power raking of wet, matted turf can speed spring green up by letting air move into the root zone and warm the turf. Compost all removed thatch and organic material to kill any living grass before it is used as a mulch or soil amendment.

Core Cultivation or Aerating.

This can be more beneficial than power raking. It helps improve root zone conditions by relieving soil compaction, while controlling thatch accumulation. Soil compaction, in fact, is one factor that contributes to thatch buildup. Aeration removes plugs of thatch and soil two to three inches long (the longer, the better) and deposits them on the lawn. Enough passes should be made to achieve two-inch spacing between holes.

What is done with the cores is a matter of personal choice. From a cultural perspective, there may be an advantage to allowing the cores to disintegrate and filter back down into the lawn. Mingling soil and thatch may hasten the natural decomposition of the thatch. The little fluffs of thatch and turf that remain behind can be collected and composted. Depending on soil type, core disintegration may take a few days to several weeks. Irrigation helps wash the soil from the cores. Running over dried cores with a rotary mower can be effective but will dull the blade. If the cores are removed from the lawn, compost before using as a mulch or soil amendment.

Soil Compaction

Soil compaction is the most common problem in lawn quality. With reduced soil oxygen levels, rooting systems will be more shallow. With compaction, the grass roots have reduced access to water and nutrients. Irrigation and fertilization will need to be light and more frequent.

Aerating (removing plugs) once or twice a year will help reduce soil compaction in an established lawn area <u>if enough passes are made to yield plugholes at two-inch intervals</u>. The best time of year to aerate a lawn is late August to late September, as fewer weed seeds germinate this time of year. Aerating the lawn area around a tree is also the best method to promote tree vigor. [Figure 9]

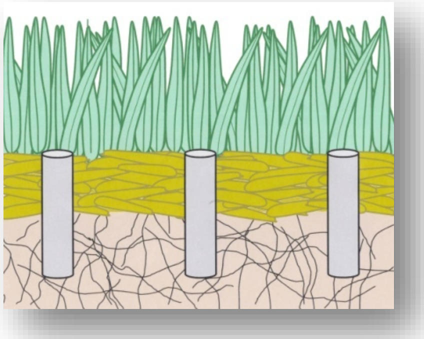

Figure 9. Core aeration helps reduce soil compaction when enough passes are made over the lawn to yield plugholes at two-inch intervals.

Weed Management

Lawn weed killers provide only temporary control if management factors that favor weeds are not addressed. In a thin turf with heavy traffic, weed problems may intensify following the use of weed killers. When the weeds (which help absorb the wear and tear of foot traffic) are removed with weed killers, the lawn may thin. The thin lawn opens the soil to increased weed problems.

Soil compaction is the primary cause of weed problems. Weed management factors include the following.

Core aeration – Soil compaction favors weeds and discourages lawn growth. Common lawn weeds including annual bluegrass, black medic, chickweed, clover, crabgrass, knotweed, prostrate spurge, and plantain thrive in compacted soils. Clover may be a good companion crop for lawns in compacted soils, filling in between the thin grass.

Mowing – High mowing height (shading) and frequent cutting discourages weeds.

Watering – Deep, infrequent watering will drought out many common shallow rooted lawn weeds. [Figure 10]

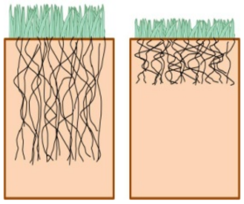

Figure 10. Deep infrequent watering will drought out many common shallow root lawn weeds.

Limited fertilizer – A thick, actively growing turf chokes out most weeds. However, fertilizer will not thicken up a turf when soil compaction is the growth-limiting factor.

For additional information on turf weed management, refer to these CSU Extension Publications available online at www.cmg.colostate.edu.

- ***Annual Grassy Weed Control in Lawns***, Extension Fact Sheet #3.101

Insect and Disease Management

In semi-arid climates like Colorado, turf insect and disease problems are minimal, compared to other areas of the nation.

Frequent use of lawn insecticides may increase the occurrence of lawn insect problems. Some garden insecticides have a potential to kill birds feeding in the treated areas (refer to the insecticide label). Thus, avoid unwarranted treatments of lawn areas.

When controlling soil insects, the insecticide must be watered into the root zone to be effective. Some insecticides get heldup in the thatch and do not water in effectively.

In semi-arid climates like Colorado, lawn diseases are minimal, compared to other areas of the nation. With Colorado's dry climate, fungicides do little to nothing for home lawn disease management. Cultural practices (fertilizer, watering, and soil compaction) are the keys to disease management. [Table 3]

Table 3. Influence of Cultural Practices on Kentucky Bluegrass Diseases

	Soil Compaction	High N	Low N	Thatch	Irrigation	Mowing
Asochyta Leaf Blight	yes	yes		yes	timing	yes
Necrotic Ring Spot	yes	yes		yes	drought with heat	yes
Leafspot and Melting Out	yes	yes	yes	yes	timing (wet/dry cycle)	yes
Gray Snow Mold	yes	yes				
Dollarspot	yes		yes	yes	drought	low
Stripped Smut			yes	yes		
Fairy Ring	yes		yes	yes		

Authors: Tony Koski, PhD, Extension Turf Specialist, and David Whiting, Extension Consumer Horticulture Specialist (retired); Department of Horticulture & LA; Colorado State University. Artwork by David Whiting and Tony Koski; used by permission.

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CMG GardenNotes #552

Broadleaf Weed Control in Lawns

Dandelion, clover, plantain and other broadleaf weeds are among the most common and troublesome turf pest problems in lawns. Even though most broadleaf weeds can be easily controlled with herbicides, a completely weed-free lawn is neither practical nor environmentally sensible. A safe and sound approach to lawn weed control is to grow a healthy lawn, spot-treat weeds with the correct weed control product as they appear, and avoid the temptation to have a 100% weed-free lawn.

The best way to minimize weed problems in your lawn is through the use of good cultural practices: proper mowing height and frequency, sensible fertilization, and adequate irrigation. On the other hand, lawn weeds are encouraged by: mowing your lawn too short or not often enough; fertilizing too much, not enough, or at the wrong time of the year; and over- or under-watering.

Where Do Lawn Weeds Come From?

- Seeds of broadleaf weeds occur naturally in all soils, and can persist for 30 or more years. They will germinate when a lawn is thin and not healthy, when the seeds are brought to the surface by human or pet traffic, or when the turf is damaged or killed by drought, heavy traffic, insect feeding, or disease activity.

- Cheap, low-quality grass seed often contain unwanted weed seed. If the seed label lists ANY weed seed as a component, DON'T buy it! The best quality grass seed (sold by professional seed suppliers) will almost always be 100% weed-free, and will often cost nearly the same as poor quality products which contains weed seed. READ THE SEED LABEL! The Weed Content of any grass seed you buy (expressed as a %) should be 0%.

- Weed seeds are often brought to a landscape in topsoil or low quality compost. Make sure that all soil or compost comes from a reputable supplier and is guaranteed to be weed-free.

Using Herbicides to Manage Lawn Weeds

The most common herbicide choice is a general- purpose mixture comprised of two or three of the following individual herbicides or active ingredients: 2,4-D; MCPP (mecoprop); and dicamba (Banvel). Multiple active ingredients will control a wider spectrum of broadleaf weeds, than a single active ingredient. Read and follow all directions on the herbicide label if you choose to apply a herbicide to your lawn.

The best time to apply a general-purpose broadleaf herbicide for the control of perennial broadleaf weeds such as dandelion, plantain, and clover is early-September to early November. As winter approaches, perennial broadleaf weeds are storing energy reserves in stems and roots; a fall-applied herbicide will enter the plant and travel to these plant parts with the food reserves. The second best time is in the late spring or early summer period after the weeds have flowered. If applying in the late spring, be extremely cautious with these herbicides near ornamentals, trees, flowers, and vegetable gardens because these plants can be damaged by these herbicides through direct application, drift, and/or volatilization (the herbicide turns into a vapor). This is another reason why we prefer to apply these herbicides in the fall.

- If you only have a few weeds in your lawn, simply spot-apply a herbicide rather than applying to the entire lawn. Apply just enough to wet the leaf and do not apply to the point that the herbicide is dripping off the leaf.

- Apply to actively growing, preferably young weeds.

- Do not apply herbicides when the soil moisture is low and weeds are drought-stressed; an actively growing, healthy, non-stressed weed is the easiest one to control.

- Apply herbicides on a calm, clear day when the air temperature is between 50 and 85F; applying when temperatures exceed 90^o F increases the potential for volatilization injury to other plants in the landscape.

- Don’t apply if rainfall will occur within 12 hours; avoid applying irrigation for at least 12 hours following a herbicide application.

- Don’t mow the lawn for 2 days before and after the herbicide application.

- Do not apply to new turfgrass seedlings until the grass has been mowed at least three times.

- Delay applying a broadleaf herbicide to new sod for 4 to 5 weeks after planting.

Summer Broadleaf Weed Management

Summer annual broadleaf weeds (e.g., spurge, knotweed, purslane, etc.) are very difficult to control for a number of reasons. Depending on the species, these weeds germinate at different times during the summer and mature in a very short period of time. Thus, a single application of herbicide might only control a single weed species because other species have not germinated or have grown too large to be controlled. Summer annual weeds often have a thick, waxy cuticle layer on their leaf surface to prevent water loss; this layer may also make it more difficult to get herbicide into the weed.

Some annual broadleaf weeds can be effectively controlled by preemergence herbicides. For example, summer annuals like spurge, knotweed, purslane and puncturevine can be controlled with products containing prodiamine, pendimethalin or isoxaben.

Difficult-to-Control Weeds

Weeds such as bindweed, thistles, and wild violets are difficult to control because they spread by underground stems. Multiple herbicide applications may be necessary to completely control difficult perennial weeds, including dandelions. Post-emergence broadleaf herbicides containing 2,4-D, MCPP, dicamba, triclopyr or sulfentrazone should be used.

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- For additional information on lawn care, refer to csuturf.colostate.edu.
- Colorado Master Gardener *GardenNotes* are available on-line at www.cmg.colostate.edu.
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- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.
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December 2010

CMG GardenNotes #553

Dog Urine Damage on Lawns:

Causes, Cures and Prevention

Urban Legends About Urine Damage

Dog urine damage is a common problem for home lawns, and one that has generated numerous home remedies and commercial products claiming to be cures for the spots. This lawn problem is misunderstood when it comes to causes and cures. Dog spotting on turfgrass is caused by the deposition of a high concentration of nitrogen (N)-containing compounds and associated salts on a small area in the lawn. These deposits are often concentrated in a relatively small portion of the lawn, resulting in turf injury or death. Some common "urban legends" surrounding dog urine damage to lawns are:

- **Only female dogs cause spotting in lawns.**

FALSE. Dog spotting in lawns is most often caused by dogs that squat when they urinate, thus depositing a large volume of concentrated urine in a small area. Most "squatters" are female dogs, but some males do this as well, especially in their own yard. Many male dogs tend to "mark" vertical objects in the landscape (trees, posts, etc.), which presents problems for landscape plants.

- **Dog spots are more common with certain breeds of dogs.**

MOSTLY FALSE. Dog spotting is more likely to occur (or be more obvious) with larger dogs, since they produce larger amounts of urine. Dog spots can occur with smaller breeds, especially if the dog tends to urinate in a limited area of the lawn.

- **Dog spots occur because urine is alkaline (has a pH above 7.0).**

  FALSE. Dog spots occur because a high concentration of N and salts has been deposited in a very small area of the lawn. In some cases, the added N causes dark green spots and rapid grass growth, without injuring the grass. In other cases, the result is a brown spot – often surrounded by a halo of dark green grass. The browning is caused by the concentrated nitrogen deposited in the center, which burns the leaf tissue, and may or may not cause tissue death. The lower concentration of salts on the periphery fertilizes the grass – resulting in a darker green ring.

- **Dog spots can be prevented by using food supplements that acidify a dog's urine.**

  FALSE. Dog spots do not occur because a dog's urine is alkaline. Products advertised to "naturally" reduce urine alkalinity (including the amino acid, dl methionine, also known as methioform) may cause urinary system problems and can affect calcium deposition in growing bones of younger dogs. The addition of baking soda, potassium citrate and other salts are likewise not recommended as curatives for dog spots. A veterinarian should always be contacted before giving a dog a food supplement known to affect urine pH. There are medically sound reasons for altering urine pH, but the prevention of dog spots in lawns is not one of them. *There are no dietary supplements that have been scientifically proven to reduce either the incidence or severity of dog spotting in lawns.*

- **Dog spots can be "cured" by sprinkling the affected area with baking soda, gypsum, dishwashing detergent, etc. to neutralize the urine.**

  FALSE. The only "product" that can neutralize the urine's negative effects is water. Gypsum and baking soda (sodium bicarbonate) are salts and may compound the problem. Dishwashing detergents, which act as wetting agents or surfactants, may enhance water movement into and through the soil. While this theoretically could promote leaching and dilution of accumulated salts, some dishwashing detergents can burn grass plants.

Dealing with Dog Spots

What can be done with the dog(s)?

- Train the dog to use a non-turf area in the landscape, such as an area covered with mulch or gravel, or select a location where dog spotting will not become an aesthetic problem and damage can be tolerated. *This is the ONLY sure solution for the problem!*

- Always provide adequate water for your pet; increased water consumption will dilute urine, reducing the potential for turf injury.

- While the addition of salt, garlic, tomato juice and other "home remedies" to your pet's food can increase water consumption (thus diluting their urine), your veterinarian should always be consulted before doing so. The increased salt intake can cause problems for older dogs, as well as for those with heart or kidney conditions.

- Except for the addition of water to a dog's food, no additive or supplement should be fed to your pet without first consulting with your veterinarian. Certain additives may increase a dog's water intake, but can have detrimental and unintended consequences for its health.

If the affected spots are green and grass growth is stimulated (no browning is apparent):

1. Increase nitrogen fertilization frequency and/or the amount of fertilizer to help mask the urine-induced stimulation of growth and color; dark green spots will be especially visible on lawns that are not receiving adequate nitrogen fertilization.

2. Maintain adequate irrigation to prevent accumulation of salts in the soil; drought or lack of water can allow salts to accumulate and injure or kill turf.

If the affected spots are brown, (the turf may or may not be dead):

1. Increase irrigation amount and/or frequency to help dilute salts that have accumulated in the soil. This may help still-living turf recover, and will dilute salts in those areas where the turf has been killed (allowing for more effective re-seeding).

2. When turf has been killed, the dead sod and some soil (0.5-1 inch of soil) can be removed. Re-sod the area with new grass.

3. Individual dead/damaged spots can be re-seeded as follows:

    - In a **Kentucky bluegrass lawn:** Spot seed with Kentucky bluegrass (marginally effective) or perennial ryegrass (more effective). Tall fescue, K31 tall fescue, "dwarf" fescue, or annual (Italian) ryegrass should NOT be used for spot-seeding a bluegrass lawn.

    - In a **tall fescue lawn:** Spot seed with turf-type tall fescue (sometimes called "dwarf" fescue). Perennial ryegrass can also be used, but it has a finer texture and the newly seeded spots will look different from the rest of the lawn. Do NOT use K31 fescue or annual (Italian) ryegrass for spot-seeding a tall fescue lawn.

    - **Fine fescue lawns:** Seed with fine fescue seed. The use of perennial ryegrass or tall fescue is NOT recommended, as the spots will have a different color, texture, and growth rate.

    - **Zoysiagrass and bermudagrass lawns:** Patch using sod from a sod farm, or by transplanting sod from an inconspicuous area of same the lawn.

Consult your veterinarian before supplementing a pet's diet with any product or food additive claiming to reduce dog spots in lawns. Similarly, no "spray-on" product for lawns, claiming to prevent or "cure" dog spots, has been scientifically proven to be effective.

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CMG GardenNotes #554

Earthworms and Nightcrawlers

in the Home Lawn

Earthworms and nightcrawlers are considered beneficial because they aid in the decomposition of turfgrass thatch and grass clippings, which helps to recycle nutrients and organic matter into a lawn's soil. The tunneling and burrowing caused by earthworm activity provides a natural cultivation effect that is much more effective than that experienced with mechanical core cultivation/aeration equipment. These tunnels help oxygen and water to enter the turf root zone more easily.

Unfortunately, earthworms are regarded by many homeowners to be pests because their burrows and castings can cause a lawn surface to become anywhere from slightly to extremely bumpy.

Several species of earthworms are found in the U.S. The nightcrawler, *Lumbricus terrestris* Linnaeus, and the red earthworm, *Lumbricus rubellus* Hoffmeister, are the most common larger species. Smaller species belong to the genera *Allolobophora* and *Eisenia*. Earthworms are generally found in the top 12" to 18" of the soil because this is where food is most abundant. The worm ingests soil and organic matter that is swallowed and ground in the gizzard. The ejected material (called castings) is used to line the burrow or is deposited at the entrance (on the lawn surface). Earthworm activity is greatest when soil is warm and moist, becoming active when soil thaws in the spring. The worms will move deep into the soil if it becomes dry during the summer.

Pesticides and Earthworms

Preservation of a healthy earthworm population is important for thatch and compaction management in turfgrass systems. When insect, disease, or weed problems occur and a pesticide application is deemed necessary, it is important to select products that have the least detrimental effect on earthworm populations. Some pesticides can cause severe and long-term reductions in earthworm numbers. Most earthworm species grow slowly, live for several years, and have low reproductive rates. Earthworm populations may take many months or years to recover following intentional or non-intentional pesticide applications that reduce worm populations.

To reduce detrimental effects of pesticide use on earthworm populations in lawns:

1. Apply pesticides only when needed; eliminate preventive applications whenever possible.
2. Use spot applications of pesticides.
3. Select products that are least injurious to earthworms and do not exceed labeled rates.
4. Avoid pesticide applications when earthworms are near the soil surface (soon after a rain or irrigation).

Reducing Earthworm Activity in Lumpy Uneven Lawns

In many lawns earthworm activity can cause the surface to become mildly to excessively lumpy and uneven. Where earthworm populations approach nuisance levels, some measures can be taken to discourage activity or to reduce the impact of earthworm activity on surface smoothness.

1. Core cultivation of the lawn and spreading of the plugs throughout the lawn may cause some leveling of a severely bumpy surface.

2. The use of heavy rollers to flatten the lawn surface can be effective. Heavy rolling is likely to cause soil compaction. Heavy rolling should be followed by core cultivation.

3. Topdressing (spreading a thin layer of soil or other material) the bumpy lawn can provide some relief. Appropriate materials might include good quality compost, composted sewage sludge, or soil from an adjacent vegetable garden or flowerbed. Spread ½-1 inch of material on the lawn and rake it into the grass canopy; repeat every 1-2 weeks, until surface is acceptably level. Sand (on a clay soil), peat moss, sawdust, or wood shavings are not good topdressing materials because they will disrupt water movement into the soil and may cause nutrient deficiencies to occur.

4. Earthworms prefer moist soil. Less frequent irrigation that allows the soil surface to dry out between irrigation events may reduce surface activity of the earthworms.

5. Dethatching mowers, also known as power rakes, can be used to level the earthworm mounds. Adjust the power rake so that the teeth operate low enough to shave off the tops of the worm mounds, but not so low that the crowns and roots of the grass plants are pulled up. It is best to do this early in the spring, before the lawn has begun greening up.

6. Earthworms are generally intolerant of acidic soils (pH < 6.0). On some soils (those in the eastern, Midwest and southern US) the use of sulfur, ammonium sulfate, ammonium chloride, or other acidifying fertilizers can reduce worm activity. <u>However, it important to note that *the pH of most soils in Colorado lawns can NOT be easily acidified by fertilizer application.*</u>

7. Lawn care operators may not apply any pesticide for the purpose of controlling earthworms.

8. Employees of Colorado State University Extension may not recommend any pesticide application for the purpose of controlling earthworms in any turf area.

The presence of earthworms in the home lawn is an indicator of a healthy soil environment. Earthworms aid in the breakdown of thatch and other organic matter and create tunnels, which promote water infiltration, oxygen movement, microbial activity, and deeper grass rooting. Rich in nutrients, their castings are a combination of minerals moved from deep in the soil and from their main food sources: grass clippings and thatch. Although the bumpiness caused by earthworm mounds can be annoying, the homeowner should consider the benefits provided to their lawn's health and avoid the temptation to use pesticides to reduce or eliminate earthworm populations in the lawn.

Author: **Tony Koski,** Ph.D., Extension Turf Specialist, Department of Horticulture & LA, Colorado State University Extension.

- For additional information on lawn care, refer to csuturf.colostate.edu.
- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
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MASTER GARDENER
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CMG GardenNotes #561

Turfgrass Species Selection Guidelines

Outline:

Species Selection

There are many factors that SHOULD be considered when selecting a turfgrass species for planting in a new lawn situation.

- First, consider what will be the use of the turf. For example, is it being planted strictly for aesthetic purposes, or will it be played on heavily and/or frequently.
- What is the desired level of visual quality?
- Will the turf receive a high level of maintenance? Alternatively, will it receive only minimal amounts of water and fertilizer, and little or no pest control?
- What is the owner’s interest in irrigated, summer green lawns versus a summer dormant lawn? Is there a readily available supply of inexpensive water? On the other hand, is the water supply limited or expensive? Is the owner willing to pay for the amount of water that might be required to maintain a specific turfgrass species at the desired quality level? Is the water salty?
- Is the soil sandy or clayey? Does the soil have high salt levels or poor drainage?
- Is the lawn area sunny or shady?
- What is the elevation?
- How quickly must a turf cover appear, and how hard is the owner willing to work in establishing the lawn?
- Is there a history of a certain insect, mite, or disease problems on the site?
- Is there willingness to use pesticides, or are they totally out of the question?
- Will the lawn be sodded or seeded?

Unfortunately, few people ask such questions before establishing a new turf. The basic assumption is that Kentucky bluegrass must be planted, and little consideration is given to alternative turfgrass species. The following descriptions of available turfgrass species, including available cultivars (a cultivar is a cultivated or man-made variety of a plant species), provide information that might allow selection of a species better-adapted for a specific situation. There are large numbers of commercially-available cultivars for most turfgrass species, but all of them will never be available for sale by one seed company, much less a nursery or garden center. Local seed companies align themselves with specific national seed growers, thus limiting the number of cultivars sold by them. The selection of species and cultivars offered by even the best garden centers is generally quite limited. Local seed companies are often willing to sell smaller amounts of seed to the homeowner, and usually at a very reasonable price.

What Does "Low Maintenance" Mean?

"Low maintenance turf" means different things to different people. To some, it means NO maintenance (no water, no fertilizer, no/infrequent mowing, no/little pest control), such as the way in which roadside turf is managed. To most, however, it means reduced levels of irrigation, fertilization, and pest control. The quality expectations of a low maintenance turf should not be high, since minimal inputs can only be expected to produce a turf of minimal quality. Proper selection of species and/or cultivar is important, because some species do not persist under low maintenance or neglect.

Turfgrass Persistence Under Low Maintenance
(1=best persistence; 10=worst persistence)

Common Name	Scientific Name	Persistence Ranking	
Buffalograss	*Buchloe dactyloides*	1	**BEST**
Blue grama	*Bouteloua gracilis*	1	
Wheatgrass	*Agropyron spp.*	1	
Smooth bromegrass	*Bromus inermis*	1-2	
Hard fescue	*Festuca longifolia*	2-3	
Sheep fescue	*Festuca ovina*	2-3	
Creeping fescues	*Festuca rubra* spp. *rubra/trichophylla*	3-5	
Chewings fescue	*Festuca rubra* spp. *commutata*	3-5	
Tall fescue	*Festuca arundinacea*	5-6	
Common Kentucky bluegrass	*Poa pratensis*	6	
Improved Kentucky bluegrass	*Poa pratensis*	8	
Perennial ryegrass	*Lolium perenne*	9-10	**WORST**

Kentucky Bluegrass (*Poa pratensis*)

Kentucky bluegrass, *Poa pratensis*, has been a standard for the beautiful green lawn since the days of King Louis of France due to its dense stand, rich bluish green color, and wear tolerance. There are hundreds of different cultivars with vast differences characteristics and management needs.

Advantages

- + Sod-forming (has underground rhizomes)
- + High recuperative potential and rate
- + Soft, easily mowed leaves
- + High quality (color, density)
- + Readily-available in sod form
- + Excellent heat and cold tolerance

+ Good drought resistance (can go dormant and survive long periods without water)

Disadvantages

— Thatch-former
— More disease (leaf spot, necrotic ring spot, Ascochyta leaf blight)
— Poor to fair shade tolerance
— More frequent insect problems (billbug, grubs, mites)
— Poor to fair salt tolerance
— Higher nitrogen requirement than other grasses
— May require more frequent irrigation to maintain quality
— Will invade flower and vegetable gardens

Suggested Seeding Rate: three to five pounds per 1,000 square feet

Turf-Type Tall Fescue (*Festuca arundinacea*)

Seed distributors often sell turf-type tall fescue blends that are combinations of two to five different tall fescue varieties. These blends are ideal for home lawn use and are generally less expensive than buying a single variety. The use of tall fescue named "K-31" or "Kentucky 31" is discouraged, as this type of tall fescue provides poor quality turf.

Advantages

+ Establishes quickly
+ Drought resistant (deep-rooted)
+ Wear-tolerant
+ Few disease problems
+ Few insect problems
+ Turf-types possess nice texture and deep green color
+ Excellent heat and cold tolerance
+ Slow thatch-former
+ Does well in shade
+ Good salt tolerance
+ Slow to invade flower and vegetable gardens

Disadvantages

— Seeding can produce poor results unless done very carefully.
— Sod availability more limited, compared to bluegrass.
— Leaf shredding more common when mower blade is dull.
— Some varieties must be mowed more often than bluegrass.
— Heavy use by children and/or pets can produce worn areas that may require overseeding.
— If rooting is restricted by poor soil, may require the same amount of irrigation as Kentucky bluegrass (or more!)

Suggested Seeding Rate: six to eight pounds per 1,000 square feet

Buffalograss (*Buchloë dactyloides*)

Advantages

- + Excellent heat and drought resistance
- + Excellent cold tolerance
- + Few disease and insect problems
- + Sod-former (aggressive stolons)
- + Low fertility requirement
- + Requires only infrequent mowing
- + Can be established from seed, sod, plugs
- + A native species

Disadvantages

- — Warm season grass; becomes straw-colored with first hard fall frost and begins to green up in mid to late May.
- — Poor to fair shade tolerance. Needs at least a half day of full sun.
- — Fair salt tolerance. Not adapted to soils with greater than 5–8 mmhos/cm salinity.
- — Not recommended for use over 6,500 feet elevation. A protected, sunny, south- or west-facing exposure may allow buffalograss to be used successfully at 6,500 to 7,000 feet.
- — Not well adapted to very droughty, sandy soils—unless supplemental irrigation is provided.
- — Will not tolerate heavy, constant traffic. Not well adapted to small, heavily used home lawns, athletic fields (soccer, football), or other situations where foot or vehicular traffic will be concentrated and constant.
- — Prone to weed invasion if overfertilized or overwatered.
- — Aggressive stolons may invade flower beds, neighboring lawns.

Suggested Seeding Rate: two (if drilled) or three (if broadcast) pounds per 1,000 square feet

Perennial Ryegrass (*Lolium perenne*)

Advantages

- + Quick establishment
- + Wear tolerant
- + Good color and density
- + Does not form thatch
- + Compatible in color and texture with bluegrass
- + May contain endophytes
- + Good heat tolerance
- + Can possess good drought resistance (if deep-rooted in well-prepared soil)
- + Moderate to good salt tolerance (6-10 mmhos/cm)

Disadvantages

- — Poor recuperative potential
- — Leaf shredding common (dull mowers)
- — Disease prone (rust, leafspot)
- — Poor shade tolerance
- — Unavailable as pure sod
- — Poor freezing tolerance if flooded or exposed to wind

Suggested Seeding Rate: six to eight pounds per 1,000 square feet

Fine Fescues (*Festuca* spp.)

Advantages

- + Quick germination (but matures slowly).
- + Fine leaf texture
- + High leaf density
- + Prefers low nitrogen fertility
- + Tolerates poor (rocky, sandy, clay) soil conditions
- + Drought resistant (but will go dormant)
- + Moderate salt tolerance (6-10 mmhos/cm)
- + Very good shade tolerance
- + Very cold tolerant
- + EXCELLENT high elevation/mountain grass

Disadvantages

- — Moderate wear tolerance (NOT for high traffic areas)
- — Slow to recuperate from traffic injury
- — Can become thatch
- — May be difficult to mow (lays down; "tough" leaves)
- — May go dormant during extended (1-2 weeks) heat (90s +)
- — Susceptible to red thread, leaf spot, and dollar spot

Suggested Seeding Rate: five pounds per 1,000 square feet

Blue Grama (*Bouteloua gracilis*)

Advantages

- + Excellent cold, heat, drought tolerance
- + Low fertility requirement
- + Requires infrequent mowing
- + Few insect and disease problems
- + Rapid germination and establishment
- + Native species

Disadvantages

- — Warm season grass that becomes straw-colored with first frost in fall, greening up in late spring (May)
- — Not traffic tolerant
- — Not shade tolerant
- — Not a sod-forming grass
- — Not adapted to high elevations (>6,500 feet)
- — High seed cost
- — Difficult to seed (high % inert component; "fluffy")

Suggested Seeding Rate: one to three pounds per 1,000 square feet

Crested Wheatgrass (*Agropyron* spp.)

Advantages

- + Excellent cold, heat, drought tolerance
- + Low fertility requirement
- + Rapid recovery from dormancy (drought)

Disadvantages

- — Becomes dormant quickly under drought conditions
- — Does not form a tight sod (bunch grass)
- — Light green or blue-green color

Suggested Seeding Rate: five pounds per 1,000 square feet

Zoysiagrass (*Zoysia* spp.)

Zoysiagrass use is not recommended for Colorado, especially when it is introduced to the lawn via the use of plugs. Solid sodding can be successful, but no zoysiagrass sod is available in Colorado. Some winter dieback can be expected with this species. Since it is a warm-season grass, it becomes straw-colored with the first fall frost and remains so until the following spring (May). It can be quite invasive (forms stolons and rhizomes) and nearly impossible to eradicate once established. This species requires close mowing (one to one and half inches), and can become quite thatchy. The cultivar 'Meyer' is the only commercially available cultivar with adequate cold tolerance.

Suggested Seeding Rate: usually not seeded, but some seeded types now available

Bermudagrass (*Cynodon* spp.)

There are naturalized biotypes of bermudagrass throughout Colorado, even in the northernmost portions of the state. Some people have used these bermudagrasses for home lawn purposes, often with great success. They will perform in a fashion similar to buffalograss, since Bermuda is also a warm-season grass. It can be quite invasive and aggressive because of prolific stolon and rhizome production. When found in most lawn situations, it is considered a weed. It is quite difficult to eradicate once it becomes established in a lawn. The varieties Yukon and Riviera have demonstrated excellent cold hardiness and persistence in Fort Collins research plots since 2005.

Alkaligrass (*Puccinellia distans*)

This is a specialty grass, useful for high saline soil conditions. One commercially available cultivar, 'Fults', was developed at Colorado State University. Other commercially available cultivars include ‘Salty’ and ‘Fults II’. Alkaligrass resembles fine fescue in appearance and is a bunch grass. It requires moist soil conditions.

Suggested Seeding Rate: two to three pounds per 1,000 square feet

Inclusion of variety or trade names does not imply any endorsement; exclusion does not imply any criticism. Inclusion neither guarantees ready availability, nor implies any level of performance.

Availability of grasses named here is not guaranteed; see your local seed supplier for availability.

Author: **Tony Koski,** Ph.D., Extension Turf Specialist, Department of Horticulture & LA, Colorado State University Extension.

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CMG GardenNotes #562

Best Turf Varieties:

Variety Recommendations for Bluegrass, Tall Fescue, Fine Fescue, Ryegrass, and Buffalograss

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Recommendations for Kentucky Bluegrasses

- America
- **Arcadia**
- **Avalanche**
- **Award**
- **Awesome**
- Bedazzled
- Bewitched
- Bordeaux
- Brilliant
- **Cheetah**
- **Diva**
- **Everest**
- Full Moon
- **Julius**
- Kingfisher
- Langara
- Limousine
- Marquis
- **Midnight**
- **Midnight Star**
- Moonbeam
- **Moonlight**
- **Moon Shadow**
- **NuDestiny**
- **NuGlade**
- **Odyssey**
- **Orfeo**
- **P-105**
- Prosperity
- **Quantum Leap**
- **Rampart**
- **Rugby II**
- SR2284
- **Touchdown**
- **Ulysses**

Cultivar names in **BOLD** have exhibited better traffic tolerance

Recommendations for Turf-Type Tall Fescues

- 3rd millennium SRP
- AST 7002
- AST9001
- AST9002
- AST9003
- Biltmore
- Bullseye
- Cezanne
- Compete
- Darlington
- Einstein
- Escalade
- Faith
- Firecracker LS
- Firenza
- Gazelle II
- Hudson
- Hunter
- Justice
- Lindbergh
- Magellan
- Monet
- Mustang 4
- Padre
- Raptor II
- Rembrandt
- Renovate
- Reunion
- Rhambler SRP
- Skyline
- Speedway
- Spyder LS
- SR 8650
- Talladega
- Tulsa Time
- Turbo
- Van Gogh
- Wolfpack II

Recommendations for Fine Fescues

Chewing	**Creeping**	**Hard**	**Sheep's**
Ambassador	Aberdeen	Berkshire	Quatro
Compass	Audubon	Firefly	
Intrigue 2	Cardinal	Gotham	
J-5 (Jamestown 5)	Class One	Oxford	
LaCrosse	Epic	Predator	
Longfellow II	Fortitude (TL 53)	Reliant IV	
SR 5130	Garnet	Scaldis	
Treasure II	Pathfinder	Spartan II	
Zodiac	Shoreline	SR 3000	
	Wendy Jean		

Recommendations for Perennial Ryegrasses

1G squared
Accent II
Allstar 3
Amazing GS
Apple GL
ASP 6004
Attribute
Baccarat
Barlennium
Brea
Brightstar SLT
Buena Vista
Cabo II
Caddieshack II
Calypso 3
Cutter II
Dart
Dasher 3
Defender
Derby Xtreme
Edge II
Exacta II Glsr
Fiesta 4
Fiji
Firebolt
Forever
Fusion
Galatti
Grand slam 2
Gray star
Harrier
Hawkeye 2
Homerun
Inspire
Keystone 2
Kokomo II
La Quinta
Line drive GLS
LS 2300
Mach I
Majesty II
Monterey 3
Nexus XR
Overdrive
Palace
Palmer IV
Palmer V
Panther GLS
Paragon GLR
Pentium
Phenom
Pizzazz
Plateau
Pleasure Supreme
Premier II
Primary
Prototype
Quick Silver
Regal 5
Repell GLS Revenge
GLX
Ringer II
Secretatiat II GLSR
Silver Dollar
Soprano
SR 4600
Stellar GL
Sunshine 2
Top Gun II
Transformer
Uno
Wayfarer
Wind dance 2
Zoom

Recommendations for Buffalograss

Seeded Varieties

(will be a mixture of male and female plants)

Bison
Bowie
Cody
Plains
Topgun

The varieties Texoka and Sharp's Improved will produce a lesser quality lawn. Certain varieties of buffalograss are only available in vegetative form (sod or plugs).

Vegetative Varieties

(female only; planted as sod or plugs)

Prairie (likely to winterkill in northern CO)
609 (may suffer winter injury/winterkill in northern CO)
Legacy
Prestige
Turffalo

These varieties will form the best quality buffalograss lawn, but are more expensive than using the seeded cultivars.

Author: **Tony Koski,** Ph.D., Extension Turf Specialist, Department of Horticulture & LA, Colorado State University Extension.

- For additional information on lawn care, refer to csuturf.colostate.edu.
- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.

- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
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December 2010

CMG GardenNotes #563

Hybrid (Kentucky X Texas) Bluegrasses for Turf Use in Colorado

In the 1990s, Dr. James Read of Texas A&M University, successfully crossed Kentucky bluegrass (*Poa pratensis*) and Texas bluegrass (*Poa arachnifera*, a bluegrass species native to the Panhandle of Texas). He named the first commercially available variety 'Reveille'. There are a number of potential advantages to using these Kentucky x. Texas bluegrass hybrids for lawn and sports turf applications in Colorado. The following observations and comments are based on limited research at CSU, as well as field observations and testimonials from sod producers and those who have planted these hybrids in the Western United States.

1. ***Excellent heat tolerance.*** This grass, in fact, seems to grow better the warmer it gets in the summer. The growth and vigor of most Kentucky bluegrass varieties will generally decline under high heat (upper 80s to 100s), which can reduce its traffic and wear tolerance during the hottest times of the growing season. The hybrid bluegrasses appear to maintain more active summer growth, which translates into better traffic tolerance and ability to recover from traffic injury.

2. ***Deep and extensive root production.*** These hybrids produce an extensive root system, which can enhance heat and drought resistance. A dense root system will also improve traffic tolerance, ability to recover from wear, and will improve footing (traction) in a sports turf application.

3. ***Extensive and aggressive rhizome formation.*** These grasses form large, extensive and aggressive rhizomes (underground stems). Different from roots, rhizomes contain growing points that produce new grass plants. Grasses that produce rhizomes are better able to tolerate traffic and will recover more quickly from traffic-induced wear – often without the need to reseed the worn areas. An aggressive rhizome system also means better traction in a sports turf situation.

4. ***Low mowing height tolerance***. Its excellent heat tolerance and aggressive root and rhizome formation characteristics allow this grass, when necessary, to be mowed at lower heights than many Kentucky bluegrasses – especially during the heat of summer. This can be important for "showcase" sports turf applications.

5. ***Potential to require less irrigation***. Variability exists among the hybrid bluegrasses with respect to irrigation requirement and drought resistance. Research has shown some of them to possess very good drought resistance

(compared to other bluegrasses, and even to tall fescue), while as other varieties are only moderately (or have poor) drought resistant. The ability to sustain growth and vigor with less irrigation results from deeper roots and its excellent heat tolerance.

Commercially Available Hybrid Bluegrass Cultivars

- Fahrenheit 90 (Mountain View Seeds)
- Fire and Ice (Turf Merchants)
- Longhorn (Scotts Turf-Seed)
- Bandera (Seed Research of Oregon)
- Spitfire (Seed Research of Oregon)
- Reveille (Gardner Turfgrass)
- Dura Blue (Scotts)
- Solar Green (Scotts)
- Thermal Blue (Scotts)
- Thermal Blue Blaze (Scotts)

Inclusion of cultivar or variety names does not imply any endorsement, nor does exclusion imply criticism.

Availability of grasses named here is not guaranteed; see your local seed supplier for availability.

Author: **Tony Koski,** Ph.D., Extension Turf Specialist, Department of Horticulture & LA, Colorado State University Extension.

- For additional information on lawn care, refer to csuturf.colostate.edu.
- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
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December 2010

CMG GardenNotes #564

Fine Fescues for Lawns

Advantages and Disadvantages of Fine Fescue

The fine fescues are among the most complex groups of turfgrass species, comprising at least five different types. Hard fescue, Chewings fescue, (blue) sheep fescue, creeping red fescue and slender creeping red fescue are the five species or subspecies. While all are fescues, they differ both in appearance and where they are most effectively used. In general, this group of grasses performs well in the cooler, more temperate climates of the world (including cool, maritime locations). I n North America, the fine fescues do well where most cool-season turfgrasses are used. The relative advantages and disadvantages of using the fine fescues for turf are as follows:

Advantages

+ quick germination (but may establish slowly)
+ fine leaf texture
+ high leaf density
+ prefers low nitrogen fertility
+ tolerates poor (rocky, sandy, clay) soil conditions
+ drought resistant (but will go dormant)
+ moderate to very good salt tolerance (6-10 mmhos/cm)
+ good to very good shade tolerance
+ very cold tolerant
+ EXCELLENT high elevation/mountain grass

Disadvantages

- moderate wear tolerance (NOT for constant high traffic areas)
- slower to recuperate from traffic injury
- can become thatchy
- may be difficult to mow (lodges; "tough" leaves)
- may go dormant during extended (1-2 weeks) heat (90s +)
- some are susceptible to red thread, leafspot, and dollarspot

Types

Hard fescue (*Festuca longifolia* or *duriuscula*) is gaining wider use due to its better heat tolerance, relative to the other fine fescues. This better tolerance to warm summer conditions makes it especially well suited to use in the Front Range of Colorado. As with the other fine fescues, hard fescue performs best with minimal nitrogen fertilization and when soil is kept on the drier side (but supplemental irrigation IS required to keep a good hard fescue lawn in Colorado). This is a bunch grass, so uniform seeding at establishment is essential for obtaining a good quality lawn.

Chewings fescue (*Festuca rubra* subp. commutata), named after George Chewings of New Zealand (who discovered and first sold the seed of this species in the late 1800s), is typical of the fine fescues in that it possesses excellent shade tolerance. It has a darker green color and very fine texture, resulting in a very good quality turf. This species does not creep, so uniform seeding is essential.

Creeping red fescue (*Festuca rubra* subp. rubra) is a creeping fine fescue (has rhizomes) that has been used in shady lawn seed mixtures for years (‘Pennlawn’ was commonly used a number of years ago). A “common type” (possessing lesser turf qualities), grown in large amounts in Canada is sold in lower quality, less expensive seed mixes (sometimes called ‘Boreal’ in these mixes). Improved cultivars, sometimes referred to as “strong creeping red fescue”, are produced in the Pacific Northwest, with a few being imported from Europe.

Slender creeping red fescue (*Festuca rubra* subp. litoralis) produces rhizomes, but is not as vigorous a grower as (strong) creeping red fescue. These fescues are tolerant of lower mowing heights, which can allow their use in golf course fairways. However, the biggest advantage of fine fescues in this grouping lies in their generally good to excellent salinity tolerance. This makes them attractive for use where deicing salts are aggressively used. Their fine texture and compatible color allow them to be mixed with alkaligrass (*Puccinellia distans*). ‘Fults’ is the most commonly planted alkaligrass variety) for use on salty soils.

Sheep fescue (*Festuca ovina*), sometimes called “blue sheep fescue” is generally used in lower maintenance lawns, performing especially well in infrequently- or un-mowed, naturalized lawn areas. They are long-lived bunch grasses that mix well with wildflowers, without dominating them. Some sheep fescues have been developed to produce a blue-green or glaucous green color (Azay Blue, SR3200), while others are more powder blue or “flat” blue in color (Azay, Quatro).

Management of Fine Fescue Turf

Establishment/Seeding

Use 5-7 pound of seed per 1000 square feet. Late summer/fall (September) fall planting is recommended at lower elevations. Spring or summer planting can be done at higher elevations. Can be dormant seeded (late in fall, when temperatures will prevent germination). Will germinate in 7-10 days, under warm soil conditions.

Mowing

Mow 1-3 inches (or leave unmowed, for naturalizing). A sharp blade is necessary to prevent leaf fraying, for optimal turf quality.

Irrigation

The fine fescues prefer drier soils. Constant root zone moisture will cause rapid decline and thinning, as well as increase the potential for disease. While preferring dry soil, fine fescue lawns REQUIRE supplemental irrigation in Colorado. Fine fescue will require 18-20 inches of supplemental irrigation (compared to 24 inches for bluegrass) in a normal precipitation year (10-11 inches, April to October) along the Front Range; less irrigation. These grasses can go dormant without irrigation, but their dormancy mechanism is not as good as that of Kentucky bluegrass.

Fertilization

The fine fescues require only 1-2 pounds of nitrogen per 1000 square feet per year under average lawn conditions. Where traffic is heavier, on sandy soils and where higher quality is desired, 3-4 pounds of nitrogen can be used. Late season (fall) or early spring nitrogen benefits fine fescue lawns. Summer fertilization may reduce heat tolerance, resulting in partial dormancy. Naturalized (unmowed) fine fescue requires only infrequent fertilization, especially when growing with wildflowers.

Pest Problems

In Colorado the fine fescues will have few pest problems. Possible insect problems include: billbugs, grubs, and winter mites. Dollarspot can be common on some fine fescues; this can be a sign that some nitrogen fertilization is required. Red thread may be common during moist, cool spring or early summer conditions; it rarely causes any permanent turf injury. The fine fescues are generally tolerant of herbicides used on Kentucky bluegrass and other cool-season grasses, but the label should always be consulted before use on fine fescue turf.

Inclusion of cultivar or variety names does not imply any endorsement, nor does exclusion imply criticism. Availability of grasses named here is not guaranteed; see your local seed supplier for availability.

Author: **Tony Koski,** Ph.D., Extension Turf Specialist, Department of Horticulture & LA, Colorado State University Extension.

- For additional information on lawn care, refer to csuturf.colostate.edu.
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December 2010

CMG GardenNotes #565

Buffalograss Lawns

Outline:

Buffalograss (*Buchloë dactyloides*) is a perennial, warm-season grass species. It is a sod-forming grass that spreads by stolons (aboveground stems) which root at nodes, forming new plants. Buffalograss is native to the North American Great Plains, and displays a wide range of adaptability. An important range and pasture grass for both wild and domesticated animal herds, its use as an alternative lawn grass was proposed as early as the 1930s. Older range-type varieties form an open, low-density turf when mowed; the newer, turf-type buffalograss varieties can form a dense, attractive turf during its active growing season.

Because of its warm-season physiology, this species becomes dormant with the onset of cold temperatures in the fall and breaks dormancy in mid to late spring, well after bluegrass and fescue lawns become green. Buffalograss grows most actively during from late May through early September, becoming brown and dormant with the first hard frost in the fall. Its long dormant period and reputation as an expensive and difficult-to-establish lawn has made it a less-attractive lawn option for many homeowners.

However, the development of attractive turf-type cultivars and greater availability of less expensive sod and plugs has generated new interest in this grass for home lawns. These new varieties are darker green, form a dense, short-growing turf, and are more resistant to weed invasion than previously used varieties. Those who choose to plant newer buffalograss varieties find that their lawn can remain green and attractive on 50-75% less irrigation than Kentucky bluegrass, and that buffalograss requires less frequent mowing, will thrive when fertilized only once or twice yearly, and has good resistance to weed invasion.

Available Cultivars

Turf-type seeded cultivars of buffalograss that will produce a good quality lawn include: Bison, Bowie, Cody, Plains, and Topgun. The varieties Texoka and Sharp's Improved will produce a lesser quality lawn.

Certain varieties of buffalograss are only available in vegetative form (sod or plugs). These varieties will form the best quality buffalograss lawn, but are more expensive than using the seeded types. Commercially available vegetative types include: Prairie, 609, Legacy, Prestige, and Turffalo. Prairie and 609 will suffer significant winterkill during most winters if planted along the Colorado Front Range, and are not recommended except in Pueblo and southeastern CO and in the Grand Junction area. Legacy, Prestige and Turffalo have proven to be quite winter hardy throughout Colorado and will produce high quality buffalograss turf.

Buffalograss Establishment and Management

Acceptance of buffalograss in the marketplace is critically dependent upon the knowledge of proper establishment and management. While it can be considered a low-maintenance grass, proper management is necessary to realize the full benefits of the species. ***The amount of water required to establish a buffalograss lawn from seed, sod or plugs will be equal to (and occasionally greater than) that amount required to establish a bluegrass or tall fescue lawn.***

Seeding

Proper seedbed preparation is critical in obtaining uniform stands. Seed should be planted to half-inch depth (drill seeding is preferred). If broadcast, seed should be covered with ¼ to ½ inch of soil to obtain a reasonable stand. Seeding should begin in mid-late May or early June. Seeding too late in the season (beyond August 1) may result in winter seedling loss. Use a seeding rate of three to five pounds seed/1,000 square feet.

With warm soil and consistent irrigation, germination and appearance of seedlings will occur in seven to 21 days. Preemergent herbicides should NOT be used at the time of seeding, but may be safe after seed has germinated. Apply one pound of nitrogen (N) per 1,000 square feet two to three weeks after the seedlings appear; fertilize again about six weeks later. Irrigate to prevent excessive drying and to maintain active grass growth.

Plugging

The use of pre-rooted plugs can provide complete cover within eight to 12 weeks after planting. Proper soil preparation is essential for successful establishment using plugs. Plant plugs on 12 to 18 inch centers following the last spring frost and at least six weeks prior to the first expected fall frost. Apply one pound of nitrogen per 1,000 square feet using a starter-type fertilizer at planting, and again about six to seven weeks after planting. Irrigate to maintain a moist surface for seven to ten days, and to maintain active grass growth thereafter. The preemergence herbicide pendimethalin (sold as Pre-M or Scotts Halts/Crabgrass Preventer) can be used to prevent weed invasion and is safe to use at the time of planting.

Transplanted plugs will often go dormant (become brown) after planting, even with adequate irrigation. This is quite normal. T he grass will come out of dormancy after the plugs have formed a healthy root system. *It is important that the plugs and soil be kept moist after planting, even though the plugs may appear to be dead or dormant.*

Sodding

Buffalograss can be sodded like many other grass species to produce an instant lawn. Adequate soil preparation and careful post-plant care will aid in sod establishment. Transplanted buffalograss sod should be irrigated like any other transplanted sod - enough water to maintain a moist, but not saturated, rootzone under the sod. It is very common for buffalograss sod to quickly turn brown following transplanting, even when irrigated. It may remain dormant for one to two weeks while new roots are being formed. New, white root growth can be seen on the bottom of the sod after a few days of watering, even though the top of the sod may be entirely brown in color. After enough rooting has occurred, the buffalograss will begin to form new leaves and green up. *Proper irrigation is crucial during this root formation period.*

Fertilization

Color and growth of buffalograss will improve with fertilization, but little advantage can be seen beyond two pounds of total nitrogen per 1,000 square feet per growing season. A suggested application schedule is one-half to one pound of nitrogen per 1,000 square feet in late May to mid June, and again in late July. Excessive fertilization (more than two pounds of nitrogen per 1,000 square feet per year), especially in combination with excessive irrigation, can cause serious weed invasion in the buffalograss lawn. Buffalograss is sometimes prone to iron chlorosis (yellowing) on high pH soils; supplemental iron applications will help to prevent this problem.

Mowing

Weekly mowing at two inches will be adequate for irrigated buffalograss lawns. Buffalograss that is supplied with only infrequent irrigation or is not irrigated will require less frequent mowing. Left unmowed, buffalograss produces little growth above three to six inches and will remain attractive.

Irrigation

Once established, buffalograss can survive without irrigation. However, however unirrigated buffalograss will become dormant during most summers, and will be prone to weed invasion while dormant. Buffalograss lawns require a minimum of one to two inches of rainfall or irrigation every two to four weeks during the summer to maintain active growth and be acceptably green. Deeper, infrequent irrigation (for example, one inch every two to four weeks, depending on rainfall) will produce a good quality buffalograss lawn and discourages weed invasion. Irrigation can begin in mid- to late-May if the spring is dry; earlier season irrigation will not speed spring green-up and will encourage weed growth.

Weed Management

Weed invasion is the most common and frustrating problem in the buffalograss home lawn. Buffalograss appears to have adequate seedling and/or established turfgrass tolerance for benefin (Balan), bensulide (Bensulide), carfentrazone (Quicksilver), clopyralid (Lontrel), imazapic (Plateau), isoxaben (Gallery, Portrait), metsulfuron (Manor), oxadiazon (Ronstar), pendimethalin (many, including Pre-M, Scotts Crabgrass Preventer/Halts), prodiamine (Barricade), quinclorac (Drive) when the label use recommendations were followed. Tenacity appears safe on established buffalograss (but is not labeled for this use).

Some turf injury is likely when the following are used: 2,4-D, dicamba, dithiopyr (Dimension), fenoxaprop-ethyl (Acclaim Extra), mecoprop/MCPP, MSMA, oryzalin (Surflan), sethoxydim (Poast, Vantage) , siduron (Tupersan), triclopyr (Turflon), triclopyr + 2,4-D (Turflon D), and triclopyr + clopyralid (Confront). Buffalograss can be especially sensitive to off-the-shelf herbicides (especially 2,4-D) bought by homeowners for the control of dandelions and other broadleaf weeds, particularly when these herbicides are applied during periods of very warm temperatures (80s and 90s). These products can be safely used on fully dormant buffalograss in spring or fall (spot treat only; do not broadcast apply).

One effective (but risky) method of controlling winter/early spring weeds in buffalograss is to apply glyphosate (Round-up, Kleen-up) when the buffalograss is **TOTALLY** brown and dormant, but while the weeds are green and growing (March to early April). Glyphosate will work better when applied on a warm day (55-60 degrees F or greater) and weeds are not drought-stressed. Remember that glyphosate will kill any green buffalograss which it contacts. When applied to dormant buffalograss, the glyphosate should be applied as a very light mist (use the pre-mixed, hand-pump products if possible) and only on those spots where the weeds are growing. Glyphosate applied too heavily will move down onto green stolons in the buffalograss lawn, causing dead spots in the lawn. **DO NOT APPLY GLYPHOSATE ONCE BUFFALOGRASS BEGINS TO SHOW SIGNS OF SPRING GREEN-UP!**

Disease Management

No diseases have been observed as causing problems on buffalograss lawns in Colorado.

Insect Management

Mealybugs (*Tridiscus sporoboli* and *Trionymus* sp.) and a short-winged species of chinch bug (*Blissus* sp.) have been found in Nebraska buffalograss lawns, but have not yet caused problems in Colorado. Leafhoppers and grasshoppers are common nuisance pests, but do not generally damage buffalograss lawns.

Where Buffalograss Is Not Well-Adapted.

- Moderate to very shady locations (more than ½ day complete shade).
- Saline soils (greater than 6-8 mmhos/cm salinity).
- Above approximately 6500 feet elevation. A protected, sunny, south- or west-facing exposure may allow buffalograss to be used successfully at 6500-7000 feet, but the growing (green turf) season will be short.
- Very droughty, sandy soils - unless supplemental irrigation is provided.
- Small, heavily used home lawns, athletic fields (soccer, football), or other situations where foot or vehicular traffic will be concentrated and constant.

Author: **Tony Koski,** Ph.D., Extension Turf Specialist, Department of Horticulture & LA, Colorado State University Extension.

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CMG GardenNotes #566

Sources of Grass Seed, Sod and Plugs for Colorado Lawns

Seed

The following are Colorado seed companies that will sell seed directly to homeowners. Some may work cooperatively with select garden centers and nurseries to fill homeowner orders. They are all reputable seed companies that carry high quality, weed-free seed at fair prices.

Arkansas Valley Seed Solutions
I-25 & Hwy 66
Longmont, CO 80504
970-535-4481
http://www.avseeds.com

Pawnee Buttes Seed Company
605 25th Street
Greeley, CO. 80632
800-782-5947 or 970-356-7002
FAX 970-356-7263
www.pawneebuttesseed.com

Rocky Mountain Seed Co
1925 County Rd 54G
Fort Collins, CO 80524
970-493-7100
www.rockymountainseedco.com

Sharp Bros. Seed Co.
104 East 4th Street Road
Greeley, CO 80631
970-356-4710 or 800-421-4234
Fax 970-356-1267
http://www.sharpseed.com

Southwest Seed
13260 County Road 29
Dolores, CO 81323
970-565-8722
www.southwestseed.com

Sod Producers

For information on Colorado sod producers, go to:
Rocky Mountain Sod Growers Association at
sod-growers.com

Buffalograss Plugs

To order buffalograss plugs (Legacy, Prestige):

- **Todd Valley Farms** (Mead, NE – near Lincoln) at www.toddvalleyfarms.com
- **High Country Gardens** at www.highcountrygardens.com

Author: **Tony Koski,** Ph.D., Extension Turf Specialist, Department of Horticulture & LA, Colorado State University Extension.

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Native Plants

Reading / Reference Materials

CSU Extension Fact Sheets

#7.242	Native Herbaceous Perennials
#7.421	Native Trees
#7.422	Native Shrubs

Web: Visit the CSUCE Gilpin County, CMG "Mountain Gardening" web site at www.coopext.colostate.edu/gilpinmg

Review Questions

1. List five benefits of using native plants in the landscape.
2. What soil amendments should be used for growing native plants?
3. Why are aspens not recommended for planting in Front Range cities?
4. Why is it hard to find native plants in nurseries/garden centers?
5. All native plants can survive on natural rain and snowfall in your yard. True or False? Explain your answer.

Native Plants Curriculum developed Irene Shonle, PhD.

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CSU Extension, Gilpin County Office
Irene.shonle@colostate.edu
303-582-6002

- Colorado Master Gardener Training is made possible, in part, by a grant from the ***Colorado Garden Show, Inc.***
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CMG GardenNotes #581

Native Grasses

For Use In Colorado Landscapes

Why use native grasses?

- Bunchgrasses can be used ornamentally as specimens or in groups.
- Sod forming grasses can make great low maintenance turf and offer savings in mowing, fertilizing and irrigation.
- Grasses provide excellent forage and cover for birds and beneficial insects.

Scientific Name	Common Name	Season	Height	Planting Elevation	Notes
Achnatherum hymenoides (Oryzopsis hymenoides)	Indian rice grass	Cool	12-24”	To 9,000’	Delicate, lacy bunchgrass with attractive showy panicles. Very low water use. Short lived. Edible seeds. Most well-drained soils.
Andropogon gerardii	Big bluestem	Warm	48-72”	To 7,500’	Robust bunchgrass with upright growth. Turns red-burgundy in the fall with color retention well into winter. Tolerates most soils (esp. clay) and water regimes.
Andropogon saccharoides	Silver beard grass	Warm	24-48”	To 7,500’	Bunchgrass with fine textured leaves and large seed heads which catch the light and persist through the winter. Orange fall color. Grows in all soils, including clay. Low water use.
Bouteloua curtipendula	Sideoats grama	Warm	24-36”	To 9,000’	Bunchgrass with small pennant- like seeds on one side of stem. Very low water use. Most well-drained soils.
Bouteloua gracilis	Blue grama, eyelash grass	Warm	6-20”	To 9,500’	Bunchgrass with large curved flowering spikes that resemble eyelashes. Excellent lawn alternative. Withstands moderate traffic and light shade. Low water use;
Buchloe dactyloides	Buffalo grass	Warm	2-8”	To 6,500’	Sod-forming grass, moderate to low water use. Long-lived with a vigorous root system. Prefers clay soils.
Eragrostis trichodes	Sand lovegrass	Warm	24-48”	To 6,500’	Bunchgrass with a lacy, airy inflorescence. Does especially well on sandy soils, but tolerates most. Low water use.
Festuca arizonica	Arizona fescue	Cool	10-24”	To 10,000’ or higher	Graceful clumping bunchgrass with fine-textured blue-green leaves. Low water use. Tolerates light shade but not traffic.

Scientific Name	Common Name	Season	Height	Planting Elevation	Notes
Koeleria macrantha	June grass	Cool	12-24”	TO 11,000’	Bunchgrass with attractive open panicles of flowers. Great mixed with low-growing perennials. Low water use but will tolerate wetter sites. Most soils and light shade.
Pascopyrum smithii (Agropyron smithii)	Western wheatgrass	Cool	12-40”	To 10,500’	Sod-forming grass with upright blue leaves and spikes. Most soils. Because it is strongly rhizomatous, it should be used only where there is adequate growing space.
Panicum virgatum	Switchgrass	Warm	36-48”	To 7,000 (maybe higher)	Slow sod-former with upright growth, vase shaped. Many delicate panicles, high above the foliage in some strains, turn reddish-bronze in the autumn. Often used at the back of the perennial border or as a tall screen.
Schizachyrium scoparium (Andropogon scoparius)	Little bluestem	Warm	12-48”	To 7,500 or higher	Upright growing bunchgrass with green to blue-green leaves and fluffy seed heads that catch the light, persisting through winter. Fall color is a red to bronze, which fades slowly in winter. Sun. Good for clay soils, but tolerates most. Low to moderate water use.
Sporobolus airoides	Alkali sacaaton	Warm	36-60”	To 7,500’	Striking robust grass with fine textured bluish leaves and a showy, airy, open inflorescence. Low water use, tolerates most soils. Easy to establish.
Sorghastrum nutans	Indian grass	Warm	36-60”	To 6,500’	One of the most ornamental of the native grasses. Upright growth with large tawny seed heads and golden-orange fall color. Moderate water use. Needs space to grow.

Season: Cool season grasses green up earlier in the spring and can go dormant and turn brown in the heat. Warm season grasses stay dormant longer in the spring, and grow during the warmer season.

Grasses prefer full sun unless stated otherwise in the notes section.

Author: Irene Shonle, Ph.D., Colorado State University Extension, Gilpin County

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GardenNotes #582

Native Plants Reference List

CSU Extension Fact Sheets

- Native trees #7.421
- Native shrubs #7.422
- Native Herbaceous Perennials #7.242

ID books

Ackerfield, J. Flora of Colorado.Brit Press. 2015

- Carter, J.M. Carter, D. Stevens and J. Bousselot. Common Southwetern Native Plants, third edition. Colorado Native Plant Society, 2018.
- Carter, J. and M. Leggit. ***Trees and Shrubs of Colorado***. Johnson Books 1995.
- Carter, J. ***Common Southwestern Native Plants: An Identification Guide***. Silver City, NM: Mimbres Publishing, 2003. (has some landscape uses, too)
- Guennel, G.K**. *Guide to Colorado Wildflowers. Vols 1& 2.*** Westcliffe Publishers 1995. Nelson, R.A. and R. Williams. ***A guide to Rocky Mtn Plants, 5th Ed***. Roberts Rinehart Publishers, 2002.
- Weber, William et at. ***Flora of Colorado, Eastern Slope. 3rd Ed***. University Press of Colorado 2001.
- Weber, William et at. ***Flora of Colorado, Western Slope. 3rd Ed***. University Press of Colorado 2001.
- ***Weeds of the West, 9th Ed***. Western Society of Weed Science. 2001.
- Wingate J. ***Rocky Mountain Flower Finder.*** 1990. Nature Study Guild Publishers.
- Wingate and Yeatts. ***Alpine Flower Flinder.*** 2003. Johnson Books.

Gardening with native plant books

- Busco, J. and N. Morin. ***Native Plants for High-Elevation Western Gardens***. Fulcrum Publishing, 2003.
- Phillips, Judith. ***Natural by Design.*** Museum of New Mexico Press 1995.
- Phillips, Judith. ***Plants for Natural Gardens***. Museum of New Mexico Press 1995

Web-based

- Colorado Plant Database at www.coloradoplants.jeffco.us
- Colorado Native Plant Society: www.CONPS.org

Author: Irene Shonle, Colorado State University Cooperative Extension, Gilpin County Office

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CMG GardenNotes #583

Sources of Colorado Native Plants

This list was compiled by the **Colorado Native Plant Society** of nurseries that are known to sell Colorado native plants. It is not inclusive, and does not imply any endorsement of vendors.

Chelsea Nursery
3347 G Road
Clifton, CO 81520
970-434-8434
Stock: container

The Flower Bin
1850 Nelson Rd.
Longmont, CO 80501
303-772-3454
www.theflowerbin.net
Stock: container and seed

Fort Collins Nursery
2121 East Mulberry
Fort Collins, CO 80524
970-482-1984
www.fortcollinsnursery.com
Stock: container

Harlequin's Garden
4795 N 25th St
Boulder, CO 80301
303-939-9403
www.harlequinsgardens.com
Stock: container

Pawnee Buttes Seed Co.
PO Box 100
Greeley, CO 80632
800-782-5947
Fax: 970-356-7623
www.pawneebuttesseed.com
Stock: seed

Pleasant Avenue Nursery
506 S Pleasant Ave
Buena Vista, CO 81211
719-395-6955
pan@amigo.net
Stock: container and seed

Ramshorn Native Plants
PO Box 881810
Steamboat Springs, CO 80488
970-276-4448
Ramshorn.np@att.net
Stock: container

Rocky Mountain Rare Plants
1706 Deerpath Rd
Franktown, CO 80116
303-688-6645
www.rmrp.com
Stock: seed

Sharp Brothers Seed Co.
104 East 4th Street Rd
Greeley, CO 80631
970-356-4170
www.sharpseed.com
Stock: Seed

Southwest Seed
13260 County Road 29
Dolores, CO 81323
970-565-8722
www.southwestseed.com
Stock: seed

Western Native Seed
PO Box 188
Coaldale, CO 81222
719-942-3935
www.westernnativeseed.com
Stock: seed

Contact: Irene Shonle, Colorado State University Cooperative Extension, Gilpin County Office

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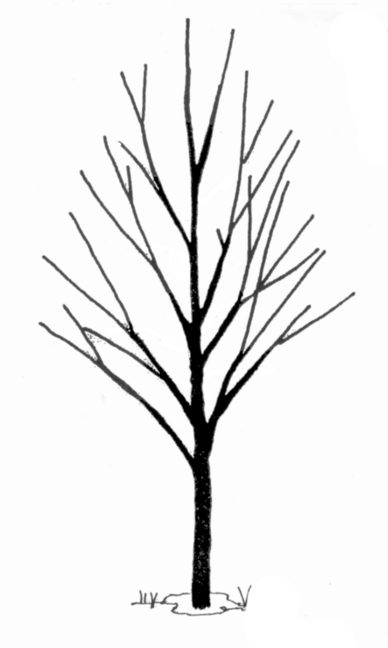

The Science of
Pruning

Pruning Reference

Books (available from the *International Society of Arboriculture* at www.isa-arbor.com)

- ***An Illustrated Guide to Pruning, Third Edition.*** Edward F Gilman. Cengage Learning. 2011.
- ***Best Management Practices: Tree Pruning***. Edward F Gilman and Sharon J. Lilly. International Society of Arboriculture. 2008.
- ***ANSI A300 Pruning Standards, Part 1.*** American National Standards Institute. 2008.

Books (available from Urban Tree Foundation at www.urbantrees.org)

- ***Structural Pruning, A Guide for the Green Industry.*** Dr. Edward F Gilman, Brian Kempf, Nelda Matheny, and Dr, Jim Clark. Urban Tree Foundation. 2013.

Web: http://hort.ifas.ufl.edu/woody/pruning.shtml for sample pruning specifications.

Pruning curriculum develped by David Whiting (retired), Alison O'Connor, and Eric Hammond, Colorado State Univeristy Extension

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- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

Revised May 2018

Learning Objectives

At the end of this unit, the student will be able to:

- Explain how trees grow and decay, and the implications for pruning.
- Explain removal cuts, reduction cuts and heading cuts.
- Structurally prune a young shade tree.
- Describe pruning of maturing shade trees, including objectives (whys) and methods (hows).
- Prune flowering shrubs
- Prune evergreen shrubs

Review Questions

Tree Growth and Decay

1. What is the branch collar?
    a. Explain how it develops.
    b. Explain the size relationship between the side branch and trunk/parent branch necessary for a branch collar to develop.

2. Explain how trees grow, adding xylem rings each year. Define the following terms:
    a. Phloem
    b. Xylem
    c. Sapwood
    d. Heartwood
    e. Ray cells
    f. Compartmentalization

3. Explain how trees respond to wounds (i.e., CODIT).
    a. What are the roles of annual growth rings and ray cells?
    b. In CODIT, explain why trees decay with a pipe-like structure. How does a break in the pipe-like structure impact structural strength?

4. What is percent shell? What are significant about 33% and 25% shells?

5. Describe methods to evaluate decay and cracking in trees.

Pruning Cuts

6. Identify/define the following:
    a. Branch bark ridge
    b. Branch defense zone
    c. Reaction zone
    d. Woundwood

7. What is a removal cut?
    a. What are the advantages of a removal cut?
    b. When the branch bark ridge is visible, where is the removal cut made?
    c. If the branch collar is not easy to identify, where is the removal cut made?
    d. If the branch has no branch collar, where is the removal cut made?
    e. What happens when the branch collar is cut or injured?
    f. What happens when nubs or very short branches are left?
    g. With hindsight, how does one evaluate when the thinning cut was properly made?

8. What is a reduction cut?
    a. What are the uses and limitations of reduction cuts?
    b. What is the proper angle for a reduction cut?
    c. In a reduction cut, what is the proper size relationship of the branch being removed to the branch pruned back to? is it important?

9. What is a heading cut?
    a. How does it influence regrowth of the plant?
    b. What are the effects of using heading cuts on larger branches?

10. Explain the three-step method for pruning large branches. Why is it needed? When is it needed?

11. Describe the pros and cons of pruning live branches during the:
    a. Late winter (dormant)
    b. Spring (during growth flush)
    c. Midsummer (after leaves harden and turn dark green)
    d. Late summer and fall
    e. Late fall and early winter
    f. During drought

Structural Training of Young Shade Trees

12. In structural training of young shade trees, give the rule-of-thumb for dosage (i.e., the maximum amount of live wood/foliage removed per season)? How does the gardener determine the growth rates to set dosage? How is the dosage range adjusted for the specific tree?

13. Define *excurrent* and *decurrent* growth habits.

14. List the steps and pruning objectives for excurrent and decurrent trees.

15. Define codominant trunks. Why do arborists have zero tolerance for codominant trunks?

16. What are the options if multiple leaders develop? If the main leader is killed?

17. What is the standard height for the lowest permanent branch of sidewalk trees? Street tree? Trees in forest areas (fire management)?

18. What is the proper size relationship between the trunk and side branch? Why is it important? What are the options if a side branch is growing too large?

19. Define scaffold branch. What is the rule of thumb for minimum spacing of scaffold branches?

20. How do multiple branches arising at one site influence the branch collar and thus structural integrity?

21. What is the role of temporary branches on young trees?

22. Describe the management of temporary branches.

23. Given a young excurrent or decurrent tree (or a picture of a young excurrent tree), describe specific training for this tree.

24. When decurrent trees are not trained from early growth in the nursery and on the landscape site, it is often impossible to fully achieve the five training objectives. To minimize potential storm damage, what is the most important objective to pursue?

Pruning Mature Trees

25. List the objectives (whys) for pruning a mature tree.

26. List the methods (hows) of pruning to achieve purposes.

27. Describe key elements in writing specifications for general pruning of maturing trees.

28. What is the overall objective in structural pruning of medium-aged and mature trees? Why will it generally require work over a period of years? How does larger branch size influence the potential for structural pruning?

29. Describe *subordinate pruning*. What factors should be considered when deciding where to make a subordinate pruning cut?

30. Describe how to subordinate prune a medium-aged tree with the following situations:

    a. Codominant trunks
    b. Rounded off
    c. Choked-out central leader
    d. Too many upright-growing branches

31. Describe key elements in writing specifications for structural pruning of medium-aged trees.

32. Define *cleaning*. In cleaning, how much of the live wood should be removed? Why?

33. When is it important to remove dead branches? At what size and height does dead branch removal become an important management issue?

34. When woundwood is growing out along a dead branch, where is the final cut made?

35. Describe key elements in writing specifications for cleaning.

36. Describing thinning.

    a. What are the purposes of thinning the crown?
    b. Will thinning lower a tree's height?
    c. In thinning the crown, what types of cuts are made?
    d. What is the general maximum size of branches to be removed?

   e. What is the long-term effectiveness in overall crown thinning to reduce storm damage potential? What pruning method would be more effective?

37. What is *lion-tailing*? How does it differ from thinning the crown? What are the problems associated with lion-tailing?

38. What is the rule of thumb on dealing with excessive sucker growth?

39. Describe the key elements in writing specifications for thinning.

40. In raising, what is live crown ratio? What is the rule of thumb on how fast a tree can be pruned up?

41. In raising, what options may be workable other than removal of lower branches? Why may removal of lower branches cause problems?

42. Describe the key elements in writing specifications for crown raising.

43. Describe the reasons for crown reduction. Describe the limitations of crown reduction.

44. List pointers on crown reduction, as given in chapter.

45. What is the long-term effectiveness in overall crown reduction to reduce storm damage potential? What pruning method would be more effective?

46. How does topping a tree impact its structural integrity and internal decay potential?

47. Describe the key elements in writing specifications for crown reduction.

48. Explain the pruning objectives for the following situations:

    a. Storm-damaged trees
    b. Old and declining trees
    c. Root-damaged trees
    d. Hazard trees

Flowering Shrubs

49. What's the difference in flowering habit and pruning of spring-flowering shrubs and summer-flowering shrubs?

50. Many gardeners prune flowering shrubs by topping them. Describe the impact on growth and flowering.

51. Explain the pros of, and limitations for, shrub pruning by

    a. Shearing to shape
    b. Thinning old wood
    c. Pruning to the ground
    d. Replacement

52. What types of shrubs are successfully renewed by pruning to the ground? List situations where this approach may not work.

Evergreens

53. How can a gardener make a young spruce, fir or Douglas-fir bushier? What about a pine?

54. A large evergreen tree is overgrowing the space. Explain options to prune back the bottom branches for spruce, fir and Douglas-fir. Explain options for pruning back bottom branches for pine. Why is pine different from spruce, fir and Douglas-fir?

55. Explain what happens when a gardener shears a mugo pine shrub.

56. On junipers and arborvitae, explain the pros and cons of

    a. Shearing
    b. Thinning

57. Explain the problems associated with trying to prune back a severely overgrown juniper or arborvitae.

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #611

Tree Growth and Decay

Outline:

As forest scientists observed how trees respond to wounds, pruning techniques changed and pruning objectives were clarified.

This *CMG GardenNotes* provides background information on how trees grow and decay and therefore the implications of pruning cuts and structural training. Refer to other CMG GardenNotes for additional details on pruning cuts and structural training.

> Note: in this publication, the term “trunk” refers to a trunk or parent branch and “side branch” refers to a side branch arising from the trunk (parent branch). The same relationship would exist between a side branch and a secondary side branch.

Developing a Strong Branch Union

In Colorado (and other snowy climates) the most common type of significant storm damage in landscape trees results from failures at the ***branch union*** (crotch), primarily with ***codominant trunks*** (adjacent trunks of similar size). Primary objectives in training young trees are to develop strong branch unions and eliminate structurally weak codominant trunks. [Figure 1]

Figure 1. Codominant trunks (adjacent trunks of similar size) account for the majority of storm damage in Colorado landscapes.

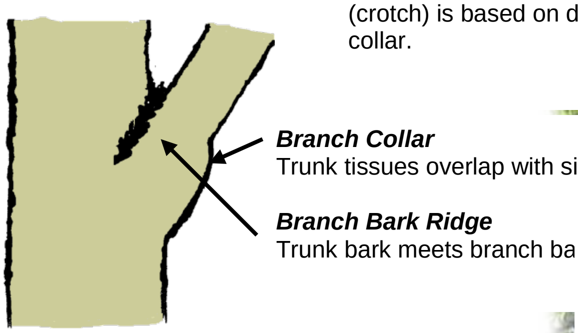


Figure 2. Structural strength of the branch union (crotch) is based on development of a branch collar.

Structural strength of a branch union is based on the development of a ***branch collar***. The branch collar is where the annual growth rings of the trunk overlap the annual growth rings of the side branch, like shuffling a deck of cards. In lumber, the branch collar is called the knot. [Figures 2 and 3]

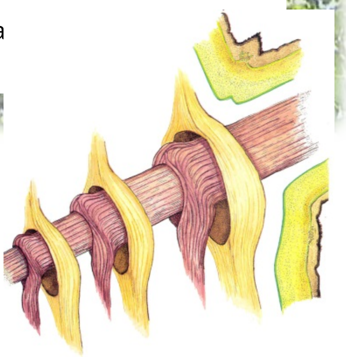


Figure 3. The branch collar is where annual growth rings of the trunk overlap the annual growth rings of the side branch, like shuffling a deck of cards. This creates a very solid section of wood, known as the “knot” in lumber. (Line drawing: U.S.D.A.)

As the branch collar develops, side branch tissues connect into the trunk in a wedge shape, making a structurally strong unit. **For the branch collar to develop, the side branch must be less than half the diameter of the adjacent trunk**. **Less than one-third is preferred.**

If the side branch is too large in diameter, prune back the side branch by 1/3 to 2/3s to slow growth (or remove the branch entirely). Over a period of years, a branch collar will develop. [Figure 4]

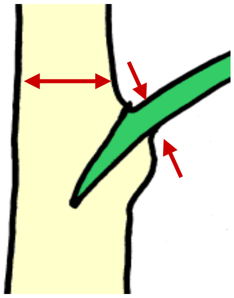


Figure 4. As the branch collar develops, side branch tissues connect into the trunk in a wedge shape making a structurally strong unit. For the branch collar to develop the diameter of the side branch must be less than half the diameter of the adjacent trunk. Less than one-third is preferred.

The size relationship between the trunk and side branch is called ***Aspect Ratio***. A branch union with high *aspect ratio*, like 1 to 1 (two trunks of the same diameter), is highly prone to failure in wind and snow loading. A branch union with a low aspect ratio, like 1 to 3 (side branch is 1/3 the diameter of the adjacent trunk), would not likely fail due to the development of the branch collar.

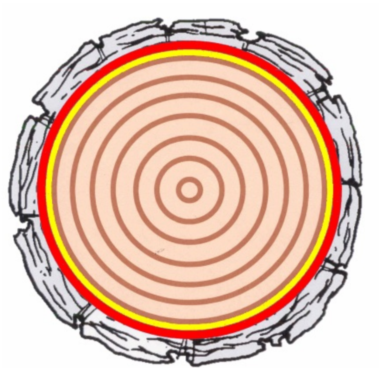
A branch collar will not develop on codominant trunks (adjoining trunks of similar size), making this branch union structurally weak. [Figure 5]

Multiple branches arising at the same location also compromise the branch collar's structural strength. Some tree species (like elm, maple, and crabapple) naturally develop multiple branches at one location. This predisposes the tree to storm damage if the situation is not corrected by structural training when the tree is young. [Figure 5]

Figure 5. (Left) A branch collar does not develop on co-dominant trunks, making the branch union structurally weak. (Right) Multiple branches arising at the same location are also structurally weak as the branch collars cannot knit together into a strong union.

Spread of decay – Due to the constriction of xylem cells where the side branch annual growth rings are overlapped by the trunk annual growth rings, the development of a branch collar significantly reduces the potential spread of decay. In addition, branch unions with a right angle of attachment are more effective in preventing the spread of decay.

To reduce the potential for decay, 1) prune to develop branch collars (the side branch must be less than half the diameter of the adjacent trunk) and 2) select branch unions with a wide angle of attachment. In pruning, remove codominant trunks and narrow branch unions while young (smaller than two inches). [Figure 6]



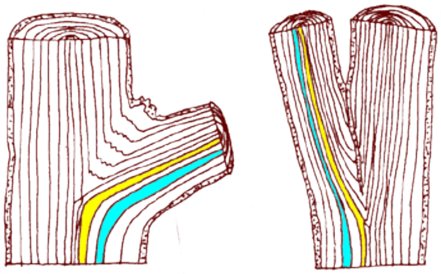


Figure 6. Branch unions that form a right angle are more resistant to decay. A branch union with codominant trunks and a narrow angle of attachment is highly prone to the spread of decay.

How Trees Grow

Xylem tissues – Each year a tree puts on a new outer ring of wood (xylem tissue) under the bark resulting in the increased diameter of a trunk or branch. The number of rings indicates the limb's age and the width of individual rings indicates that year's growing conditions. [Figures 7 and 8]

Figure 7. Tree cross section
Bark – Outer protective covering
Phloem (red in drawing) – Inner bark tissue. *Photosynthates* (sugars and carbohydrates produced in the leaves by photosynthesis) move throughout the tree in the phloem tissues, including down to feed the roots.
Cambial Zone (yellow in drawing) – Layer of active cell division between bark and xylem.
Xylem (brown layers in drawing) – Each year the cambium adds a new ring of xylem tissue just under the cambium layer, resulting in a growth in limb diameter. Xylem tissues are the technical name for the "wood".

Figure 8. The "wood" of a tree is the xylem tissue. Xylem tissues that grew in the spring and early summer enlarge and are the tubes in which water with minerals flows from the roots to the leaves. In a cross-section of the log, these are light colored rings. Xylem tissues that grew mid-summer, at the end of the growth cycle, are higher in fiber content creating a wall to the outside. In a cross-section of a log, these are the darker colored rings.

Younger ***annual growth rings*** (annual rings of xylem tissue) with their living cells active in water transport and storage of photosynthates are called ***sapwood***.

Depending on the species and vigor, sapwood comprises approximately the five youngest (outer) annual growth rings. ***Heartwood,*** the older annual xylem rings no longer active in water transport, is very susceptible to decay organism. Due to chemical changes in these non-living cells, heartwood is often darker in color. [Figure 9]

Figure 9. On this Douglas-fir log, the *sapwood* is the light colored annual growth rings active in water transport and storage of photosynthates. The darker colored *heartwood* in the center has no resistance to decay.

Ray cells grow through the annual growth rings functioning like staples or nails to hold the growth rings together. Ray cells also function as the path to move photosynthates in and out of storage in the xylem tissues. On some species, ray cells are not readily visible. On other species, ray cells create interesting patterns in the wood. [Figure 10]

Figure 10. The cracks on this willow stump show ray cells.

The wood is a series of boxes or "compartments" framed by the ***annual growth rings*** and ***ray cells***. Each compartment is filled with xylem tubes in which water with minerals moves from the roots to the leaves. [Figure 11 and 12]

CODIT: <u>C</u>ompartmentalization <u>o</u>f <u>D</u>ecay <u>i</u>n <u>T</u>rees (How Trees Decay)

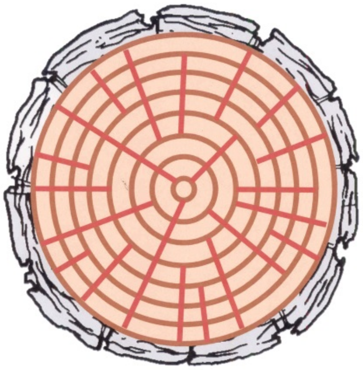


Figure 11. The xylem tissue (wood) is a serious of compartments or boxes created by the annual growth rings and ray cells.

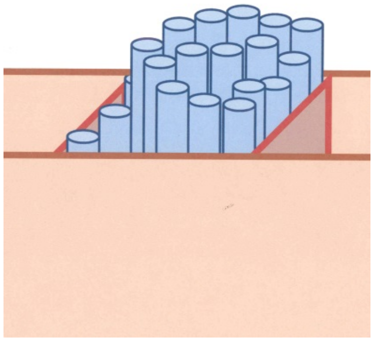


Figure 12. Each compartment or box framed by the annual growth rings and ray cells is filled with xylem tubes. Water moves in the xylem tubes up from the roots.

Unlike animals and people, trees do not replace damaged tissues. Rather, cells in the damaged area undergo a chemical change in a method to seal off or "compartmentalize" the damaged area from the spread of decay. This area of chemical change is called the ***reaction zone***. In most species, a reaction zone appears as darker colored wood.

The spread of decay is related to this compartmentalization of the xylem tubes in a box-like structure created by the annual growth rings and ray cells. In this box-like structure, the four walls differ in their resistance to the spread of decay. [Figures 11]

Wall 1 – Resistance to the spread of decay is very weak up and down inside the xylem tubes. Otherwise, the tubes would plug, stopping the flow of water, and kill the plant. From the point of injury, decay moves upwards to a small degree, but readily moves downward. The downward movement may be 20 or more feet and can include the root system.

Wall 2 – The walls into the older xylem tissues (toward the center of the tree) are also rather weak allowing decay to readily move into older annual growth rings.

Wall 3 – The walls created by the *ray cells* (being high in photosynthates) are somewhat resistant to decay organisms. This may help suppress the spread of decay around the tree.

Wall 4 – New annual growth rings that grow in years after the injury are highly resistant to the spread of decay.

Resistance to the spread of decay by the new annual growth ring and ray cells creates a pipe-like structure, with a decayed center. This concept of how decay spreads in a tree (as controlled by the *annual growth rings* and *ray cells*) is called CODIT, for Compartmentalization Of Decay In Trees. [Figure 13 & 14]

Figure 13. Spread of decay in trees

The spread of decay in trees is suppressed by the four walls created by compartmentalization of the annual growth rings and ray cells.

In the drawing, injury occurred three years ago when the yellow colored annual growth ring was the youngest. That year and everything older (grayed annual growth rings) are subject to a reaction zone and decay. The two new annual growth rings (brown color) that grew in years after the injury are highly resistant to decay.

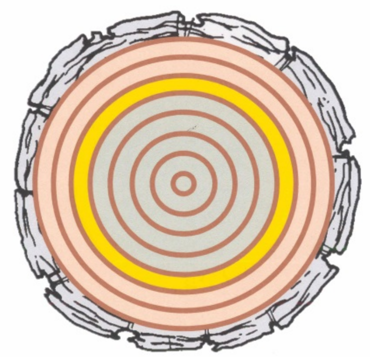


Figure 14. Decay in a tree creates a pipe-like structure with a hollow center. The light colored wood represents new annual growth rings that grew after the year of injury. The darker colored ring is a reaction zone created in the sapwood. The heartwood has completely decayed away.

Evaluating Decay

Percent Shell

A trunk or branch with some internal decay is not necessarily at risk for failure. Structural strength is based on 1) the minimum thickness of the healthy wood (xylem tissues) and 2) the structural strength of wood (tree species).

In evaluating potential hazards, arborists (tree care professionals) work with a technical term called ***percent shell***. Percent shell is calculated by dividing the thickness of the healthy wood at the thinnest point (not including bark, reaction wood, or decaying tissue) by the radius of the trunk/branch (not including bark).

Thirty three percent shell = high risk potential – Trees with a 33% shell or less are termed "high risk" with a statistically high probability of failure in a storm event. For example, a six-inch diameter (three-inch radius) trunk with only a one-inch thick ring of healthy wood would have a 33% shell with a hollow center. If injury or property damage would occur upon tree failure, corrective action (such as removal of the defective branch or removal of the tree) should be considered.

Twenty percent shell = critical risk potential – Trees with a 20% shell or less are considered a "critical risk" with a very high probability of failure in storms. For example, a tree with a ten-inch diameter (five-inch radius) trunk with only one-inch ring of healthy wood would be considered a "critical risk". If injury or property damage would occur upon tree failure, corrective action (such as removal of the defective branch or removal of the tree) should be taken. [Figure 15]

Figure 15. This cottonwood branch has a 25% shell, putting it at "high risk" for potential failure. Percent shell is measured by dividing the thickness of the healthy wood at its narrowest point (not including the reaction wood [darker ring towards the center] and the bark) by the radius of the limb (not including bark).

The *Percent Shell Formula* is valid only when the decay column is centered in the trunk/branch. Researchers are developing other formulas to evaluate off-sided decay and open cavities, which are significantly weaker.

On older mature trees, percent shell formula standards may overstate the thickness of healthy wood needed to be structurally acceptable. Additional research is needed to better clarify this standard for older/mature trees.

Measuring Decay

So, how thick is the healthy wood in a trunk or branch? Researchers are working to address this big question. At the present time, arborists are limited in their ability to measure and evaluate the internal structure of a trunk or limb. The following are procedures with limited potential to evaluate the internal structure of trees.

Visual Indicators of Decay

Large pruning wounds suggest the potential for internal decay. Often decay may be observed within the pruning wound. [Figure 16]

Figure 16. The black material in the pruning cut is decay fungus. Notice the cracking; it also raises flags of structural integrity.

Cankers suggest the potential for internal decay. If the canker extends down into the soil, decay organisms will always be active.

Valleys, ridges, cracks, and splits along the trunk/branch suggest the potential for decay.

Wildlife living inside the tree is a sign of decay.

Abnormal swellings or shapes could be a sign that the tree is growing around a decayed area.

Coring Devices

Note: All coring devices have a small potential to spread decay, as the coring tools break the strong exterior wall of a reaction zone and bring decaying tissues out though healthy wood in the removal. Thus they are generally not used on living trees except when there is a special need to evaluate risk potential. Coring devices only indicate the decay potential at the point of drilling and do not represent the entire trunk or branch.

- An **Increment Borer** is a hand tool that removes a small core from a trunk or branch. The relative effort it takes to drill the borer through various layers of the tree and examination of the core removed gives the arborist some idea about the internal structure at this location. Increment borers are rarely used today in arboriculture.

- **Drill with small drill bit** – Drilling the trunk or branch with a 1/8 inch fully fluted drill bit is a tool used by some arborists. Pressure to push the drill through the annual growth rings and examination of the sawdust removed gives the arborist some idea about the internal structure at this location. An experienced arborist can be rather accurate in evaluation by drilling. Drilling has little value, however, for the inexperienced person. [Figure 17]

Figure 17. Examination of the sawdust and the pressure to push the drill through the annual growth rings give the experienced arborist a handle on internal decay. The yellow earplug on the drill bit helps the arborist know the depth as he works the drill bit in and out. With experience, the arborist could estimate percent shell for the spot drilled.

- A **Resistograph** is a specialized drill that graphs the pressure needed to push a small drill bit through various layers of annual growth rings. The graph gives a visual indication of internal structure at this location. Due to cost, few arborists have a resistograph. [Figure 18]

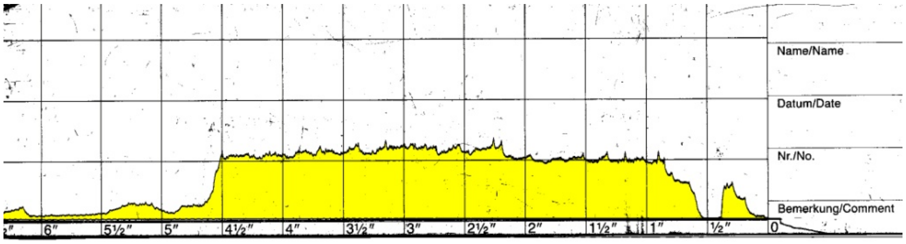


Figure 18. Sample printout of resistograph – This tree has a decayed center at 4½" from the outside bark.

- A **Digital Microprobe**, a specialized drill bit rotating at 7,000 rpm, measures the pressure needed to drill/burn its way through tissues. Data is fed into a computer database for evaluation and printout. This equipment is new to the industry and cost prohibitive for most arborists.

Listening and Radar Devices

- **Rubber mallet** – Tapping the trunk/branch with a rubber mallet and listening for a hollow sound may give some indication of critical internal decay. It will not give any percent shell to help evaluate risk potential and may not be effective on thick bark trees (like old cottonwoods). However, do not totally discount this technique, as may give clues of where to use other tools.

- **PiCUS Sonic Tomography** is a new device that listens to how sound waves move through the trunk/branch. A series of listening devices are attached around the trunk/branch and connected to a computer. When the tree is tapped with a mallet, the computer measures how the sound moves through the wood and creates a graphic cross-section of the trunk/branch interior. Measurements taken at multiple heights up the trunk can generate a three-dimensional image. This type of equipment has the potential to totally change tree care when it becomes available to arborists. Currently the cost is prohibitive for most arborists. [Figure 19]

Figure 19. PiCUS tomography listens to the movement of sound through the tree and draws a picture of the tree's internal structure.

- **Electrical Impedance Tomography** is similar to sonic tomography and measures the distortion of the electrical field by wood conditions. Electrical impedance tomography is better at detecting "Y" crevices and cracks and thus is often used in conjunction with sonic tomography.

- **Tree Radar** – A hand held radar device is run around the trunk/branch. The computer database is sent to the company for evaluation. Currently the cost is prohibitive for most arborists. [Figure 20]

Figure 20 – Tree radar taking a look at the tree's internal wood structure.

Breaks in the Pipe-Like Structure

When a wound or pruning cut breaks the pipe-like structure of a trunk/branch, the tree is especially weak at this location creating a higher potential for tree failure. [Figure 21]

Figure 21. Structural strength is significantly compromised when the pipe-like structure of a trunk has a break in the cylinder wall.

Lack of Trunk/Branch Taper

Branch failure (often breaking a few feet to 1/3 of the branch length out from the branch union) is a common type of storm damage. Branch failures often cause minimal damage to the tree. However, failure of a major branch may create holes in the tree canopy, introduce decay and cracking, and make the tree look unacceptable. ***Trunk failure*** refers to breaking of the lower trunk, above ground level (not at a branch union).

Branch and trunk failures are associated with lack of trunk/branch taper. That is the trunk/branch does not thicken adequately moving down the trunk/branch. This can be caused by pruning up the trunk too fast and by removing small branches and twigs on the lower trunk or lower interior canopy of the tree.

Very upright branches without a lot of side branches also typically fail to develop adequate taper. For structural integrity, shorten these branches with appropriate reduction cuts.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension).
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May 2018

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #612

Pruning Cuts

Outline:

A pruning cut may or may not predispose the tree to internal decay and cracking, depending on the type of cut used, technical precision of the cut, size of the branch removed, species, and general health of the tree. For details on tree growth and decay, refer to *CMG GardenNotes* #611, Tree Growth and Decay.

In pruning, there are three primary types of pruning cuts, ***removal (thinning) cuts, reduction cuts*** and ***heading cuts***, each giving different results in growth and appearance.

Note: In this publication, the term "trunk" refers to the trunk or parent branch, and "side branch" refers to the adjacent side branch arising from the trunk (parent branch). The same relationship exists between a side branch and secondary side branch.

Maximum Diameter of Pruning Cuts

Sapwood, the living cells in the newer xylem rings active in water transport and storage of photosynthates, is resistant to decay. On branches two inches and less in diameter, sapwood dominates the branch structure making the branch resistant to decay. In a removal type cut, ***woundwood*** (the callus tissue that grows over pruning cuts or wounds) quickly grows over these small pruning cuts.

Heartwood, the older xylem rings no longer active in water transport, has no resistance to decay. Due to chemical changes in these nonliving cells, heartwood is often darker in color. Depending on species and growth rates, heartwood becomes significant as branches reach two to four inches in diameter. At approximately four inches, heartwood dominates the branch structure, and the branch becomes highly susceptible to decay organisms and internal cracking. [Figure 1]

Figure 1. Cross section of a Douglas-fir. The light colored outer ring of wood is the sapwood. The dark wood in the center is the heartwood.

In an ideal world, all pruning cuts would be two inches in diameter or smaller. This small size is especially important on tree prone to decay (a factor of species and tree vigor). On tree species resistant to decay, with good vigor and without growth limiting factors (such as severe soil compaction or drought stress), the two-inch or less standard may be pushed to 2-4 inches. [Table 1]

Table 1. Tree Species Prone/Resistant to Decay

Weak Compartmentalizers **<u>Prone to Decay</u>**	**Strong Compartmentalizers** **<u>Resistant to Decay</u>**
o Beech (*Fagus* spp.) o Birch (*Betula* spp.) o Cherry, Peach, Plum and other *Prunus* spp.) o Crabapple (*Malus* spp.) o Hackberry (*Celtis* spp.) o Horsechestnut and Buckeye (*Aesculus spp.*) o Maples (some *Acer* spp.): Norway, Silver o Oak (some *Quercus* spp.): Pin, Shumard o Poplar, Cottonwood, & Aspen (*Populus* spp.) o Redbud (*Cercis* spp.) o Willow (*Salix* spp.)	o Black Locust (*Robinia pseudoacacia*) o Catalpa (*Catalpa* spp.) o Elm, American (*Ulmus Americana*) o Honeylocust (*Gleditsia* spp.) o Hornbean (*Carpinus* spp.) o Maples (some *Acer* spp.): Red, Sugar o Oak (some *Quercus* spp.): Bur, English, Live, Northern Red, White o Pine (some *Pinus* spp.) o Walnut (*Juglans* spp.) o Yew (*Taxus* spp.) Note: Will lose resistance with stress factors such as severe soil compaction, drought, hardscape over rooting area, etc.

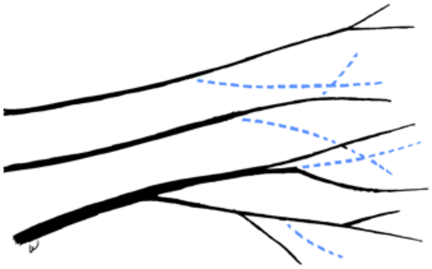
However, we don't live in the ideal world. Sometime larger diameter cuts are needed. Any pruning cut four inches and larger needs to take into account the increased risk for failure and reduced health associated with internal decay and cracking. Cuts on large branches often create new problems with high potential for failure!

Removal Cuts

Removal cuts (also known as thinning cuts or collar cuts) remove side branches back to the <u>larger</u> parent branch or trunk. If the branch union has a branch collar, removal cuts have the advantage of preserving the *branch defense zone*, providing a strong defense against internal decay.

Removal cuts reduce the canopy density but have little influence on height. Thinning with removal cuts allows better light penetration into the canopy, which encourages desired growth of interior branches. This improves trunk taper and increases the general vigor of primary branches and the trunk. Removal cuts reduce the weight on large branches, giving the tree resilience to snow loading. The primary use of removal cuts is in structural pruning of small, middle-aged and older trees and on shrubs.

Figure 2. Removal cuts eliminate a side branch back to the trunk or parent branch.



Two features on the branch, the *branch collar* and the *branch bark ridge*, help identify the proper cut angle. The ***branch collar*** is the area where the annual growth rings of the trunk fold in between the annual growth rings of the side branch, in a manner similar to shuffling a deck of cards. On some species, the branch collar is readily noticeable, while on other species the branch collar is less obvious. [Figure 3]

The ***branch bark ridge*** is where the bark from the trunk joins the bark from the side branch. It looks like a dark line or small mountain range extending out from the crotch down both sides of the trunk/branch. It mirrors the angle of attachment of the side branch. [Figure 3]

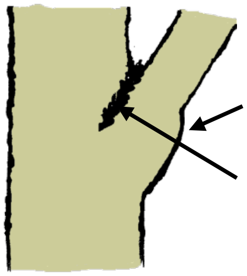


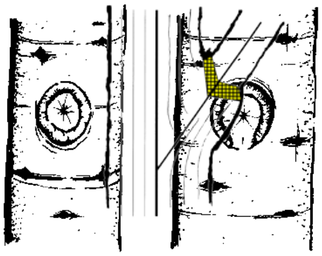
Figure 3. Branch collar and branch bark ridge.

Branch Collar
Trunk tissues overlap with side branch tissues

Branch Bark Ridge
Trunk bark meets side branch bark

Within the branch collar is a narrow cone of cells called the ***branch defense zone***. These cells activate the growth of ***woundwood***, the callus tissue that grows over the pruning cut. With a proper cut, the woundwood grows out from all sides in a donut shape over the wound. If the branch collar is nicked, the woundwood does not grow from that point. It is common to see a pruning cut where the woundwood fills in only from two sides, indicating that the top and bottom of the branch collar were injured. [Figures 4]

Figure 4. Branch Defense Zone – Within the branch collar is the branch defense zone, a narrow ring of cells that effectively initiates a strong reaction in which chemical changes protect the trunk from decay. If the branch collar is cut or nicked in pruning, the defense zone may fail, predisposing the wound to decay.



The branch defense zone also plays an important role in activating a strong reaction zone inhibiting the spread of decay organisms into the trunk. If the branch collar is injured or removed during pruning, the branch defense zone will fail, limiting the growth of woundwood and predisposing the cut to decay. Thus, a primary objective in a correct removal cut is to preserve the branch collar intact.

With a *removal cut,* the final cut should be just beyond the branch collar. Because the woundwood that grows over the pruning cut originates in the branch defense zone, it is imperative that the branch collar not be cut or otherwise injured in pruning. To eliminate error, cut a little beyond the collar region (i.e., 1/8 inch for small-diameter twigs and 1/4 inch for larger branches). [Figure 5]

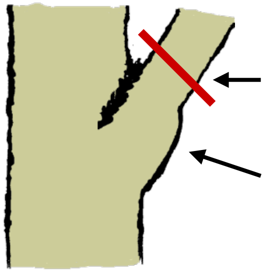


Figure5. Removal Cut

Final Cut made just outside the branch collar, taking care not to nick the branch collar.

Branch Collar
Trunk tissues overlap with side branch tissues

In species where the branch collar is not clearly identifiable, look for the branch bark ridge. Make the final cut at the angle that mirrors (lies opposite) the angle of the *branch bark ridge*. [Figure 6]

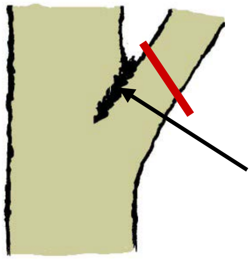


Figure 6. When the branch collar is not clearly identifiable, make the final *thinning cut* at the angle that mirrors the angle of the *branch bark ridge*.

Branch Bark Ridge

When a branch union has no branch collar (the side branch is greater than half the diameter of the adjacent trunk), tilt the angle of the final cut out a little more to minimize the size of the wound. Be aware that in the absence of a branch collar there is no branch defense zone to activate rapid woodwood growth and activate a strong reaction to suppress the potential for decay. (Fig.7.)

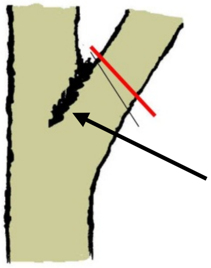


Figure 7. When the branch union has no branch collar (the side branch is greater than half the trunk diameter), tilt the cut angle out a little more to reduce the diameter of the cut wound.

Branch Bark Ridge

When removing a dead branch, the final cut should be just outside the branch collar of live bark tissue. If a collar of live wood has begun to grow out along the dead branch, remove only the dead stub, leaving the collar intact. Do not cut into living tissues. [Figure 8]

Figure 8. When removing a dead branch, do not cut into or otherwise damage the branch collar or woundwood growing around the dead branch.

Reduction Cuts

Reduction cuts remove a larger branch or trunk back to a smaller-diameter side branch. Reduction cuts are commonly used in training young trees. They are also the only type of cut that will significantly lower a tree's height.

However, reduction cuts do not have a *branch defense zone*, leaving the branch with a weak defense against decay. This is not a major concern on young, actively growing branches. However, reduction cuts are discouraged on mature trees and on limbs larger than two inches in diameter. On trees under stress or in decline, avoid reduction cuts as they can accelerate the decline.

In a reduction cut, make the final cut to bisect (split the difference) between the *branch bark ridge* angle and an imaginary line perpendicular to the stem being removed. Alternatively, the angle could be tilted up a little more to perpendicular to reduce the size of the wound. The exact angle is not critical as long as it is not flat on top (water needs to readily run off). [Figure 9]

To prevent undesired suckering at this point, the diameter of the smaller side branch should be at least one-third (preferably one-half) the diameter of the larger branch being removed. If the diameter of the smaller branch is less than one-third the diameter of the larger branch being removed, the cut is considered a heading cut and is generally unacceptable in pruning standards. [Figures 10 and 11]

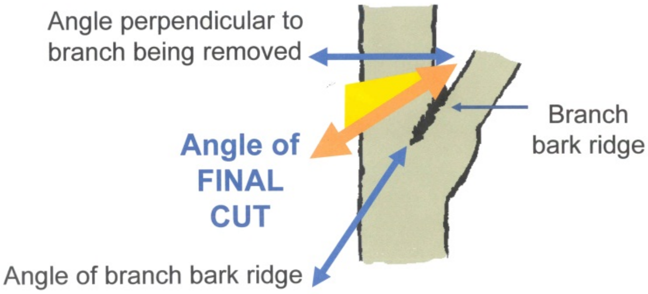


Figure 9. Reduction Cut – When pruning back a larger branch to a smaller branch, the angle of the final cut should split the difference between the angle of the *branch bark ridge* and the angle perpendicular to the branch being removed.

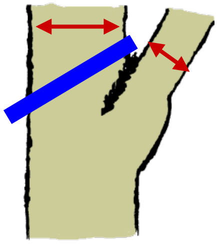


Figure 10. To prevent excessive suckering, the smaller branch should be at least one-third the diameter of the larger branch.

Figure 11. This adventitious sucker growth from a reduction cut is structurally unsound and prone to storm damage as it grows.

Heading Cuts

Heading cuts remove the growing tips of branches. This releases the side buds to grow, resulting in more dense growth at the point of pruning. [Figure 12]

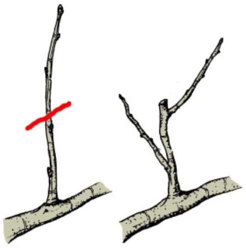
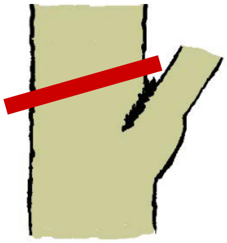


Figure 12. Heading cuts remove the growing tips of branches, releasing side buds to grow.

Another type of undesirable heading cut is the removal of a large trunk/branch back to a smaller side branch when the side branch is less than one-third the size of the larger trunk being removed. Structurally unsound water sprouts often emerge along the branch, and the tree may become more unsound than before the pruning. [Figure 13]

Figure 13. Removing a larger trunk or branch back to a small side branch when the side branch is less than one-third the diameter of the adjacent trunk is also considered a heading cut. This leads to structurally unsound growth of water sprouts and is not considered an acceptable pruning cut.



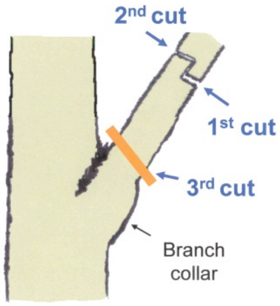
Heading cuts are undesirable for most pruning objectives on shade trees. Topping a tree with heading cuts gives a surge of new branch growth at the tree's top. The new growth is often structurally unsound and prone to storm damage. Growth in the tree's interior thins out from increased shading, decreasing the tree's overall health and vigor.

On shrubs, heading cuts or "shearing" creates a very dense upper/outer canopy that shades out the lower/inner portion, creating a woody base.

Three-Cut Method for Larger Branches

When removing any branch larger than one inch in diameter, use a three-cut method to protect the bark from tearing. [Figure 14]

Figure 14. Three-cut method for any branch larger than one inch.



Cut 1. Coming out 12 to 15 inches from the branch union (crotch), make an undercut approximately one-third to halfway through the branch.

Cut 2. Moving a couple of inches out past the first cut, make the second cut from above, removing the branch. This double-cut method prevents the weight of the branch from tearing the bark below the collar.

Cut 3. Make the third and final cut at the correct pruning point. For example, on a *removal cut*, just outside the branch collar. For *woundwood* growth, take extra caution not to cut into or otherwise injure the branch collar.

Wound Dressings

Wound dressings do not prevent decay organisms from moving in. In fact, the older, tar-type dressings actually interfere with the natural *woundwood* growth and may create conditions favorable for decay organisms. Generally, leave pruning cuts dry and untreated.

Occasionally a thin layer of water-based dressing or paint may be applied solely for aesthetic purposes. Never use an oil-based paint, tar or other materials that contain petroleum solvents. A dark-colored material over a wound may predispose the wound site to winter injury. When managing diseases such as fire blight, a fungicide/bactericide may be used as a wound dressing.

The key to good wound closure is proper pruning, making a smooth cut just beyond the *branch collar*, and making all cuts on branches less than two inches in diameter. Trees under stress (soil compaction, drought, overly wet soils, insect or disease problems, lawnmower damage to the trunk, etc.) are less capable of fighting the invasion of decay organisms.

Time of Year to Prune

Dead, diseased, and damaged wood can be removed any time of year as needed.

When it comes to removing live wood, there are better times of year for pruning. Light pruning—up to 10% of the foliage—may generally be done any time of year on healthy trees without stress factors.

Late winter—Pruning in the late dormant season (before buds swell) is considered the routine pruning time on many tree species. However, some species are prone to bleeding if pruned in the spring. While this is more of a cosmetic issue than a health issue, most arborists avoid pruning bleeders in the late dormant season. [Table 2]

Table 2.
Examples of Trees Prone to Spring Bleeding

- Birch
- Black locust
- Elms
- Goldenchain tree
- Hackberry
- Japanese pagodatree
- Kentucky coffeetree
- Maple
- Mulberry
- Poplar
- Walnut
- Willow

Spring, during growth flush, is generally considered an undesirable time to prune trees. The bark and cambium tissues are easily damaged. Pruning may stimulate excessive watersprout growth or reduce overall vigor.

Midsummer, following growth flush (as leaves reach full size, harden and turn dark summer green) is considered an excellent time to prune. It is the preferred time for spring bleeders. It may be the best time of year to suppress decay potential.

Late summer to fall is generally considered an undesirable time to prune. It may stimulate canopy growth and interfere with winter hardiness.

Late fall to early winter is generally considered an undesirable time to prune. Extreme cold (below zero) may cause cambium damage near the pruning cut.

Drought – Do not remove live wood from trees in drought stress. This removes stored photosynthates that the tree is living on during the stress.

Pest management consideration – In some insect management programs, pruning may need to be timed before insect flight periods or avoided during insect flight periods.

Pruning Equipment

Hand pruners are used to cut small limbs up to ¼ to ½ inch in diameter (depending on the wood hardness). The bypass or scissor-type pruner (cutting as the blade crosses past the hooked anvil in a scissor action) is considered the best type. The anvil type (cutting as the blade pushes against the anvil) is more prone to tearing and mashing the tissues. The best advice on pruners is to purchase the best pair you can afford. It will last for years. Inexpensive pruners are short-lived.

In using bypass-type hand pruners, place the blade toward the tree with the anvil toward the outside. This allows for a closer cut. For bypass pruners, sharpen only the beveled edge of the blade pointing toward the anvil, never the anvil side of the blade.

Loppers are used for larger branches, generally up to ½ inch in diameter. With long handles, they make quick work of cutting up prunings on the ground.

Pole pruners make poor-quality cuts. They are used to cut small branches out of reach from the ground.

Handsaws are used for branches larger than ½ inch. There are two general types of tree saws. Tree saws with curved blades cut as the saw is pulled and are considered safer to use. Tree saws with straight blades cut as the saw is pushed. To remove the moist sawdust, tree saws have wider teeth spread than lumber saws. In a cut larger than 1 inch, a three-cut method should be used.

Chain saws are extremely dangerous. In the United States 40,000 to 90,000 people have serious injuries, and 40 to 60 are fatally injured each year from chain saw accidents. Most accidents occur to the left leg, the shoulders, and the face. Chain saws should only be used by someone specifically trained in chain saw safety. A common accident occurs when the limb kicks back as the cut is being completed. Personal protective clothing is also needed. Safety glasses and boots are required by law. Helmet, hearing protection, gloves, and leg protection are also recommended.

Authors: David Whiting (CSU Extension, retired), with Alison O'Connor and Eric Hammond (CSU Extension). Artwork by David Whiting and Scott Johnson; used by permission.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #613

Structural Training of Young Shade Trees

Pruning Basics

Structural training is a multi-year investment requiring evaluation and corrective pruning on an annual basis. Young trees require little pruning. However, the training a tree receives while in the early "growth phase" of its life cycle determines its structural integrity for life. Many trees become prone to wind and snow damage as they mature due to the lack of structural training while young. Proper structural training of the young tree makes it especially resilient to storm damage when mature.

In this *CMG GardenNotes*, we look at the ideal structure for a young tree making it resilient to wind and snow loading. In selecting trees at the nursery, choose trees that will not require extensive pruning to reach the desired structure (e.g., no codominant trunks, straight central leader, evening branching along all sides, etc.). In real world settings, not all trees will fit the ideal description. The objective is to set the direction of what is desirable, recognizing that some trees simply do not meet the preferred structure for storm resilience.

Note: For additional information on a tree's life cycle, refer to CMG GardenNotes #101, *Plant Health Care*. For additional information on branch collar development refer to CMG GardenNotes #611, *Tree Growth and Decay* For additional information on types of cuts, refer to CMG GardenNotes #612, *Pruning Cuts*.

Time of year

Structural pruning is typically done in late winter, before trees break dormancy. Pruning is generally avoided during the spring growth flush as bark is rather tender at this point in time. Mid-summer pruning is preferred for tree species prone to bleeding if spring pruned (including birch, black locust, elms, goldenchain tree, hackberry, Japanese pagodatree, Kentucky coffeetree, maples, mulberry, poplars, walnuts, and willows).

Size of branches

Ideally, all pruning cuts are two inches in diameter and smaller. On tree species more resistant to decay, the standard could be pushed to two to four inches, maximum (depending on actual vigor and growth of the tree).

The structural training stage basically ends when pruning cuts would be greater than this standard. Larger cuts become general pruning rather than training of the tree. Any pruning cut four inches and larger must be justified by taking into account the potential for decay.

Structural Training Steps

Structural training follows a series of steps. Considerations at each step determine the direction to take in following steps.

Step 1 – Dosage: Maximum Amount of Live Wood/Foliage to Remove

The maximum amount of foliage/live wood that can be removed per season depends on the actual growth rate of the tree. Look at six to 12 branches around the tree to assess growth rates. Look for what is the typical growth rate for most branches, rather than the fastest or slowest growing branches. [Table 1]

Growth and Annual Growth Rings – Starting at the branch tip, look at the length back to the first ***annual growth ring*** (*terminal bud scare*). This is where the growth ended the previous year. The annual growth ring looks like a small ring or crown going completely around the twig. On some trees it is easy to identify, on other trees it is only a simple ring. To avoid confusing it with a side bud, the annual growth ring goes completely around the twig. On some trees, a slight change in bark color helps identify where the annual growth rings are located. [Figure 1]

Figure 1. The annual growth rings (terminal bud scar) looks like a small ring or decorative crown going complete around the stem.

Table 1. Dosage: Maximum Amount of Live Wood/Foliage to Remove per Season on Young, Actively Growing, Trees

Actual Annual Growth	Estimated Maximum Amount of Live Wood/Foliage to Remove Per Season
3 to 4+ feet.	25% to 50%
1 to 2 feet	10% to 25%
6 to 12 inches	Approximately 10%.
Little annual growth.	Limit pruning to a light dosage, correcting codominant trunks.
Tree under critical stress with minimal annual growth.	Limit pruning to cleaning (removal of dead and damaged branches).

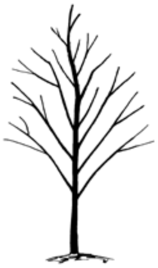
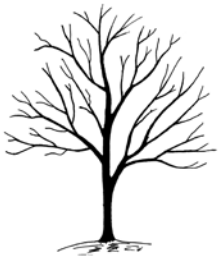
In situations where trees are pruned annually (the ideal situation), the appropriate pruning dose would be light. However, in real world situations, trees are often pruned only once every several years. Here the appropriate pruning dose may be higher. In situations where heavy pruning is needed, complete the work over a period of years.

Excessive pruning can lead to watersprouts (upright, sucker-like shoots emerging on the trunk or branches). Waterspouts, a common response to over pruning and storm damage, are structurally unsound. Excessive pruning also creates a hormone imbalance between auxins (produced in the terminal buds) which stimulates root growth, and gibberellins (produced in the root tips) which stimulates canopy growth. Since roots have multiple regeneration periods each season, this imbalance puts the root system into a decline, resulting in a multi-year decline in canopy growth.

<u>Step 2 – Growth Habit</u>

The desired branching structure depends on the natural growth habit of the tree. Trees with an ***excurrent*** growth habit develop with a ***central leader*** (single trunk) to the top. Examples of excurrent trees include aspen, linden, and pines. Trees with a ***decurrent*** growth habit develop a more rounded form with multiple ***scaffold branches*** (secondary trunk-like branches) or secondary trunks originating from the trunk. Examples of decurrent trees include maple, ash, elm, and honeylocust. Table 1 shows comparisons in pruning objective of excurrent and decurrent trees. [Table 2]

Table 2 – Structural Training Objectives for Young Trees

	 **Excurrent Trees** Single trunk to the top	 **Decurrent Trees** Scaffold branches arise from the trunk becoming the main structural system
Training Objective 1	Remove dead and damaged branches.	
Training Objective 2	Maintain single trunk to top of tree.	Maintain single dominant trunk to at least two-thirds of the tree's mature height.
Training Objective 3	Select lowest permanent branch.	Select lowest scaffold branch.
Training Objective 4	Maintain diameter of all branches less than one-half the diameter of adjacent trunk.	Select other scaffold branches.
Training Objective 5	Manage temporary branches removing them over time (before they reach a two inch diameter).	

Step 3 – Pruning Objectives

Structural training of young shade trees is based on five pruning objectives. Evaluation of all five is generally done before actual pruning occurs, as considerations are interrelated.

Objective 1 – Remove Dead and Damaged Branches

Actual pruning begins with the removal of dead, broken, and damaged branches. [Figure 2]

Competing branches (branches growing in the same space) are also a consideration. However, which one to keep and which ones to remove generally sorts out in the other steps.

Figure 2. Rubbing branches

Objective 2 – Develop Trunk

The primary pruning objective is to eliminate multiple trunks. If multiple trunks start to develop, remove all but one. If the leader is killed, select a side branch to become the new leader, removing its competition (a multi-year process). It may be helpful to loosely tie the new leader to a stick to bend it to an upward orientation.

Codominant Trunks

In training trees, arborists have zero tolerance for ***codominant trunks*** (adjacent trunks of similar diameter). Codominant trunks account for the majority of wind and snow related tree failures in Colorado and other snowy climates.

With codominant trunks, no branch collar develops to wrap the two trunks together. (The ***branch collar*** is the area where trunk wood wraps around the branch wood creating a structurally strong branch union.) The ***branch union*** (crotch) is structurally weak and prone to breakage as the trunks reach a size greater than 3-4 inches in diameter. [Figure 3]

Note: In selecting a tree, it is advisable to avoid purchasing trees with codominant trunks.

Figure 3. Codominant trunks – A branch union with two trunks of similar size is structurally weak and prone to storm damage. "Included bark" (hidden bark) between the trunks prevents the wood from growing together. Without a branch collar, wood of the two trunks does not knit together. In structural pruning, there is zero tolerance for codominant trunks.

Excurrent Trees – Maintain Single Trunk to Top of Tree

On excurrent (central leader) trees, maintain a single trunk to the top of the tree. If a side branch begins growing upright in a trunk-like fashion, prune it back to redirect the growth to an outward direction or removed it entirely. Generally, do not prune or "head back" the central leader (trunk). [Figure 4]

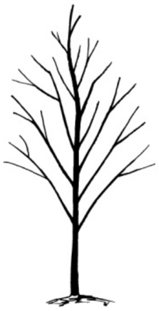


Figure 4. On excurrent trees, maintain a single trunk to the top.

Decurrent Trees – Maintain Single Dominant Trunk to at Least Two-thirds of the Tree's Mature Height

The overall objective with decurrent trees is to develop a structural system of *scaffold branches* rather than secondary trunks. ***Scaffold branches*** are the major structural, trunk-like branches that originate off of the trunk. By definition, a scaffold branch must be less than one-half the size of the adjacent trunk. Less than one-third is preferred. This allows for a branch collar to develop, creating a structurally strong branch union. In contrast, ***secondary trunks*** lack the size relationship for branch collar development, creating structurally weak branch unions.

In an open landscape setting, most decurrent trees naturally develop multiple secondary trunks often arising at the same location predisposing the tree to storm damage.

On decurrent trees, maintain a single dominant trunk to at least two-thirds of the tree's mature height. For example, if the mature tree height is 30 feet, a single trunk should dominate to at least 20 feet. If the mature tree reaches 60 feet, a single trunk dominates to at least 40 feet. Scaffold branches become the secondary framework of the tree. By training, secondary trunks are avoided. [Figure5]

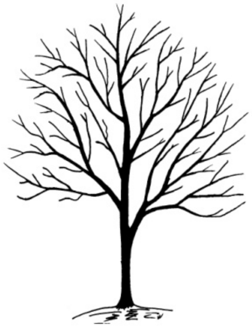


Figure 5. On decurrent trees, maintain a single dominant trunk to at least two-thirds of the tree's mature height.

If vigorously upward-growing side branches begin to compete with the central leader, prune back the branch to a more outward growing side branch. Some tree species naturally put out many upward growing secondary trunks. Heavy pruning over a period of years will be desirable to establish a dominant central leader with subordinate smaller side branches.

Generally, do not "head-back" (prune) the central leader.

Objective 3 – Select Lowest Branch

It is often desirable to ***raise*** the canopy (remove lower branches) so they are out of the way of human activities like mowing the lawn and lawn games. For shade trees in lawns, patios, and along sidewalks, the lowest permanent branch generally starts 7 to 10 feet above ground level. On smaller specimen trees in a garden bed, lower branching may be preferred. Over streets, the lowest branches start at 14 feet. In wooded settings, the canopy is raised to 10 feet as a fire prevention technique.

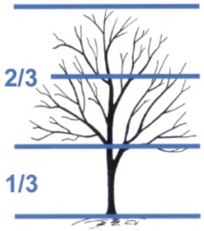
Many gardeners mistakenly plan to remove lower branches as the tree reaches a more mature size. Removing these larger branches as the tree matures opens the tree to internal decay. On decurrent trees, these lower branches typically make up a significant portion of the tree.

The objective is to identify what will be the lowest permanent branch at this early time in life, allowing the gardener to manage and remove lower branches over time. Branches below the lowest permanent branch are called ***temporary branches***. Management and removal of the temporary branches will be discussed in Objective 5.

The lowest branch on any tree should originate in the bottom one-third of the tree. In establishing the lowest branch, don't "limb-up" a young tree too early in its growth. To develop a trunk taper resilient to wind, one-half of the leafing area should be found in the lower two-thirds of the tree. Lower ***temporary branches*** should be removed only as the tree grows in height, but before they reach two-inches in diameter. (Refer to Objective 5 for details). [Figure 6]

Figure 6. To develop a strong trunk taper, at least one-half of the foliage must be in the lower two-thirds of the tree.

Temporary branches below the lowest permanent branches will be removed over time. (Refer to Objective 5.)



On excurrent trees, select the lowest permanent branch. Branches below this point become temporary branches.

On decurrent trees, select the lowest permanent branch, which will become the first *scaffold branch*. Other scaffold branches will be selected based on the location of this branch. Branches below the lowest (first) scaffold branch become temporary branches.

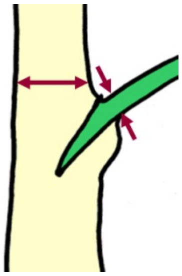
Objective 4 – Developing Branching Structure

In Objective 4, branches are managed differently for excurrent and decurrent trees.

Excurrent Trees: Maintain Diameter of All Branches Less Than One-Half the Trunk Diameter

For structural integrity, side branches must be less than one-half the diameter of the adjacent trunk. Less than one-third is preferred. Without this important size ratio, the branch collar fails to develop, creating a weak branch union. [Figure 7]

Figure 7. For a branch collar to develop, the side branch must be less than one-half the diameter of the adjacent trunk.



If the diameter of a branch is growing too fast compared to the trunk, prune the branch back by 1/3 to 2/3s to slow its growth rate.

Spacing of branches along the trunk is not a critical structural issue on excurrent trees, as long as the trunk to side branch ratio is within limits. Many species of excurrent trees develop branches in a whorl. This is structurally acceptable as long as the branch to trunk size ratios are within limits. On some species of trees, thinning of competing branches (branches growing in the same space with the potential to rub and damage each other) may be desirable.

Decurrent Trees: Select Other Scaffold Branches

In the structural pruning of decurrent trees, an overall intent is to guide development of the branching structure, creating *scaffold branches* and eliminating secondary trunks. The intent is to create strong branch unions with a branch collar. For the branch collar to develop, the branch must be less than one-half (less than one-third preferable) the size of the adjacent trunk. Without the branch collar, secondary trunks are structurally weak and prone to breakage as the tree matures.

The selection of other scaffold branches takes place over a period of years as the tree grows in height. Branches along the trunk not destined to become scaffold branches are managed as ***temporary branches*** being removed over time.

In selecting other scaffold branches, consider branch spacing and branch union (crotch) angles. In an open landscape setting, decurrent trees naturally develop more branches than is desirable, predisposing the tree to wind and snow damage as the tree matures. The objective of training is to correct this situation while the tree is young.

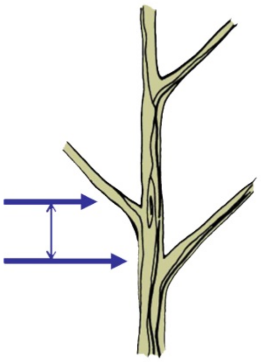
Branch spacing – Desired spacing for scaffold branches depends on the mature height of the tree. The rule of thumb is to allow at least 6 inches per 10 feet of mature tree height. Table 2 shows spacing for various mature heights. [Table 3]

Table 3 – Minimum Spacing for Scaffold Branches

Mature Tree Height	Minimum Scaffold Branch Spacing
20 feet	1 foot
30 feet	1.5 feet
40 feet	2 feet
50 feet	2.5 feet
60 feet	3 feet
70 feet	3.5 feet
80 feet	4 feet

Select scaffold branches with even distribution around the tree trunk. Where a scaffold branch is growing directly above another, vertical spacing should be at least 60 inches on trees with a mature height of 30 feet and taller, and 18 to 36 inches on smaller trees. [Figure 8]

Figure 8. Minimum scaffold branch spacing is based on the mature height of the tree at 6 inches per 10 feet of mature height. A tree that will grow to 30 feet should have scaffold branches spaced at least 18 inches apart.



Multiple branching at one location — When multiple scaffold branches arise from the same area, the branch collars cannot knit together into a strong branch union. These branches become vulnerable to wind and snow damage. In training a young decurrent tree, eliminate multiple branches arising at the same location. Many common shade trees, including maples, cottonwoods, poplars, and elms naturally develop multiple branching at the same location. [Figure 8]

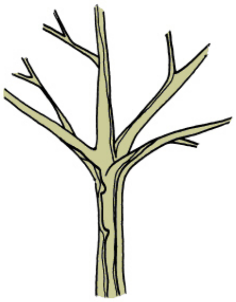


Figure 8. Multiple branches originating from the same location are structurally weak. An objective in structural training is to space scaffold branches.

Branch union angles – The problem with a narrow branch union (crotch) angle is the development of ***included bark*** (bark against bark inside the branch union) as the tree grows. With included bark, the branch collar cannot wrap the trunk wood around the side branch wood, creating a weak branch union. A branch union with a wide angle of attachment is also more resistant to the spread of decay.

In selecting scaffold branches, select outward growing branches with a wide angle of attachment rather than upward growing branches.

Objective 5 – Manage Temporary Branches, Removing Them Over Time

Temporary branches on the lower trunk are important to the tree's early growth. *Photosynthates* (carbohydrates and proteins produced by photosynthesis) produced in the lower canopy help develop the natural trunk taper giving wind resilience. Shading by the lower foliage helps reduce sunscald of the tender bark.

Manage growth on temporary branches by keeping them short and removing them over time as the tree grows in height. Ideally, temporary branches are pruned back to a few buds. On temporary branches that have grown significantly before training begins, start by cutting them back by about 50%, removing more over time.

Temporary branches are removed before they reach a two inch diameter. Pruning back a temporary branch slows the growth, giving more time before the branch must be removed due to size.

Keeping temporary branches short suppresses their rapid growth while encouraging the desired growth up in the scaffold branch structure. During the early training process, a young tree will have a cylinder of short temporary branches along the lower trunk (below the lowest permanent branch), with the tree's significant growth developing up in the permanent branch structure. [Figure 10]

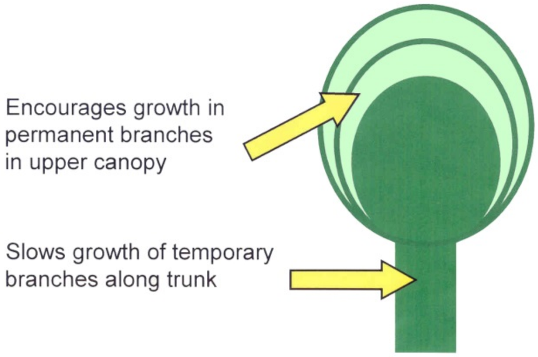


Figure 910 of a young tree: temporary branches on the lower trunk (below the lowest permanent branch) create a narrow cylinder of short branches.

Preferred vertical spacing of temporary branches is four to six inches. Thus some branches would be removed outright. On decurrent trees, no temporary branch should be within six inches of a scaffold branch. Branches between scaffold branches are also considered temporary branches. Maintain these temporary branches for one to five years, removing them before they reach a two-inch diameter.

On decurrent trees, it generally takes several years to manage and eventually remove temporary branches. Remember that the total amount of foliage that can be removed per season depends on the growth rate of the tree. In purchasing, select trees that require minimum corrective pruning to make them structurally sound.

Authors: David Whiting (CSU Extension, retired), with Alison O'Connor and Eric Hammond (CSU Extension).

Photographs and line drawings by David Whiting; used by permission.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #614

Structural Training Summary

for Young Shade Trees

Dosage: How much to remove

The amount of live wood/foliage to remove per season depends on the growth rate of the tree. Look at 6 to 12 twigs around the tree to assess actual growth rates.

- For trees with critical stress and insignificant annual growth, limit pruning to *cleaning* (removal for dead and damaged branches).
- For trees putting on little growth, limit pruning to a light dosage correcting codominant trunks.
- For trees putting on approximately six to 12 inches of new growth per season, 10% would be an estimate.
- For trees putting on a foot or two of new growth, 25% would be an estimate.
- Trees putting on three to four plus feet of new growth may tolerate 25% to 50% of the live wood/foliage being removed.

Ideally, all pruning cuts are two inches in diameter and smaller.

Growth habit

The desired branching structure depends on the natural growth habit of the tree. Trees with an ***excurrent*** growth habit develop with a ***central leader*** (single trunk) to the top. Examples of excurrent trees include Aspen, Linden and pines. Trees with a ***decurrent*** growth habit develop a more rounded form with multiple ***scaffold branches*** (secondary trunk-like branches) or secondary trunks originating from the trunk. Examples of decurrent trees include Maple, Ash, Elm and Honeylocust.

Codominant trunks – A branch union with two trunks of similar size is structurally weak and prone to storm damage. “Included bark” (hidden bark) between the trunks prevents the wood from growing together. In structural pruning, there is zero tolerance for codominant trunks.

Developing Trunk

The primary pruning objective is to eliminate multiple secondary and codominant trunks. If multiple trunks start to develop, remove all but one. If the leader is killed, select a side branch to become the new leader, removing competition.

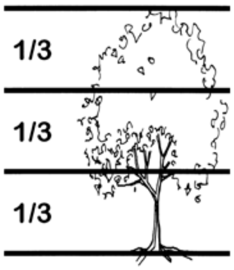
On excurrent (central leader) trees, maintain a single trunk to the top of the tree. If a side branch begins growing upright in a trunk-like fashion, prune it back, redirecting growth to an outward direction. Do not prune or “head back” the central leader (trunk).

On decurrent trees, maintain a single dominant trunk to at least 2/3s of the tree’s mature height. For example, if the mature tree height is 30 feet, a single trunk should dominate to at least 20 feet. If the mature tree reaches 60 foot, a single trunk dominates to at least 40 feet. Scaffold branches become the secondary framework of the tree. Through training, secondary trunks are avoided. Do not “head-back” (prune) the central leader.

The overall objective with decurrent trees is to develop a structural system of *scaffold branches* rather than secondary trunks. ***Scaffold branches*** are the major structural, trunk-like branches that originate off of the trunk. By definition, a scaffold branch must be less than one-half the size of the adjacent trunk. Less than one-third is preferred. This allows for a branch collar to develop creating a structurally strong branch union. In contrast, “secondary trunks” lack the size relationship for branch collar development creating structurally weak branch unions. In an open landscape setting, most decurrent trees naturally develop multiple secondary trunks arising at the same location predisposing the tree to storm damage.

Managing Side Branches

Selecting lowest branch – The objective is to identify what will become the lowest permanent branch early in the tree's life, allowing the gardener to manage and remove lower branches over time. Branches below the lowest permanent branch are called ***temporary branches***.



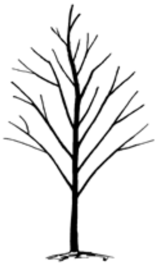
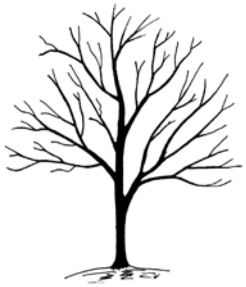
To develop a strong trunk taper, at least one-half of the foliage must be in the lower two-thirds of the tree. *Temporary branches* below the lowest permanent branches will be removed over time, as the tree grows in height.

<u>On excurrent trees</u>, select the lowest permanent branch. Branches below this point become temporary branches.

<u>On decurrent trees</u>, select the lowest (first) scaffold branch. Other scaffold branches will be selected based on the location of this branch. Branches below the lowest (first) scaffold branch become temporary branches.

Developing branching structure – For a branch collar to develop (creating a structurally strong branch union) the side branch must be less than one-half the diameter of the adjacent trunk. Less than one-third is preferred. If a side branch is growing too fast, compared to the trunk, prune back the side-branch to slow the growth.

In structural training of decurrent trees, the overall intent is to guide development of the branching structure, creating *scaffold branches* and eliminating secondary trunks. Minimum spacing on scaffold branches is based on the mature height of the tree, based on the formula of six inches per ten feet of mature height. For example, a tree with a mature height of 30 feet should have scaffold branches spaced at least 18 inches apart.

	 **Excurrent Trees** Single trunk to the top	 **Decurrent Trees** Scaffold branches arise from the trunk becoming the main structural system
Objective 1	Remove dead and damaged branches.	
Objective 2	Maintain single trunk to top of tree.	Maintain single dominant trunk to at least 2/3^{rds} of the tree's mature height.
Objective 3	Select lowest permanent branch.	Select lowest scaffold branch.
Objective 4	Maintain diameter of all branches less than ½ the diameter of adjacent trunk.	Select other scaffold branches (Scaffold branch must be less than ½ the diameter of adjacent trunk.)
Objective 5	Manage growth on temporary branches by routinely pruning them back, and eventually removing them over time as the tree grows in height. Ideally, temporary branches are pruned back to a few buds. On temporary branches that have grown significantly before training begins, start by cutting them back by about 50%, removing more over time. <u>Temporary branches are removed before they reach a two inch diameter.</u>	

MASTER GARDENER
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CMG GardenNotes #615

Pruning Mature Shade Trees

Outline:

When to Hire a Professional Certified Arborist

Pruning large trees is a safety issue beyond the training and experience of home gardeners. Hiring a bonded professional is the best approach for most tree pruning jobs. Look for arborists with certification from the ***International Society of Arboriculture, ISA***. Many are listed in the phone book yellow pages and a list of ISA Certified Arborists working in the area can be found on the ISA web site at www.isa-arbor.com. Also, ask about liability insurance coverage.

This *CMG GardenNotes* is written to help the home gardener understand issues around pruning of mature trees and help with communications with their certified arborists.

General Pruning Guidelines

Limitations on Diameter of Cut

Ideally, all pruning cuts are two inches in diameter and smaller. On tree species resistant to decay, the standard could be pushed to two to four inches, maximum (depending on actual vigor and growth of the tree). These small wounds minimize the potential for internal decay. The two-inch diameter and smaller branch is primarily ***sapwood*** (newer xylem rings of living cells active in water transport and storage of photosynthates) that is not prone to decay.

Unless there is a strong justification, (taking into account the potential for a decay column and internal cracking) avoid removing branches larger than four inches in diameter. At approximately four inches, ***heartwood*** (older xylem rings of non-living cells no longer active in water transport) dominates the branch structure. The branch becomes prone to decay as heartwood has no resistance to the spread of decay and is prone to internal cracking. (Note: Due to chemical changes in the cells, heartwood is often darker in color.) [Figure 1]

Figure 1. Cross section of Douglas-fir. Light colored outer rings are sapwood. The dark wood in center is the heartwood.

When a pruning cut or other injury opens a branch to decay, the decay column will take the current season of xylem ring and everything older. Decay creates a pipe-like structure in the branch. The healthy, undecayed wood will be the xylem rings that grow in future years. [Figure 2]

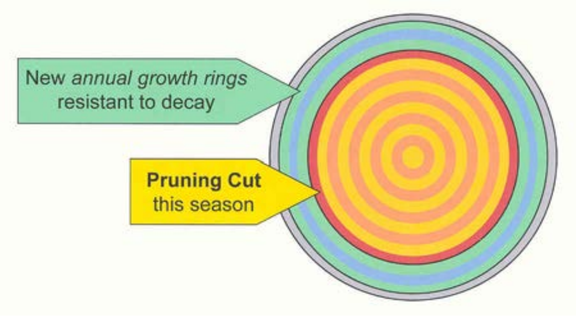


Figure 2. When injury (such as improper pruning cuts) leads to decay, it takes the current season's xylem ring and everything older (inward). New growth (xylem rings that grow in future years) will be resistant to decay. Decay creates a pipe-like structure.

For example, if a branch with eight-inch diameter xylem (wood) is pruned back to a trunk with 12-inch diameter xylem (wood) and decay results, the decay column in the trunk will be 12 inches wide (that is, the diameter of the trunk wood at the time the injury occurred). The tree would have to add six inches of healthy new growth to meet the minimum standards for structural strength (33% shell). If annual growth rings were ¼" wide, this would take 12 years! For additional information on tree decay and percent shell, refer to *CMG GardenNotes* #611, Tree Growth and Decay. [Figure 3]

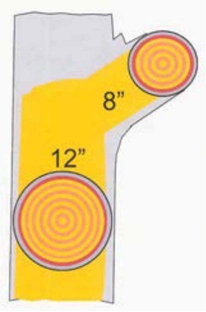
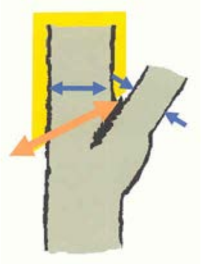


Figure 3. The diameter of the decay column will be the diameter of the current season's xylem ring for the year that injury occurred and inwards. Structural weakness from the decay is offset by the growth of new wood (xylem rings) in future years.

Limitations on Size Relationship with Reduction Cuts

Pruning often involves subordinating side branches or secondary trunks to a more dominant leader. This can only be achieved with ***reduction cuts*** (removing a larger trunk/branch back to a smaller side branch). In reduction cuts, the diameter of the side branch must be at least one-third the diameter of the trunk/parent branch removed. If the side branch is smaller, it becomes a ***heading cut***. [Figure 4]

Figure 4. In reduction cuts (removing a larger trunk/parent branch back to a smaller side branch), the side branch must be at least one-third the diameter of the trunk/parent branch removed. If the side branch is less than one-third the trunk diameter, it is a heading cut. Heading cuts are not acceptable in pruning standards.



A common mistake in lowering branch height is the use of heading cuts, which release waterspout (sucker) growth from the pruned branch. The regrowth will be structurally unsound, resulting in trees that may be more prone to storm damage than before pruning occurred. When pruning maturing trees, heading cuts are not acceptable in pruning standards!

For additional details on reduction cuts refer to *CMG GardenNotes* #612, Pruning Cuts.

Dosage: Maximum Amount of Live Wood / Foliage to Remove

Do not indiscriminately remove branches with live foliage as this can add stress to the tree. **The amount of live wood and foliage to remove per season depends on the actual growth rate of the tree.** Young, actively growing, trees are rather tolerant of a heavy pruning dose. As trees become mature, they become intolerant of heavy pruning. Look at six to 12 branches around the tree to assess growth rates. Look for what is the typical growth rate for most branches, not the fastest or slowest growing branches.

- **Trees under severe stress putting on insignificant annual growth –** Limit pruning to *cleaning* (removal of dead and damaged branches). Live wood should not be removed on trees under severe stress (including drought stress). Heavy pruning simply removes the stored photosynthates that the tree is living on during the stress period!

- On **mature trees** (greater than 75% mature size for the site), pruning dose should be limited to 5% to 10%, based on actual growth and vigor of the tree.

- On **medium aged trees**, the dosage really depends on actual growth. Typical range would be 10% to 25% depending on actual growth and vigor of the tree.

In situations where trees are pruned annually (the ideal situation), the appropriate pruning dose would be on the lighter side. However, in real world situations, trees are often pruned only once every several years. Here the appropriate pruning dose may be heavier. In situations where heavy pruning is needed, complete the work over a period of years.

Excessive pruning can lead to watersprouts (upright, sucker-like shoots emerging on the trunk or branches). Waterspouts, a common response to over pruning and storm damage, are structurally unsound.

Excessive pruning also creates a hormone imbalance between Auxins (produced in the terminal buds of the canopy) which stimulates root growth and Gibberellins (produced in the root tips) which stimulates canopy growth. This puts the root system into a multi-year decline, resulting in a multi-year decline in canopy growth.

Storm damage may take of excessive amounts of live wood leading to heavy canopy growth and watersprouts the first year due to high Gibberellins. The natural root generation declines the first year due to low Auxins. This decline in root regeneration leads to a multi-year decline in root and canopy growth. The storm damage counts into the dosage of life wood removed. When storm damage takes off more than the appropriate dosage for the trees actual growth, limit pruning to cleaning (removal of dead and damaged) until the tree rebalances and resumes normal growth rates.

Removal of dead wood does not count into the dosage.

Other General Guidelines

- To maintain trunk taper resilient to winds, at least one-half of the foliage should be in the lower two-thirds of the tree. The lowest limb should originate in the bottom one-third of the tree's height.

- Pruning should maintain the tree's natural shape.

- Avoid "lion-tailing" where the small twiggy inner foliage is cleaned-out on the lower scaffold branches and secondary trunks. This shifts weight to the ends of branches and reduces the damping effect on the branch; increasing the potential for wind damage. It reduces the taper (widening of the branch/trunk as it moves downwards) increasing the potential for branch/trunk failure. It also reduces the stored photosynthate reserves in the lower branching structure decreasing resilience to stress factors.

- Avoid topping a tree. Topping opens the tree to internal decay and cracking. Regrowth of watersprouts (adventitious shoots) is structurally unsound.

- Written specification for any pruning job should include the following:

  - Clearly state which tree(s) will be pruned.
  - Clearly indicate the objectives for pruning (why prune), such as reduce risk of failure due to wind damage or snow loading, manage health, improve aesthetics, provide clearance, improve view.
  - Specify pruning methods (how to prune) to meet the objectives, such as structural pruning, cleaning, thinning, raising, reducing, restoration pruning.
  - State the size specification for the minimum and/or maximum branch size to be removed. For example, *"Cuts should be made on branches two inches and less in diameter"* and *"In a reduction cut, the side branch pruned back to should be at least one-third the diameter of the branch removed."*
  - Specify the dosage (maximum amount, by percentage, of live wood/foliage to be removed per season). For example, *"Pruning should not remove more than 15% of the live crown."*
  - In writing pruning specifications, the word "should" refers to a practice that is routine and recommended. The word "shall" refers to a practice that is mandatory.
  - Include these generic safety statements to reduce the homeowner's and pruning crew's liability. *"All work shall be performed in accordance with American National Standards Institute A300 Pruning Standards and Z133.3 Safety Standards." "All work shall be performed under the supervision of a licensed, International Society of Arboriculture certified arborist."*

Pruning Objectives

Pruning should be based on pruning objectives (why to prune). Do not indiscriminately remove branches. Pruning objectives determine methods (how to prune) to be used, which in turn determine the type of pruning cuts made. Table 1 lists common objectives, methods and types of pruning cuts.

Table 1. Objectives and Methods for Pruning Maturing Trees

Objectives (Whys)	Methods (How)	Pruning Cuts
Reduce risk of failure (wind and snow)	Structural	Removal cut
Improve structure	Cleaning	Reduction cut
Maintain health	Thinning	Heading cut
Improve aesthetics	Raising	
Provide clearance	Reducing	
Improve view	Restoring	
Reduce shade	Pollarding	
Influence flowering and fruiting		

Pruning Methods

Structural Pruning

A common pruning objective with maturing trees is to reduce the potential risk of failure from wind and snow loading. Significant wind damage occurs on structurally weak trees with wind gusts of 60 to 75 mph. Even structurally sound trees may fail with wind gusts above 95 mph.

In Colorado (and other snowy climates), most significant storm damage is due to codominant trunks (trunks of similar size). Structural problems of this type should have been corrected while the tree was in the early growth stage. Arborists have a limited potential to correct structural defects on middle-aged and mature trees without predisposing the tree to internal decay, cracking, and creating an unsightly shaped tree. [Figure 5]

Figure 5. Codominant trunks (adjacent trunks of similar size) account for the majority of storm damage in Colorado landscapes.

Structural pruning centers around developing a dominant trunk with subordinate side branches and secondary limbs. To be most effective, it requires annual pruning over a period of years, rather than an occasional one-time pruning.

Written pruning specifications for structural pruning of maturing trees should include the following:

- Identify branches where work will be done (for example, "*codominant trunk on south side of tree*").
- Identify the methods to be used in pruning (for example, "*the secondary trunk on the south side should be reduced by 10 feet").*

Subordinate Pruning Considerations

Structural pruning of maturing trees is often referred to as ***subordinate pruning,*** where secondary trunks (and side branches) with weak branch unions are subordinated to a dominant trunk. To avoid removing too much foliage/live wood in one season, subordinate pruning generally requires work over a period of years.

In evaluating how to prune the maturing tree, take into account the following considerations:

What Is the Purpose for Pruning the Tree?

Structural pruning (subordinating weak side branches to a more dominant trunk) is more effective in reducing failure potential than general crown reduction or crown thinning. With general crown reduction or thinning, regrowth simply replaces what was pruned off in a few years.

Wind loading – To reduce potential of failure due to wind loading, the height of secondary trunks and side branches with weak branch unions must be lowered. This is done with reduction cuts, and proper reduction cuts may not be possible on many maturing trees without introducing decay and internal cracking, and structurally unsound waterspout growth.

For example, many cottonwood and popular trees will not have side branches of adequate size for proper reduction cuts (side branch prune back to must be at least 1/3 the diameter of the trunk removed).

A slight reduction in secondary trunk/branch height will not achieve the objective. To significantly reduce the risk of failure, reduction may need to be 1/3 or more of the branch length. On maturing trees, this may be into braches too larger for pruning by pruning standards. Not all branches can be effectively reduced.

Snow loading – To reduce potential of failure due to snow loading, the snow catching volume of the branch needs to be reduced. This is best achieved with structural pruning of weak branches.

What Is the Structural Integrity of the Branch Union?

To evaluate the structural integrity of the branch union (crotch) look at the ***Aspect Ratio*** (that is the diameter of the side branch to the diameter of the trunk). Any side branch with an aspect ratio larger than 1 to 2 (diameter of side branch greater than ½ the diameter of the trunk) will be structurally weak due. For example, if the diameter of the trunk is four inches, all side branches should be less than two inches.

A structurally strong branch union has a ***branch collar*** (where the annual growth rings of the trunk wrap around the annual growth rings of the side branch). For a branch collar to develop, the side branch needs to be less than one-half the diameter of the adjacent trunk. Less than one-third is preferred. Branch unions with branch collars are also more resistant to the spread of decay. For more details on branch collars, refer to *CMG GardenNotes* #611, Tree Growth and Decay. [Figure 6]

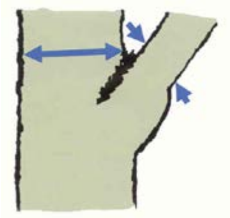


Figure 6. To evaluate the structural strength of a branch union, compare the diameters of the trunk and side branch. A branch union is structurally strong when it has a branch collar. For the branch collar to develop, the diameter of the side branch needs to be less than one-half the diameter of the adjacent trunk.

Branch unions can also be compromised with narrow crotch angles, leading to ***included bark*** (bark against bark) and multiple branching originating in the same area.

What Is the Aesthetic Value of the Branch?

Is the branch in question important to the tree's balance and appearance? If the branch were removed, would its removal create a major gap in the canopy?

Where Should the Pruning Cut Be Made?

If the three previous questions lead to the conclusion that a secondary trunk or branch needs to be pruned, several considerations are needed to determine where to make the actual cut. Sometimes none of the options meet pruning guidelines, and the better of the bad options is chosen.

For illustration, look at the tree in Figure 7. It has three trunks. If the branch unions do not have branch collars (that is, the secondary trunks are more than half the diameter of the primary trunk), the tree is prone to storm damage.

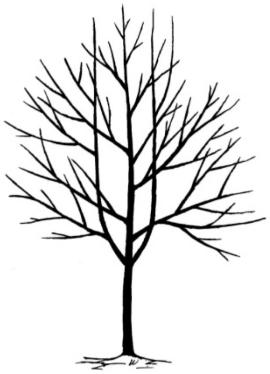


Figure 7. As drawn, the tree has three trunks. Evaluate the need for subordinate pruning by comparing the diameters of the secondary (left and right) trunks to the center trunk. To be structurally strong with branch collars, the left and right trunk need to be less than half the diameter of the center trunk.

Considerations for the Secondary Trunk on the Left

As drawn in Figure 8, there are four sites where pruning could occur to lower the height of the secondary trunk (wind loading) and reduce the snow loading potential.

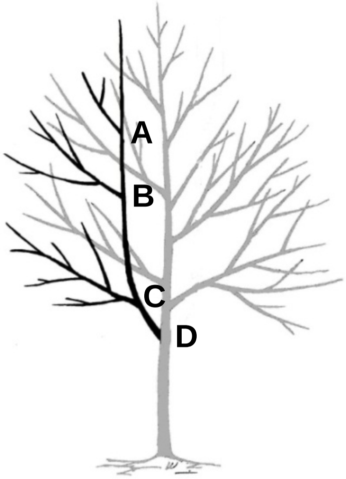


Figure 8. As drawn, there are four locations where pruning could occur.

Considerations for locations A, B and C with reduction cuts (removing a larger trunk back to a smaller side branch)

- If location A has a 2-inch trunk with a 1-inchside branch, it meets the pruning guidelines for both size (decay potential) and reduction cut (waterspout growth). However, as drawn, it may have little potential to minimize storm damage, as the height is not significantly lowered (wind loading), and the total potential for snow loading has not been significantly reduced.

- If location A has a 2-inch trunk with a half-inch side branch, it does not meet the reduction cut guideline (waterspout growth), as the side branch is one-fourth the size of the trunk being removed. Due to the size relationship, this becomes a heading cut. Watersprouts regrowth on the trunk could make it more prone to storm damage than before pruning!

- If location B has a four-inch trunk and a 3-inch side branch it violates the size (decay) guideline because the trunk is too large, predisposing the trunk to decay and internal cracking. This is typical when pruning maturing trees, as branches will be too large except in the outer canopy. The 3” side branch is within the reduction cut (waterspout) guideline, making it a reduction cut.

- If location B has a 4-inch trunk and a 1-inch side branch it violates both the size (decay) and the reduction cut (waterspout) guidelines.

- If location C has a 6-inch trunk and a 3-inch side branch it violates the size (decay) standard. The 3-inch side branch is within the reduction cut (waterspout) standard.

Considerations for location D with a removal cut (removing a smaller side branch back to a larger trunk/parent branch)

- Is the branch important to the aesthetics of the tree? As drawn, the removal of the entire branch would create a gap in the canopy.
- Removal of the left side secondary trunk plus additional pruning on the right side to aesthetically balance the tree would remove too much of the tree's foliage/live wood in a single season.
- If location D has an 8-inch trunk with a 6-inch side branch (secondary trunk), it violates the size (decay) guideline. Being a removal cut (removing a smaller side branch back to a larger trunk/parent branch); it does not have a reduction cut standard. Without a branch collar, the branch union is prone to decay.

Better of the Bad Options

In reality, it is common that none of the potential cuts meets acceptable pruning guidelines, and the arborist looks for the better of the bad options. Due to the diameter of the limbs, large trees have few acceptable options based on the size guideline (potential for internal decay and cracking). It is common that secondary trunks may not have any side branches of an acceptable size relationship for a reduction cut.

- If the tree species is prone to decay, avoid compromising on the size (decay) guideline, opening the tree to decay and internal cracking.

- If the tree is in a stressed site (including limited water or root spread potential) avoid compromising on the size (decay) guideline, as the tree is more prone to decay.

- If the tree is vigorously growing or the total amount of foliage/live wood being removed is at the maximum allowed in pruning standards, avoid compromising on the reduction cut (waterspout) guideline, as the tree is more prone to waterspout growth. With growth, the tree may become more prone to storm damage than before pruning. If the tree will be pruned each year (dealing with the waterspout growth) this becomes less of an issue.

- If tree failure would not cause injury or significant property damage, no pruning may be the better option.

- If tree failure would cause injury or significant property damage, it may be better to accept limited decay and work with resulting structural issues from regrowth than to leave the tree at high risk for storm damage.

- Storm failures are more common on young and medium-sized trees as the co-dominant and secondary trunk reach 3-4 inches in diameter. Old, mature trees are actually less prone to storm damage, having had their weakness tested in previous mega storms.

Illustrations of Subordinate Pruning Situations

Medium-Aged Tree with Codominant Trunks

With codominant trunks, one trunk is subordinated to a dominant trunk. Figure 9 illustrates this. It may require annual pruning over a period of years.

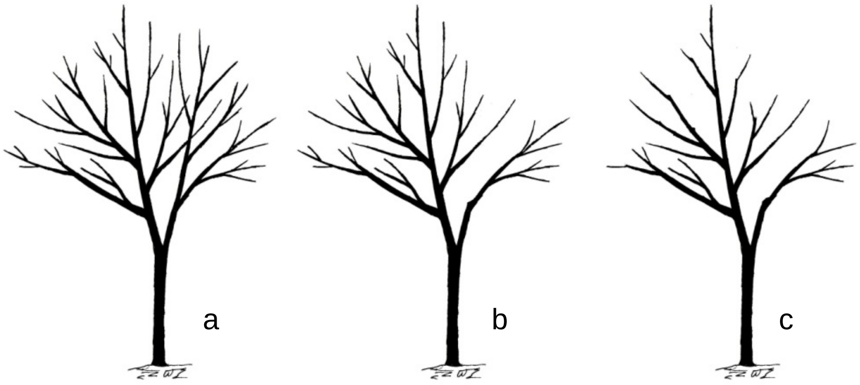


Figure 9. Before and after pruning with codominant trunks.

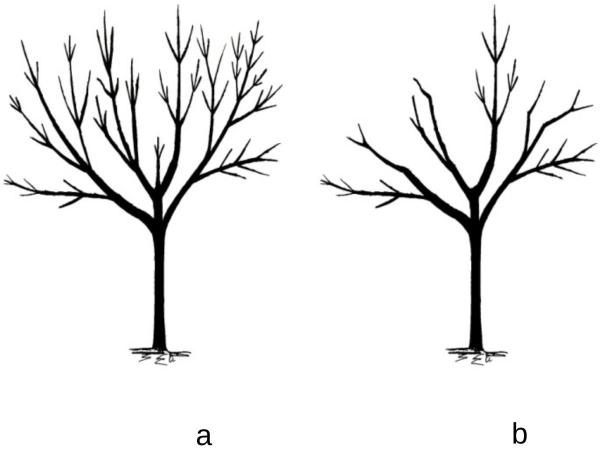
a. Tree before pruning.
b. Codominant trunk on right subordinated to trunk on left.
c. Tree balanced with other, more upright growing branches on left subordinated to the dominant trunk.

Vigorously Growing Branches Choke-Out the Central Leader

On species with opposite branching patterns, vigorously growing lower branches often choke-out the central leader. Figure 10 illustrates the pruning approach. It may require annual pruning over a period of years.

Figure 10. Before and after views of a tree who's vigorously growing branches choke-out the central leader.

a. Before pruning
b. Desired look after pruning



Young Tree Rounded with Heading Cuts

Trees should never be rounded with heading cuts. Figure 11 illustrates the pruning approach. It may require annual pruning over a period of years.

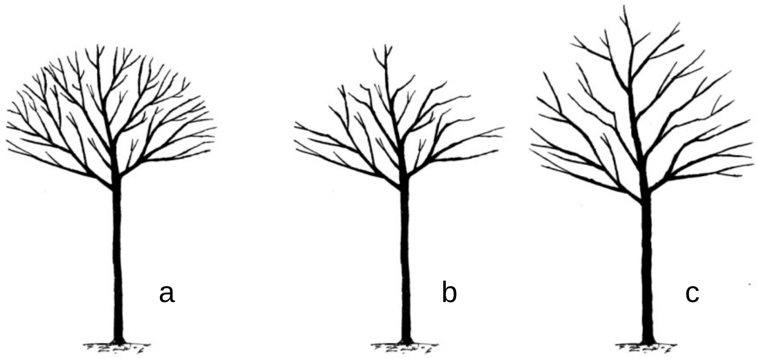


Figure 11. Before and after views of a young tree rounded with heading cuts.

a. Before pruning
b. Desired look after pruning, subordinating side branches to a dominant trunk.
c. Tree with growth.

Upright Growing Trees with Numerous Upright Growing Branches

Some species of trees (including Callery pear and some crabapple cultivars) have numerous upright growing branches. Figure 12 illustrates the pruning approach. It may require annual pruning over a period of years.

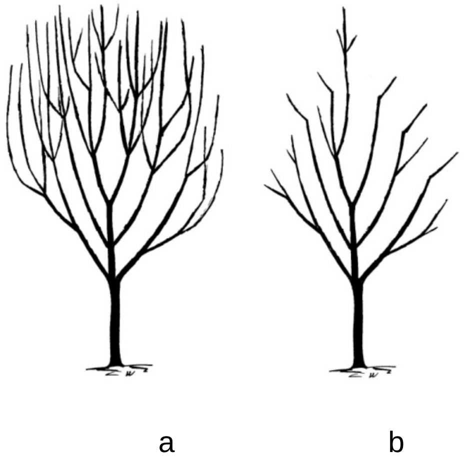


Figure 12. Before and after views of an upright growing tree with numerous upright growing branches.

a. Before pruning
b. Desired look after pruning

Cleaning

Cleaning is the removal of dead, diseased, cracked, and broken branches. This type of pruning is done to reduce the risk of branch failure, improve tree appearance, and to reduce the spread of insects and diseases. Most pruning of middle-aged and mature trees falls into this type. Trees under stress or declining trees may need cleaning every few months to ever few years. All dead wood may be removed at one time. It does not count in the total of live wood/foliage removed. In cleaning, do not remove healthy branches and live foliage. Do not clean out healthy growth in the tree's interior. [Figure 13]

Figure 13. This old cottonwood needing cleaning to remove dead branches and reduce the risks associated with branch failure.

Removing dead branches – To minimize risk if the branch were to fail, it is advisable to remove any dead branch larger than a two-inch diameter and higher than 30 feet. Dead branches may also become a source of insect and disease pressure in the tree.

Remove the dead branches using the three-step pruning technique. For details refer to CMG GardenNotes #612, *Pruning Cuts*. Do not cut into the branch collar, which would open a high potential for decay to spread into the trunk. If live wood has began to grow out along the dead limb, cut just beyond the live wood being cautious not to nick the live tissue. Never "flush cut" the dead branch. [Figure 14]

Figure 14. When removing dead branches, do not cut into the living tissues.

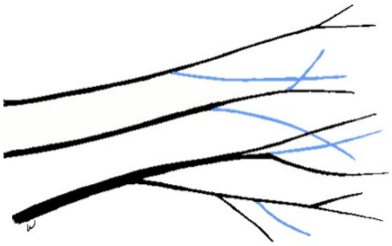
Written specifications for cleaning should specify the minimum size of dead branches to be removed. For example, *"Clean branches one inch diameter and larger"* or *"Clean branches two inches in diameter and larger that are 30 feet and higher above the ground."* The location of the branch to be removed should be specific if the entire crown is not going to be cleaned.

Thinning

Thinning is the selective removal of smaller branches (½ inch to 2.5 inches in diameter) to reduce crown density. Because the majority of small branches are in the outer canopy, thinning focuses in this area. Thinning should retain crown shape and size, and provide an even distribution of foliage throughout the crown. Removal cuts are primarily used. [Figure 15]

Because thinning is in the upper/outer canopy, it requires a trained arborist with a high level of skill. Thinning is expensive, often running $500 to over $1,000 per large tree when done correctly.

Figure 15. Thinning is the selective removal of small branches, growing parallel to each other, in the leafy upper/outer tree canopy.



Thinning can include removal of suckers from the base of the tree and some waterspouts on the interior. Excessive removal of watersprouts at one time often promotes growth of additional watersprouts, and should be avoided.

Benefits of Thinning

- Thinning is a method to minimize potential damage caused by snow loading, a primary situation leading to tree failures in Colorado. Thinning can reduce limb weight in order to compensate for structural defects.
- Thinning increases light penetration into the tree interior. This can invigorate the tree and help retain the tree's natural shape. Thinning may adequately reduce shade for shade tolerant under story plants below the tree. However, thinning middle-aged and mature trees will not adequately promote growth of sun loving plants like Kentucky bluegrass.
- Thinning is a technique to partially open a view without removing or structurally influencing a tree. This is often referred to as *vista pruning*.
- On a tall tree, thinning may not be an effective technique to reduce wind sail and potential for breakage in strong winds. Reducing is the most effective way to deal with wind loading issues.

Effectiveness of Thinning

- Researchers are questioning the overall effectiveness of overall tree thinning. Depending on growth rates, the tree may simply regrow the removed branches in a few years. **Current thought in reducing storm loading is that structural pruning will be more effective than general thinning.**

Clarification on Thinning

- As a point of clarification, *thinning* is done on relatively small branches in the leafy upper/outer canopy. *Thinning* is not removing large lower branches, which could create gaps in the crown and encourage watersprouts. Thinning is not removal of the small twiggy branches in the inner canopy. Thinning will not significantly lower a tree's height. [Figure 16]

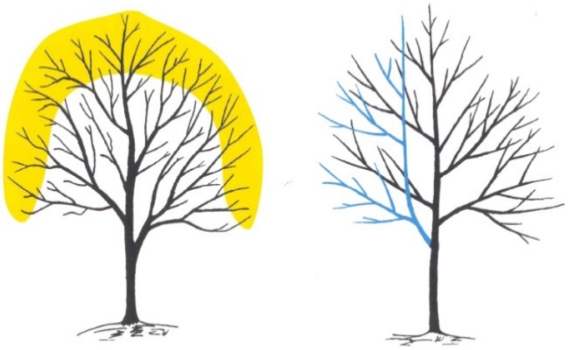


Figure 16.
Left – Thinning focuses on small branches in the upper/outer tree canopy.
Right – Thinning does NOT remove large branches, creating a gap in the tree canopy.

- Avoid ***lion-tailing*** which is the removal of the live small leafy twigs down in the tree's interior. Never clean out these lower branches and twigs on maturing trees. These small interior branches are critical to the trunk's structural integrity and vigor. They also serve to dampen tree sway in wind. Lion-tailing shifts the wind loading to the outer canopy increasing the tree's potential for wind damage. [Figure 17]

Figure 17. Do not "lion-tail" trees as in the photo. Removal of the smaller twiggy wood in the inner tree canopy decreases vigor on the major branches and trunk and shifts the weight to the top increasing the potential for wind damage.

Written specifications for a thinning job should specify the following:

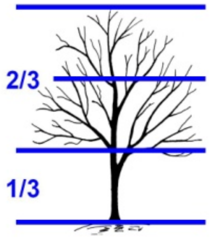
- Clarify the dosage (percent of the tree's canopy may be removed). For example, *"Pruning should not exceed 15% of the total live canopy."*
- Clarify where in the tree the pruning will occur. For example, *"Pruning should occur in the outer third of the crown."*

- Clarify size of branches to be removed. For example, *"Pruning should remove branches up to 2½ inches in diameter."*

Raising

Raising is the removal of lower branches to provide clearance for people, traffic, buildings, or a view. When removing lower branches, maintain at least one-half of the foliage in the lower two-thirds of the tree. The lowest branch should originate in the bottom one-third of the tree's height (live crown ratio). [Figure 18]

Figure 18. When removing lower branches, maintain at least one-half of the foliage in the bottom two-thirds of the tree. The lowest branch should originate in the lower one-third of the tree.



Raising should be part of the tree's structural training while young. Ideally raising would be done before branches to be removed exceed a two-inch diameter. The potential for decay is high when the branch removed is larger than four inches or when a two-inch and larger branch is greater than half the diameter of the adjacent trunk (no branch collar to suppress decay).

On many trees, lower branches make-up a significant portion of the tree's entire canopy and cannot be removed without significantly influencing tree health and appearance. When the branch to be removed is larger than two inches, consider other alternatives. Can the clearance required be achieved with removal and reduction cuts out along the branch rather than removing the entire branch? Leaving some small diameter branches on the lower trunk for a year helps close pruning wounds and lessens the potential for trunk cracking. [Figure 19]

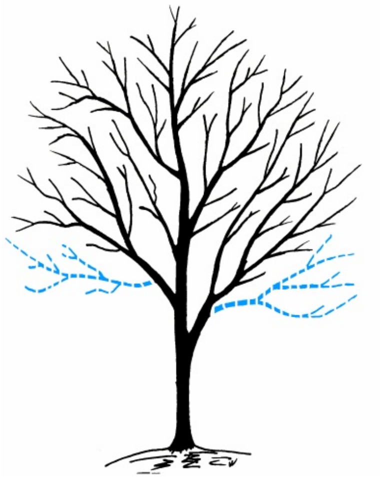


Figure 19. In raising branches on maturing trees, consider if required clearance can be achieved with removal and reduction cuts out along the branch rather than removing large branches entirely.

Excessive removal of lower branches increases the potential for tree failure by decreasing trunk taper, causing trunk cracks and decay, and transferring weight to the top.

Written specification for raising should include the following:

- Clarify the clearance required. For example, *"The tree's crown will be raised to seven feet."*

- Clarify what branch(es) will be pruned and the type of pruning cuts (removal or reduction cut) to be used. For example, *"The lowest branch on the south side shall be removed back to the trunk with a removal cut. The lowest branch on the north side will be reduced with a reduction cut at the branch five feet out from the trunk and a removal cut to the lowest side-branch."*

- Clarify what size of branches will be pruned. For examples, *"All cuts shall be two inches in diameter and smaller."*

Reduction

Reduction is the selective removal of branches to decrease the height and/or spread of a tree. It requires the use of *reduction cuts*, which remove larger branches back to smaller side branches. [Figure 20]

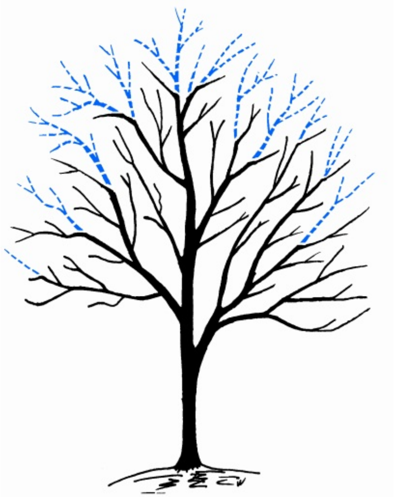


Figure 20. Reducing is the selective removal of branches to decrease a tree's height and/or spread. Just being tall does not indicate that a tree is structurally weak and prone to storm damage.

Reduction is a method to reduce potential wind loading on large trees with structural defects. Reducing and thinning both decrease potential failure from snow loading. However, researchers are questioning the effectiveness of overall tree reduction. Depending on growth rates, the tree may simply regrow the removed branches in a few years. **Current thought in reducing storm loading is that selective *structural pruning* on weak secondary trunks will be more effective than general tree reduction.**

Not all trees can be reduced without predisposing the tree to decline and death. Crown reducing requires the extensive use of *reduction cuts, which* can predispose the branch/trunk to internal decay. On older trees showing stress or decline, *heading cuts* can accelerate decline and death. [Figure 21]

Figure 21. Not every tree should be reduced. Notice the dieback associated with the previous reduction on this old cottonwood. On old trees and trees showing stress or decline, heading cuts may accelerate the decline cycle.

In a proper *reduction cut*, the side branch pruned back to will be at least one-third the diameter of the trunk/parent branch removed. Under American National Standards Institute (ANSI) pruning standards, if the side branch is less than one-third, it is considered a *heading cut*, which is generally unacceptable. For additional details on proper reduction cuts, refer to *CMG GardenNotes* #613, Pruning Cuts.

It is very difficult to use crown reducing to permanently maintain a tree at a small size without causing tree decline. Ideally, trees were selected with adequate space for their mature size. Where size control is necessary, it is best to begin reduction pruning as the tree reaches acceptable size, rather than when the tree becomes overgrown.

In crown reducing, first visualize the new outer edge of the smaller canopy. Then prune the tree back to appropriate branch unions for a proper reduction cut or removal cut. Some branches will be left taller than the visualized outer edge while others will be cut back below the visualized canopy edge. Do not make heading cuts and avoid rounding off the tree canopy. [Figure 22]

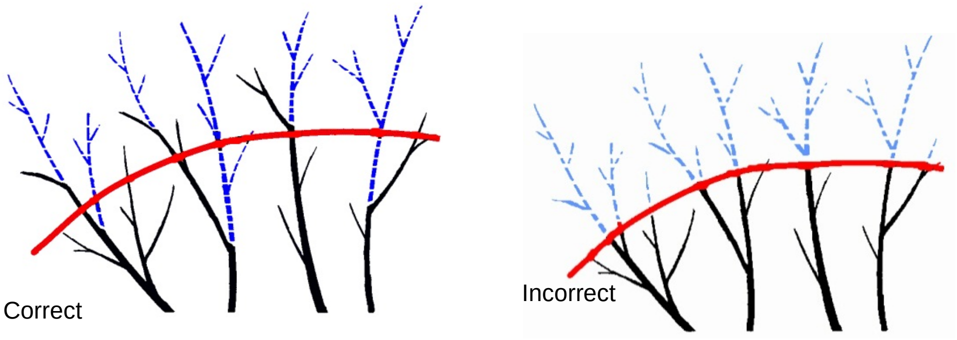


Figure 22.
Left – In reduction, visualize the new outer edge of the smaller canopy. Prune back to branch unions that make proper reduction and thinning cuts. Some branches will be taller than the new outer edge, some shorter.
Right – This tree is incorrectly rounded off with heading cuts.

In shortening primary upward growing trunks/primary branches to a lateral branch, a side branch that is somewhat upward growing with a narrow branch union angle may be stronger than a branch union with a wide angle. [Figure 23]

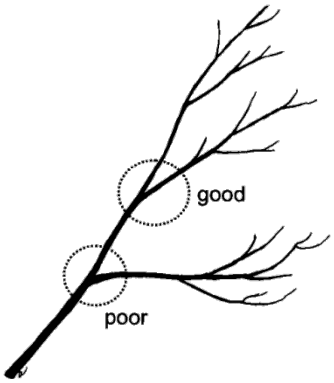


Figure 23. In shortening a main upward growing branch, pruning back to a narrow branch union may be stronger than a wide branch union.

Just because a tree is tall does not indicate that it is structurally unsound. Potential risk of failure should be evaluated by an experienced arborist based on branching structure, branch union integrity, signs of internal decay, and previous damage.

Written specifications for reduction pruning should include the following:

- Clarify the desired reduction in height/spread.
- Specify criteria for reduction cuts. For example, *"All cuts should be made on branches less than two inches in diameter. Diameter of the side branches pruned back to should be at least one-third the diameter of the branch removed."*
- Clarify the dosage (percentage of live wood/foliage to be removed). For example, *"Pruning should not exceed 10% of the total canopy."*

Restoration

Restoration is the selective removal of branches, sprouts, and stubs from trees that have been damaged by improper pruning, vandalism, and storms. The objective is to restore the trees structure, form, and appearance to the extent possible. Restoration generally requires annual pruning over a period of years.

Actual pruning procedures vary with the situation. When dealing with situations of excessive watersprouts, a rule to thumb is to remove one-third and reduce one-third with each annual pruning. Removing all of the watersprouts at one time often stimulates the growth of more watersprouts.

Pollarding

Pollarding is a training system that involves creating "heads" on secondary branches were small tertiary branches arise. The small tertiary branches are all removed back to the head every one to three years (depending on growth rates).

Pollarding started as a method to produce shoots for fuel, shelter, and products made from the young shoots. Today, it is used as an art form. Pollarding is common in some parts of Europe to keep tree small and shaped as living screens. Pollarding is not topping and should not be considered a routine method to keep large trees small. Due to annual labor involved, it is uncommon in the United States.

Frequently Asked Questions About Pruning Mature Shade Trees

What About Topping a Tree?

Shade trees should **never** be topped. The regrowth of a topped tree is structurally unsound. Topping required by utility right-of-way pruning is starkly obvious and sets an unfortunate community standard followed by others. Instead of topping, use *cleaning,* and/or proper *structural pruning* methods. [Figure 24]

Figure 24. Never top a tree, the regrowth is structurally unsound, making it very prone to wind and storm damage.

What About Utility Right-Of-Way Pruning?

Pruning for utility line clearance does not always follow desirable pruning techniques regarding appearance and health of the tree. In this situation, the needs of the utility right-of-way take priority over the tree.

When a tree under a power line requires frequent reduction, consider having the tree removed. Utility companies are generally eager to accommodate. In planting trees, selection criteria (i.e., size and placement) should be followed so that a tree's health and appearance will never be compromised by the need for utility pruning.

I Am Concerned About My Tall Tree Breaking in Storms, But I Really Do Not Want to Lose the Shade. Do I Really Need to Have the Tree Pruned or Removed?

This is a two-part question. First, does the tree show signs of being highly susceptible to storm damage, (i.e., previous storm damage, dieback or dead branches, structural problems such as codominant trunks, weak branch unions or internal decay)? This should be evaluated by an experienced ISA Certified Arborist.

Second, if yes, what would the tree or branch hit should it fail? If it would cause significant property damage or threaten life, the tree should be pruned or removed as a preventive measure.

Cleaning and ***structural pruning*** may reduce the potential storm hazard without compromising the shade. In some situations, the risk of failure cannot be reduced without removal. Remember that healthy structurally sound trees are generally windfast even when mature.

Storm damage is usually, but not always, related to structural problems that could have been addressed with proper structural training when the tree was young. Codominant trunks account for the majority of tree failures in Colorado. The hazard of wind damage is higher on the regrowth of trees that have been "topped". Consult an ISA Certified Arborist for additional details.

How Should Storm-Damaged Trees be Pruned?

First, focus on *cleaning* (removing broken and damaged limbs) keeping in mind the structural integrity of the tree. Realize that you may have to accept less than ideal pruning techniques by "Mother Nature".

Second, focus on *structural pruning* to restore the tree's structural integrity and shape to the extent possible. This may take place over a period of years.

The maximum amount of tree canopy that can be removed without putting the tree and its root system under stress includes the live wood/foliage removed by the storm. When Mother Nature removes too much live wood/foliage, limit pruning to cleaning.

On storm damaged trees where excessive live wood and foliage were removed by storm damage, wait until the roots and crown stabilize (as measured in canopy growth) before doing thinning, reducing, or other structural pruning. This may be a multi-year period.

Keep the tree if it can be pruned back to structurally sound wood and will be esthetically pleasing. Often when one side of the tree is gone, the best option is to remove the entire tree. [Figure 25]

Figure 25. Keep storm-damaged trees when they can be pruned back to structurally sound wood and has an acceptable appearance. This yard would look better if the tree was removed.

How Should Trees With Root Damage be Pruned?

Focus on *cleaning*. Avoid removing live wood and foliage as this could speed the decline. Removing live wood lowers the *auxin* content, which is the hormone that promotes root growth. Removing foliage reduces photosynthesis and levels of stored carbohydrates that the tree is living on during the recovery period. Trees in a construction site with damaged roots may require cleaning every 3-12 months for five plus years.

How Should Declining Trees be Pruned?

Focus on *cleaning*. Avoid removing live wood and foliage as this could speed the decline. Removing live wood lowers the *auxin* content, which is the hormone that promotes root growth. Removing foliage reduces photosynthesis and levels of stored carbohydrates that the tree is living on. Old declining cottonwoods and poplars may warrant cleaning every one to five years.

Authors: David Whiting (CSU Extension, retired), with Alison O'Connor and Eric Hammond (CSU Extension). Artwork by David Whiting; used by permission.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #616

Pruning Flowering Shrubs

Outline:

Why Prune?

Pruning has a major influence on a shrub's flowering habit, shape, size, and pest problems.

Prune to Encourage Flowering

Pruning has a major influence on shrub flowering. Over time, an unpruned flowering shrub becomes woody, with little new growth to support flower bud development.

Spring-flowering shrubs bloom on one-year-old wood (twigs that grew new the previous summer). Buds develop in midsummer through fall for the following spring. Pruning in the fall and winter removes flowering wood with buds. Spring-flowering shrubs can be rejuvenated or thinned in early spring before flowering or growth starts [Figures 1 and 2]. Thinning can also be done right after bloom to maximize the next season's flowers.

Spring-flowering shrubs include forsythia (*Forsythia* spp.), Nanking cherry (*Prunus tomentosa*), quince (*Chaenomelea* spp.), bridalwreath and Vanhoutte spireas (*Spiraea prunifolia, S. plenaflora* 'Plena' and *S.* x *vanhouttei*), viburnum (*Viburnum* spp.), beautybush (*Kolkwitzia amabilis*), lilac (*Syringa* spp.), honeysuckle (*Lonicera* spp.), peashrub (*Caragana* spp.), deutzia (*Deutzia* spp.), *and* weigela (*Weigela* spp.).

On spring-flowering shrubs it is recommended to "deadhead" spent blooms (remove flowers after they fade). While time-consuming, deadheading conserves the plant's energy, which would otherwise be spent on seedpod and seed development. On many shrubs, the spent flowers and seedpods are not attractive (lilacs).

Figure 1. Spring-flowering shrubs bloom from buds that developed on new wood the previous summer.

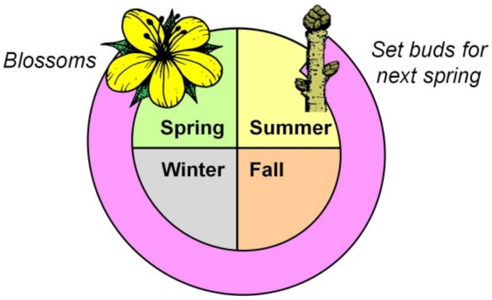


Figure 2. Fall shearing of this spring-flowering lilac removed flower buds on the lower section of the shrubs.

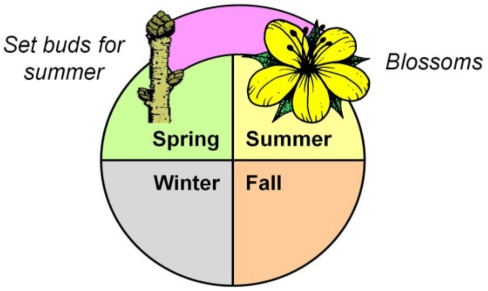
Summer-flowering shrubs bloom on new wood that grew earlier in the growing season. Summer-flowering shrubs are also pruned by thinning or rejuvenation in the early spring before growth starts. [Figure 3]

Summer-flowering shrubs include most butterfly bush (*Buddleia* spp. and *Cassia* spp.), blue mist spirea (*Caryopteris* x *clandonensis*), Hancock coralberry (*Symphoricarpos* x *chenaultii* 'Hancock'), mockorange (*Philadelphus* spp.), potentilla (*Potentilla* spp.), Bumald and Japanese spirea (*Spiraea* x *bumalda and S. japonica*), Annabelle and Peegee hydrangea (*Hydrangea arborescens* 'Annabelle' and *H. paniculata*), shrub althea or rose of Sharon (*Hibiscus syriacus*), snowberry (*Symphoricarpos albus*) *and* St. John's wort (*Hypericum* spp.).

Removing older canes of flowering shrubs also allows better sunlight penetration into the shrub. This results in better flowering throughout the shrub, instead of flowers just at the top where sunlight is sufficient.

On shrubs noted for their bark color, like red-twig dogwood (*Cornus sericea*), the new shoot growth has more brilliant color. Routine pruning at the base encourages new shoots, which have the desired red color.

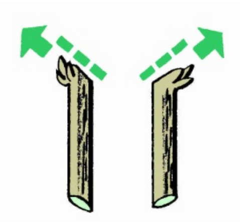
Figure 3. Summer-flowering shrubs bloom from buds that developed on new wood that grew earlier this growing season.



Prune to Direct Shape

Shaping is another reason for pruning shrubs. Shape can be managed to some degree by pruning to side buds or branches growing in the desired direction. While pruning can provide some control over size, it is not an effective method to keep a large shrub in a small space. Where shrubs have overgrown their space, consider replacing the plants with smaller cultivars or other species. [Figures 4 and 5]

Figure 4. Shape can be managed to some extent by pruning to buds and branches growing in the desired direction of growth.



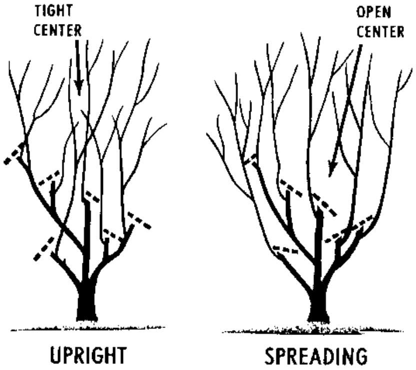


Figure 5. Pruning to inward growing buds or branches results in narrower shrubs. Pruning to outward-growing buds or branches results in wider shrubs. [Line drawing by USDA]

Prune to Manage Pests

Pruning is a management technique for some insect or disease problems. For example, removing the older wood in lilac reduces oystershell scale and borer problems. Thinning a shrub to increase air circulation reduces the incidence of powdery mildew and leaf spot diseases.

Pruning Methods for Flowering Shrubs

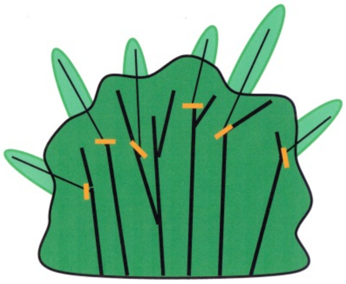
The primary objective in pruning flowering shrubs is to encourage new (flowering) growth from the base. This is best accomplished by thinning at the base, or rejuvenation.

Branch-by-Branch Shaping

Branch-by-branch shaping involves shortening the length of excessively long branches by cutting them back one-by-one. Cuts are made back in the shrub, leaving branches at varying lengths. Avoid making cuts at a uniform “edge,” creating a rounded ball. Make cuts at appropriate branch unions (crotches) or buds. [Figure 6]

This method maintains a more naturally shaped shrub but does not significantly encourage new growth of flowering wood for maximum bloom. Branch-by-branch shaping is a slow process.

Figure 6. With branch-by-branch shaping, long branches are cut back into the shrub, giving a more natural shape. Avoid making cuts at a uniform "edge," creating a rounded ball.



Shearing to Shape

Shearing shrubs to round balls or other desired shapes is a common pruning technique because it is quick and easy. However, sheared shrubs lose their natural shape, and the rounded "balls" may detract from a more natural, informal landscape design. Shaping spring-flowering shrubs after midsummer removes the new wood with next year's blossoms. Frequent shearing does not encourage new growth from the base, which is needed to promote flowering.

With frequent shearing, the plant becomes bushier on the exterior. The thick outer foliage may shade out the interior and lower foliage, and the plant becomes a thin shell of foliage with a woody interior and base. The thin shell of foliage is prone to browning and burning from wind and cold weather. Over time, shrubs become woody, with lots of dead branches and few flowers. When shrubs become overly woody from routine shearing, replacement is the best option to refresh the landscape design. [Figures 7-11]

Figure 7. Flowering shrubs pruned by topping or shearing become woody at the base. [Line drawing: USDA]

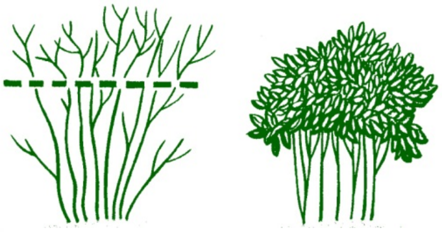


Figure 8. Over time, sheared shrubs become woody with dead sections. The only treatment at this point is to replace the shrub.

Figure 9. Sheared forsythia in full bloom. Shearing does not encourage new wood with blossoms.

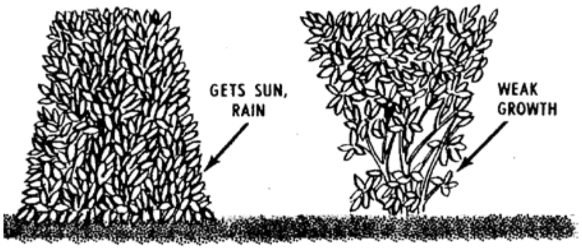


Figure 10. In shearing hedges, maintain the natural shape of the plant. A common mistake is to shape shrubs with a wide top and narrow base. Lack of sunlight shades out lower interior growth, resulting in a woody base. [Line drawing by USDA.]

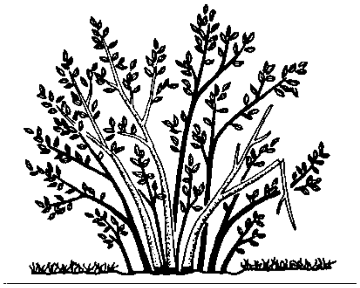
Figure 11. Properly pruned hedge, wider at the base.

Thinning

One method to encourage shrub flowering is annual thinning. The objective is to **remove one-third of the oldest wood to the ground each year**, which in turn stimulates new, better-flowering growth from the base of the shrub. Thinning is more easily done with leafless branches in early spring before growth starts but can also be done in summer. This method is time-consuming and does not work well on twiggy, multi-stem shrubs, like spirea. [Figure 12]

Cutting back and thinning an overgrown shrub will not restore its natural, informal form. It will look like an overgrown shrub that has been pruned. Rejuvenation pruning followed by thinning is better for overgrown shrubs.

Figure 12. Annual thinning removes one-third of the oldest wood to the base each spring. This encourages new growth from the base, keeping the shrub youthful looking. [Line drawing by USDA.]



Rejuvenation Pruning

Many shrubs can be easily renewed with rejuvenation pruning. The shrub is cut entirely to the ground in the early spring before growth starts. The shrub regrows from roots, giving a compact, youthful plant with maximum bloom. Rejuvenation can have a major effect on size. This method is preferred for many flowering shrubs because it is quick and easy with great results. Initial rejuvenation should be followed by thinning new canes to several strong ones over the next several years. Remove weak cane growth at the base (ground level).

Rejuvenation is typically done no more than every three to five years when a shrub begins to look gangly and woody. It works very well on multi-stemmed, twiggy-type shrubs such as spirea, *Caryopteris* (blue mist spirea), *Potentilla*, red-twig dogwood, sumac (*Rhus* spp.), and hydrangea. (Note: *Caryopteris* flowers best if renewed each spring.) Also use this method to rejuvenate lilac, privets (*Ligustrum* spp.), barberry (*Berberis* spp.), forsythia, flowering quince, honeysuckle, mockorange, flowering weigela, beautybush, many viburnums, elderberry (*Sambucus* spp.), and others.

Limitations:

- Spring-flowering shrubs will not bloom the year of rejuvenation.
- On shrubs with a rock and weed fabric mulch, rejuvenation may not be successful due to decreased root vigor and interference of the mulch with growth from the base.
- Extremely overgrown shrubs with large woody bases may not respond well to rejuvenation pruning.
- Shrubs with many dead branches will not respond well to rejuvenation pruning. As a rule of thumb, if more than one-third of the branches are woody, without healthy foliage, the shrub will probably not respond.
- Some shrubs are structurally more like small trees, with only one or a few primary trunks. They include several *Viburnum* and *Euonymus* species, and shrubby forms of *Rhamnus* (buckthorn). Do not cut these shrubs to the ground. Prune by thinning branches back to side branches.
- Lilac cultivars budded onto common lilac rootstocks should not be cut to the ground. Regrowth will be common lilac rather than the selected cultivar.

Replacement

Shrubs that have been repeatedly sheared often become woody and filled with dead twigs. The best option may be to replace them. On many commercial sites, labor issues prohibit routine pruning. When shrubs become overgrown, they are simply replaced as a low-maintenance alternative.

Shrubs can also be overwhelmed by weedy invaders seeded by birds, squirrels or wind. For example: Common Buckthorn (*Rhamnus cathartica*), Walnut (*Juglans* spp.), Elm (*Ulmus* spp.). If routine clearing of these invading woody species is not done, the original shrubs may be compromised or lost. Replacement may again be needed.

Authors: David Whiting (CSU Extension, retired), with Robert Cox and Carol O’Meara (CSU Extension), and Carl Wilson (CSU Extension, retired). Artwork by David Whiting and USDA; used by permission.

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CMG GardenNotes #617

Pruning Evergreens

Most types of evergreen trees and shrubs need little to no pruning. Pruning may make the new growth bushier, but will not effectively control size. Select plants based on mature size to minimize pruning needs. If frequent pruning is necessary to keep plant growth in bounds and prevent interference with a walk, driveway or view, consider replacing the plant. Evergreen trees and shrubs are pruned according to species growth characteristics.

Pruning Evergreen Trees

On evergreen trees, avoid pruning the central leader (trunk). This results in the development of multiple leaders that are prone to wind and snow damage. If the central leader is killed back, select one branch to become the new leader and remove potentially competing leaders.

Never allow codominant trunks (trunks of similar size) to develop. If multiple trunks begin to develop, select one and remove others.

For structural integrity on evergreen trees, all side branches should be less than half the diameter of the adjacent trunk (less than one-third is preferred). If the diameter of a side branch is too large, prune back part of the needled area to slow growth or remove the branch entirely back to the trunk.

Removing Large Branches on Evergreen Trees

New needles will not grow from branches without needles. When a side branch is removed on an evergreen, cut back to the trunk just outside the ***branch collar*** (the enlarged connecting area on the trunk around the limb).

Do not cut into or otherwise injure the branch collar. Do not make flush cuts. Remove the branch using a three-cut method. [Figure 1]

Cut 1. Coming out 12-15 inches from the trunk, make an undercut a third to halfway through the branch.

Cut 2. Moving a couple of inches out past the first cut, make the second cut from the top, removing the branch. This double- cut method prevents the weight of the branch from tearing the branch below the branch collar.

Cut 3. Make the third and final cut just outside the branch bark collar. Take extra caution to not cut into or otherwise injure the branch bark collar.

For additional details on pruning cuts, refer to *CMG GardenNotes #612,* Pruning Cuts.

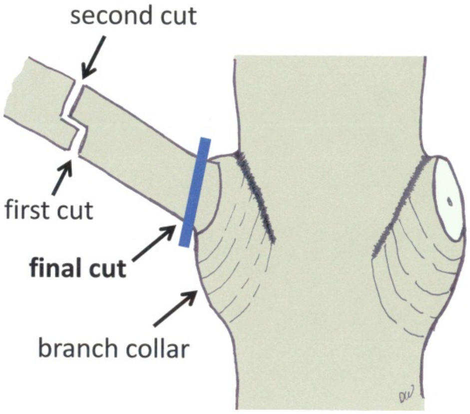

Figure 1. On evergreen trees, remove large branches back to the trunk using a three-cut method. Make the final cut just outside the branch collar. Needles only grow from the growing tips out and will not develop on the interior branch wood without needles.

Pruning Spruce, Fir, and Douglas Fir

Spruce (*Picea* spp.), fir (*Abies* spp.), and Douglas fir (*Pseudotsuga menziesii*) generally need little to no pruning.

On young trees, pruning is useful in situations where bushier new growth is desired. Because these species produce some side buds, branch tips can be removed encouraging side bud growth. Prune late winter or early spring. [Figure 2]

Figure 2. Pruning spruce and fir back to a side bud or side branch will encourage growth of side branches. (Line drawing by CSU Extension.)

Spruce, fir, and Douglas fir that are over-growing their space are somewhat tolerant of being pruned back as long as they are not pruned back past the needles. However, with constant pruning the branches may begin to show needle browning and dieback. In situations where the branch must be pruned back past the needles, remove it back to the trunk.

In landscape design, small to midsize evergreen trees, with their pyramidal form, generally look best with their lowest branches allowed to drape to ground level.

On large trees, primary growth occurs at the top with minimal growth at the lower levels. Due to slow growth, pruning of the lower branches may give a "pruned look" for a long time. On large trees, limb up lower branches only if they are in the way.

Very slow-growing species, like the dwarf Alberta spruce (*Picea glauca* var. *albertiana* 'Conica'), blue nest spruce, aka dwarf black spruce (*Picea mariana* 'Nana') and bird's nest spruce (*Picea abies* 'Nidiformis') are rather intolerant of pruning.

Pruning Pine

Pines generally need little to no pruning.

On young plants, if a more compact new growth is desired, "pinching" may be helpful. Using the fingers, snap off one-third of the new growing tips while in the "candle" stage (in the spring, when young needles are in a tight cluster). Avoid using pruners or a knife, as it will cut the remaining needles, giving a brown tip appearance. [Figure 3]

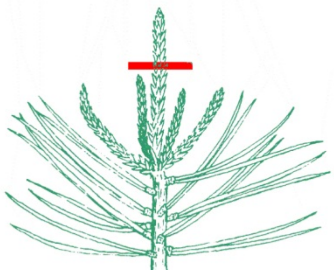

Figure 3. On pines, for bushier new growth "pinch" growing tips by snapping off one-third of the "candle" tips with the fingers. Because pines produce few side buds, they are intolerant of more extensive pruning.
(Line drawing by CSU Extension.)

Because pines produce few side buds, they are intolerant of more extensive pruning. If the terminal bud on a branch is removed, growth on that shoot is stopped, with additional growth occurring only from existing side branches. Do not shear pines.

Like other evergreen trees, small to midsize pine trees look best (from the landscape design perspective) with their lowest branches allowed to drape down near ground level. When a lower branch has to be pruned back for space issues, remove it back to the trunk.

Pruning Juniper and Arborvitae

Juniper and arborvitae generally need little to no pruning.

They may be pruned at anytime except during subzero weather. The best time is early spring, prior to new growth.

The best pruning method is to cut individual branches back to an upward growing side branch. This method of pruning is time-consuming, but keeps the plant looking young and natural. [Figure 4]

Figure 4. Pruning junipers and arborvitae back to a side shoot hides the pruning cut. (Line drawing by CSU Extension.)

While shearing is quick and easy, it is not recommended, especially after midsummer. Shearing creates a dense growth of foliage on the plant's exterior. This in turn shades out the interior growth, and the plant becomes a thin shell of foliage. Frequently sheared plants are more prone to show needle browning and dieback from winter cold and drying winds.

Any pruning that tapers in toward the bottom of the plant will lead to thinning of the lower branches due to shading. To keep the bottom full, the base of the shrub needs to be wider than the top portion.

It is common to see junipers and arborvitae that have overgrown their space. Because new growth comes ONLY from the growing tips, branches cannot be pruned back into wood without needles. If the shrub is pruned back to bare wood, it will have a permanent bare spot.

For shrubs that are getting too large, it is better to prune them back as they begin to overgrow the site. Pruning back severely overgrown shrubs generally gets into wood without needles. Consider replacing severely overgrown plants with smaller cultivars or other species.

Junipers and arborvitae growing in the shade are rather intolerant of pruning due to slow growth rates.

Authors: David Whiting (CSU Extension, retired) with Carol O'Meara (CSU Extension). Artwork by David Whiting and Colorado State University Extension; used by permission.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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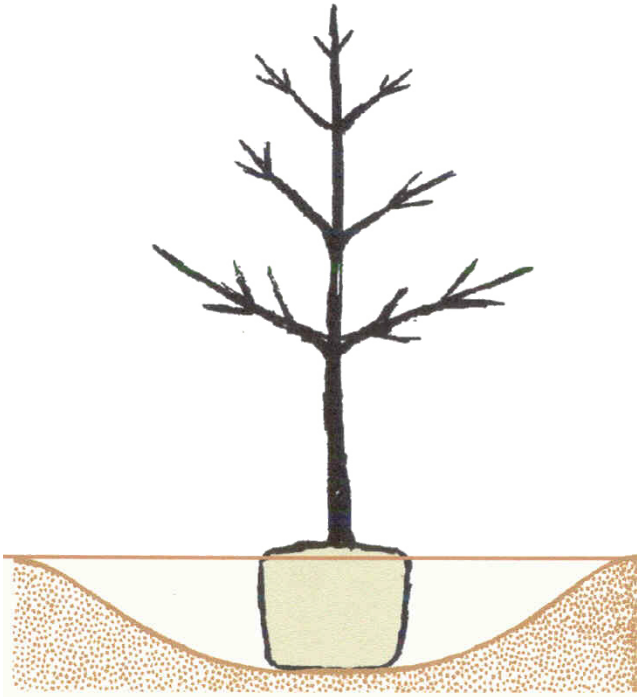

The Science of Planting Trees

Right Plant, Right Place

References / Reading

Colorado State University Extension

Books

- ***Principles and Practice of Planting Trees and Shrubs*** by Gary W. Watson and E.B. Himelick. International Society of Arboriculture. 1997. ISBN:1-881956-18-0
- ***Woody Landscape Plants for the High Plains*** by D.H. Fairchild and J.E. Klett. Colorado State University Cooperative Extension Bulletin LTLB93-1. 1993. To order call the CSU Cooperative Extension Resource Center toll-free at 877-692-9358.
- ***Manual of Woody Landscape Plants*** by Michael A. Dirr. Stipes Publishing. 2009. ISBN-10: 1588748685.

Web

- **Dr. Ed Gilman's Tree Planting Site at University of Florida:** http://hort.ifas.ufl.edu/woody/planting.shtml
- ***Front Range Tree Recommendation List*** at http://www.ext.colostate.edu/pubs/garden/treereclist.pdf

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Tree planting curriculum developed by David Whiting (CSU Extension, retired), with Joann Jones (CSU Extension, retired), Alison O'Connor (CSU Extension), and Carol O'Meara (CSU Extension).

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Learning Objectives

At the end of this training, the student will be able to:

- For a given home landscape situation, discuss *Right Plant, Right Place* considerations for tree placement.
- For a given home landscape situation, discuss *Right Plant, Right Place* considerations for tree selection.
- Plant a tree for rapid root establishment.
- Describe post planting tree care.

Review Questions

Right Plant, Right Place

1 What is the average life of a newly planted landscape tree? Why is it so short?

2. What five categories of plant care play in the success of tree plantings?

3. Describe functions of trees in landscape design.

4. Define a specimen tree, group planting, and mass planting.

5. For energy conservation, where should trees be placed to maximize summer shading and to maximize winter heating?

6. What percent of the sun's radiation will a tree block on a clear summer day?

7. What percent of the cooling effect of trees comes from evapotranspiration? How do drought and irrigation restrictions influence this cooling?

8. In order, list the four priorities for summer shading.

9. For energy conservation, what is the goal in urban forestry as to tree canopy cover?

10. For noise abatement, where should trees and shrubs be placed?

11. List benefits of shade trees.

12. What is the meaning behind "right plant, right place?" List examples of criteria to consider in selecting a tree species for a site.

13. Explain the criteria for above-ground space and below-ground rooting space in tree selection.

14. What happens when the root system cannot escape the root vault area?

15. Give examples of soil- and water-related considerations in tree selection.

16. Give examples of maintenance-related considerations in tree selection.

17. List factors that play into a tree's hardiness. What does a hardiness zone map tell about hardiness? Explain how hardiness changes through the winter in relation to weather.

18. Explain how the microclimate around a home influences plant selection.

19. Give examples of other criteria in tree selection.

20. Explain the rule of thumb for what it takes to move a tree with a 2-, 3-, and 4-foot wide root ball.

21. Where do you find standards (regulations) for plant-size-to-root-size relationships for various types of nursery stock?

22. What are the advantages of selecting a small-caliper tree? A larger-caliper tree? Which will be the largest size five years after planting?

23. Types of stock: Define the following terms and list advantages and limitations of each as indicated on the lecture slides.

    a. Container-grown
    b. In- ground, fabric grow bag
    c. Field-grown – B&B
    d. Field-grown – Balled and Potted
    e. Bare-root

24. To avoid purchasing problems, list key points in the selection and inspection of nursery plants.

25. List key points in pre-plant handling of nursery stock to minimize post-planting stress.

The Science of Planting Trees

26. What is the most limiting factor on a tree's root growth potential?

27. Compared to a field-grown, B&B tree or container-grown tree, what percent of the fine absorbing roots will be found in the nursery stock root ball?

28. What is meant by the "science of planting trees"?

29. What is the proper depth of a tree in the root ball? How can you tell if it is planted at the correct depth? What should be done by the planter if the tree is planted too deep in the root ball?

30. What is the proper depth of the root ball in the planting hole? Why should the tree sit on undisturbed soil? What should be done if the planting hole is accidentally dug too deep?

31. Explain the benefits of the saucer-shaped hole three times wider than the root ball. Explain the concerns about it filling with water.

32. If the planting hole is dug with an auger, how can it be readily modified so the tree has the benefits of a saucer-shaped hole?

33. Be able to diagram and label the routine planting specifications, including depth of tree in the root ball, depth of root ball in planting hole and planting hole depth and width.

34. How are the recommended planting criteria modified for the following planting situations?

    a. Wet soil
    b. Compacted/clayish soil
    c. Planting on slopes

35. For container-grown nursery stock, discuss considerations in removing the container and setting tree in place.

36. For field-grown, B&B nursery stock, discuss considerations in setting tree in place and removing the wrappings.

    a. For B&B materials, why is the wrapping material removed after setting the tree in place and packing soil around the bottom?
    b. What about the packing materials on the bottom? Explain why it does not interfere with root growth.
    c. What packing materials should be removed from the sides? How far down?
    d. Do wire baskets interfere with root growth?
    e. Will burlap decay fast enough to not interfere with root growth?
    f. How fast do synthetic burlap, fabric grow bags, nylon twine, and wire baskets decay?

37. What should the planter do if the root ball has circling roots? What should the planter do if the root ball has roots sticking way out from the root ball?

38. Explain the statement that unamended backfill soil is not the same as unmodified backfill soil. Discuss the issue of amending the backfill. What criteria should be used to determine what criteria are appropriate for a given site?

39. List the four types of above-ground staking. Describe criteria for each.

40. Describe techniques used in below-ground stabilization.

41. Describe criteria for mulching around a newly planted tree.

    a. How deep should the mulch be applied?
    b. What about mulch up against the trunk?
    c. What is the problem with "mulch volcanoes"?

42. Describe steps in planting bare-root nursery stock.

Care after planting

43. Describe the plan for watering newly planted trees based on size. How much should be applied? How often? For how long?

44. How should a tree in the establishment phase be fertilized?

45. What is the rule of thumb on how long the establishment phase lasts?

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CMG GardenNotes #631

Tree Placement: Right Plant, Right Place

This publication outlines considerations for tree placement in the home landscape. The average life of a tree in the landscape is only eight years due to poor design and planting techniques. Homeowners and landscape designers often place trees in situations where trees have little chance to establish and thrive. Successful tree planting and establishment need attention in these five areas:

- Functional design
- Plant selection
- Pre-plant handling
- Planting techniques
- Post-planting care

Tree Placement in Landscape Design

In landscape design, placement of trees needs careful consideration to function and design elements. Trees are typically the major plant structure in a landscape. Trees give architectural form and organization to space.

In landscape design, trees should not be randomly placed around the property. Rather, place trees as specimens, group plantings, or mass plantings.

Specimen trees – The individual tree becomes the landscape feature. It is set off from other trees and plant materials by unique spacing, form, color, and/or texture. Specimen trees are often, but not always, a focal point in the design.

<u>Group plantings</u> – In group plantings, the trees <u>as a unit</u> become the landscape feature. Groupings are often, but not always, the same species. In group plantings, do not mix contrasting forms.

<u>Mass plantings</u> – In mass plantings, individual trees lose identity and appear as one larger unit in the design. A group planting may grow into a mass planting as trees mature.

Trees serve several key roles in landscape design. They often **define space**. Their spreading branches create a canopy that forms a ceiling for an outdoor room. Because we spend a lot of time indoors, people are more comfortable with this outdoor **ceiling effect**. [Figure 1]

Figure 1. Trees create a comfortable outdoor living space with their “ceiling effect.”

Trees are used to **frame and mask views**. Vertical views are effectively framed with trees on both sides. The yard should flow into the view. Avoid specimen plants that draw attention away from the view. [Figure 2]

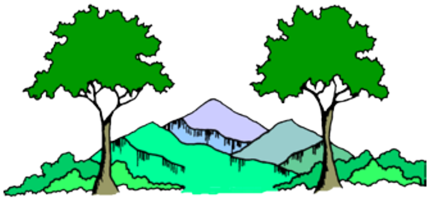


Figure 2. In framing a view, allow the yard to flow into the view.

When framing a house, consider trees in front and to the sides as well as trees that can be viewed over the roofline. For framing, use the point of reference from which most people would view the house rather than straight on. [Figure 3]

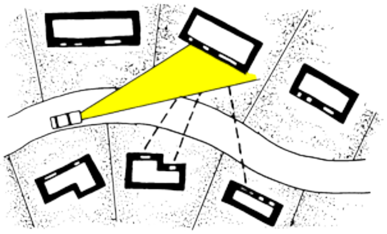


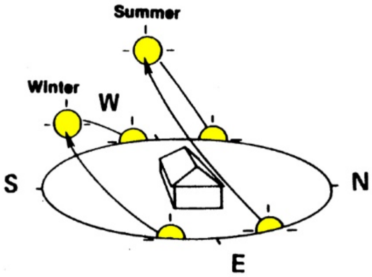
Figure 3. When framing a house, consider how others would look at the home rather than straight on.

Trees and Energy Conservation

Tree placement can play a significant role in energy conservation. Winter sun entering south-facing windows can effectively heat many homes. Summer shade on south- and west-facing windows provides summer cooling.

In evaluating shading and heating patterns, be aware that shade patterns change with the season and with the latitude. [Figure 4]

Figure 4. The shade pattern changes with the season and with latitude.



Maximizing Winter Solar Heating

Homes with south-facing windows have a great potential to capture winter solar heat.

In the winter, deciduous tree branches intercept 20-55% of the sun's radiation. For winter energy conservation, avoid placing trees where they would shade the windows in the winter, and open drapes to allow the sun's energy into the home. Winter shade patterns are large, approximately 2½ times the mature height of the tree at Colorado latitudes. [Figure 5]

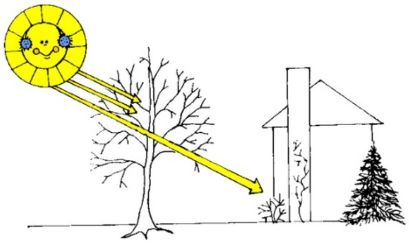


Figure 5. For homes with south-facing windows, tree placement can compromise winter heating potential.

Maximizing Summer Cooling

In the summer, trees block 70-90% of the sun's radiation on a clear summer day. When properly placed, trees can reduce air conditioning demands by 10-30%. Along the Colorado high plains and mountain communities, where temperatures typically cool in the evening, shading a home may adequately moderate temperatures without the expense of air conditioning. [Figure 6]

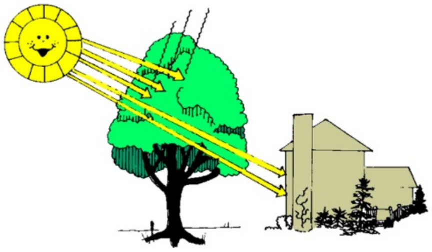


Figure 6. Carefully placed trees can reduce home cooling costs by 10-30%.

Evapotranspiration accounts for 70-80% of the cooling benefit. Under dry conditions (including water restrictions that prohibit landscape irrigation) evapotranspiration shuts down, photosynthesis stops (trees live off carbohydrate reserves), and the cooling effect is reduced. Community temperatures may rise significantly when landscape irrigation restrictions prohibit outdoor watering.

Shading the House

In shading the house, there is a 2-3 hour lag time on sun heat hitting the house and the house becoming extremely hot. Shading priorities at Colorado latitudes include the following:

1. Shade windows on south and west
2. Shade south walls
3. Shade west walls
4. Shade air-conditioning units

Shading Pavement

As illustrated in Figure 7, a paved area stores approximately 50% of the sun's energy. In comparison, a grass area only stores 5% of the energy and uses 50% for evapotranspiration, resulting in a cooling effect. This cooling effect is only operational when the grass has water for active growth.

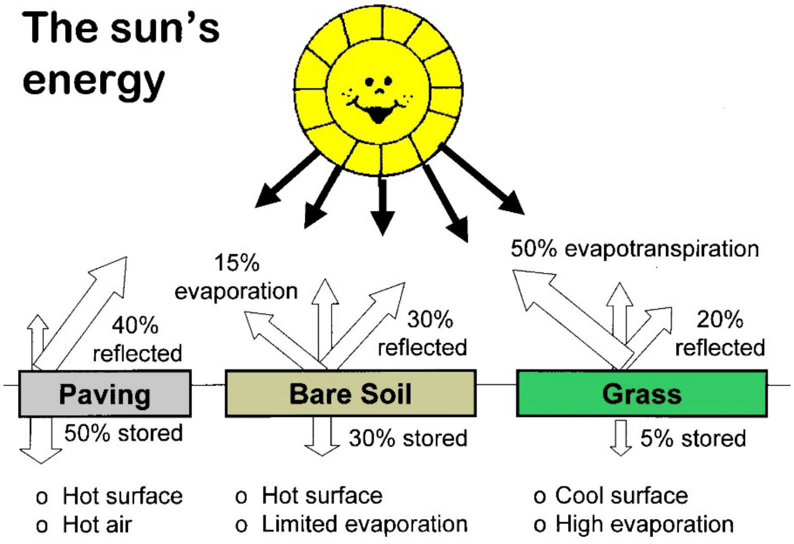
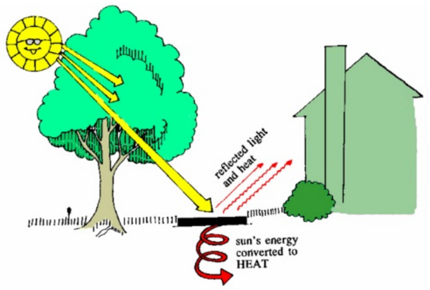


Figure 7. The sun's energy

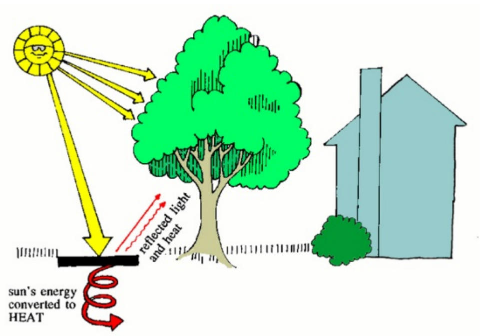
Another important cooling technique is to shade pavement and other heat-storing materials like the patio and driveway. Also, minimizing paved surfaces helps keep the living area cool. [Figure 8]

Figure 8.   For cooling, shade heat-storing areas and minimize heat-storing surfaces.



Trees and other plant materials may also be used to shield the living space from stored and reflected heat. [Figure 9]

Figure 9. Use trees to cool the air between the heat-storing surface and living space.



Shading Streets

Older communities with tree-lined streets are noted for the pleasing, inviting surroundings that street trees create. Shaded streets are 10°F to 40°F cooler.

However, street trees are often predisposed to poor growth and limited life spans due to poor soil conditions. Tree roots can generally spread under a sidewalk into open lawn areas beyond. Root spread under a street is dependent on the soil properties created during road construction.

When the planting strip between the street and sidewalk is less than eight feet wide, tree health, vigor, and life span will be reduced. In most communities, planting strip width is set by the city ordinance in effect at the time of development.

An effective alternative for tree-lined streets is to plant trees in the lawn eight feet in from the street. This may give trees a better soil environment for root growth, resulting in improved tree vigor, growth, and longevity. In this situation, trees are also less likely to be hit by cars or damaged from road repairs. Eliminating the narrow planting area between the street and sidewalk is also an important water conservation technique as the "mow strip" is difficult to irrigate efficiently.

Noise Abatement with Trees and Shrubs

Tree and shrub hedgerows (planting belts) effectively abate noise pollution. To be most effective, place the hedgerow close to the noise source away from the living area. The hedgerow should be twice as long as the distance from the noise source to the living space. To be effective, the hedgerow needs to be dense. A few trees and shrubs here and there do little to abate noise. [Figure 10]

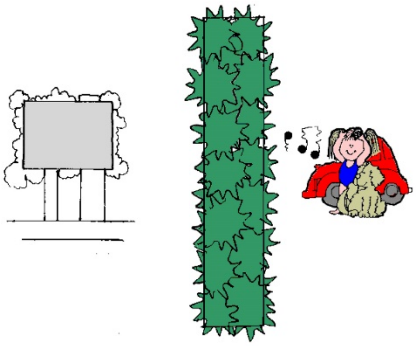


Figure 10. For effective noise abatement, place plant belt next to noise source.

Other Environmental Benefits of Trees

In a study by the USDA Forest Service, the 16,000 street trees in Fort Collins, Colorado, contribute $2.2 million in environmental benefits. The community forest has many important benefits, including:

- Energy saving from heating and cooling
- Noise abatement
- Carbon dioxide reduction – In a Sacramento California study, the carbon sequestration from the community forest more than offsets the inputs from human activity.
- Air-pollution abatement
- Hydrology (stormwater runoff)
- Property values

The USDA Forest Service evaluated the benefits of community forests. For each dollar that a city invests in a community tree program, large trees return $1.92 in environmental benefits. Medium-size trees return $1.36, while small trees return $1.00.

To maximize environmental benefits, the goal in community forestry is to have

50% of the land covered with tree canopy. That is, if we were to look down from an airplane, trees would cover 50% of the area. Here in the west, we have a great need to plant more trees in our communities. In wooded communities, the need may be to thin the forest.

To maximize the benefits of our community forests, homeowners and community leaders need to recognize that the primary benefits occur from large trees. We need to enhance efforts to protect and maintain large trees. We need to plan for large trees in landscape design. Small specimen trees may add to the landscape design, but large trees provide significantly more environmental benefits. We need to plant trees in situations where they have the potential to reach a mature size with longevity.

Growing Space

Size is a primary consideration in tree selection. Trees should fit in the available growing space without pruning. This is of primary concern under utility lines as the utility has the right-of-way. Frequent pruning required to keep utility lines clear adds to our utility rates.

As discussed previously, environmental benefits are significantly greater for larger trees. Consider large tree species whenever the space allows. With proper structural training, large trees have minimal potential for storm and wind damage.

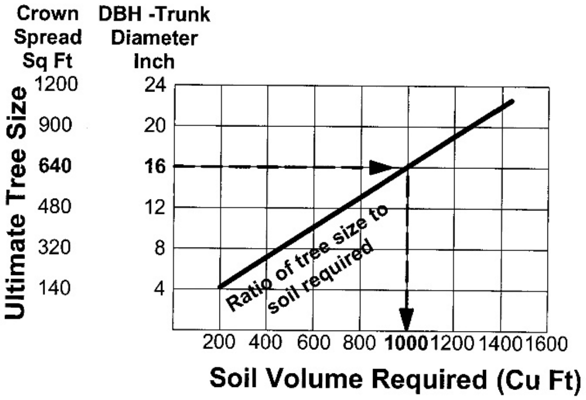
Homeowners often desire fast-growing trees. However, fast-growing species are typically more prone to insects, diseases, and internal decay. Fast-growing species typically have shorter life spans.

Rooting Space

Rooting space should be a primary consideration in tree selection. The mature size, growth rate, and longevity of a tree are directly related to the available rooting space. Many trees in the landscape are predisposed at planting to a short life and limited growth potential due to poor soil conditions and limited rooting space.

Figure 11 shows the relationship between root space and ultimate tree size. For example, a tree with a 16-inch diameter requires 1,000 cubic feet of soil. On a compacted, clayey soil, rooting depth may be restricted to 1 foot or less, and spread would be an area 36 feet in diameter. Anything less will reduce tree size, growth rates, vigor, and longevity. [Figure 11]

Figure 11. Ultimate tree size is set by the rooting space.



Example: A 16 inch diameter tree requires 1000 cu ft of soil

Tree roots can generally cross under a sidewalk to open lawn areas beyond. The ability of roots to cross under a street depends on the road base properties. A good road base does not typically support root growth due to compaction and low soil oxygen levels.

The rooting area does not need to be rounded; it can be about any shape. Trees can share rooting space.

Trees in Planters

Trees are often placed in planters and other sites with limited rooting potential. If the roots cannot escape the planting site (root vault) into other soils:

1. Root growth slows when the root vault area is filled.
2. Tree growth slows.
3. Tree declines.
4. Routine replacement is required.

The average life of trees in sidewalk planters and other restricted root vault sites is 8 years. Home gardener and landscape designers need to understand that with restricted rooting space, growth potential, and longevity are reduced accordingly.

Authors: David Whiting (CSU Extension, retired) with Carol O'Meara (CSU Extension). Artwork by David Whiting; used by permission.

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CMG GardenNotes #632

Tree Selection: Right Plant, Right Place

The average life of a tree in the landscape is only eight years due to poor design and planting techniques. This publication outlines considerations in tree selection for the home landscape.

Species Selection

Many species of trees and shrubs are well suited to Colorado landscapes. Colorado State University Extension publications listing trees and shrubs for Colorado, including the following:

CSU Extension Fact Sheets available online at www.cmg.colostate.edu.

- Deciduous Shrubs, #7.415
- Evergreen Shrubs, #7.414
- Evergreen Trees, #7.403
- Hedges, #7.208
- Large Deciduous Trees for Street and Shade, #7.419
- Native Shrubs for Colorado Landscapes, #7.422
- Native Trees for Colorado Landscapes, #7.421
- Shrubs for Mountain Communities, #7.407
- Small Deciduous Trees, #7.418
- Trees and Shrubs for Mountain Areas, #7.423
- Xeriscaping: Trees and Shrubs, #7.229

Other Publications

- ***Front Range Tree Recommendation List*** available at http://www.ext.colostate.edu/pubs/garden/treereclist.pdf

In addition, many communities and nurseries have tree lists for local areas. Some communities have small arboretums in local parks where a variety of trees may be viewed.

In selecting trees for a home landscape, remember that there is NO perfect tree. All trees have good and bad characteristics. Select trees based on site considerations as well as personal likes.

The best advice for selecting trees is to intentionally plant a diversity of species in the neighborhood and community. Avoid frequent use of only a few tree species as this increases the likelihood of insect and disease problems. Dutch elm disease spread through the United States due to the over-planting of elm trees. Ash trees became a common replacement for Elms. Now the lilac/ash borer is commonplace. Currently honeylocust is very popular, and pest problems on honeylocust are becoming common. Aspen is popular along the Colorado Front Range. While native to our mountains, it is not native to the high plains and has many problems in irrigated yards along Front Range communities.

Mature Size

Size is a primary consideration in tree selection. Trees should fit in the available growing space without pruning. This is of primary concern under utility lines as the utility has the right-of-way.

Because large trees give a higher return in environmental benefits, plant large tree species whenever the space allows. Large trees can be structurally strong if attention is given to structural training while young.

Growth Rates

Homeowners often desire fast-growing trees. However, fast-growing species are typically more prone to insects, diseases, and internal decay. Fast-growing species typically have shorter life spans.

Soil Considerations

Suitable rooting space is a major limiting factor in tree growth. Poor soil conditions contribute to 80% of tree health issues. Unfortunately, many homeowners and landscape designers fail to consider soil limitations in tree selection and planting. Impacts of poor soil conditions include the following:

- Many trees fail to establish or are slow to establish.
- Growth rates will be reduced.

  - Tree vigor will be low, predisposing trees to insects, diseases and other stress factors.
  - Mature size will be smaller.
  - Longevity will be shorter.

Soil texture, structure, and tilth are considerations in tree selection. Some trees perform poorly in compacted or clayey soils (due to low soil oxygen levels). On compacted or clayey soils, drainage can be a limiting factor. Reference books often list trees that are “flooding or compaction tolerant” as an indication of trees more tolerant of low soil oxygen and more adaptable to compacted or clayey soils. Other trees do poorly in dry sandy soils (due to drought).

If the soil has *free lime*, iron chlorosis is a common problem for some species of trees in heavily irrigated lawns. Avoid planting species susceptible to iron chlorosis (like silver maple and aspen) in this situation. For additional information, refer to *CMG GardenNotes* #223, **Iron Chlorosis**. [Figure 1]

Figure 1. Iron chlorosis (yellowing of younger leaves with veins remaining green) on aspen.

Water Needs and Tolerances

Water needs and tolerances are primary considerations in light of Colorado’s drought cycle. Gardeners need to understand that the water needed to maintain life is unrelated to the water needed for tree growth. Drought tolerance for any tree changes with the life cycle of the tree. Trees listed as drought-tolerant may not be suitable to extremely dry sites or prolonged water stress.

Scientists cannot yet answer the common question, “How many gallons of water does this tree need?” At best, listing of trees more tolerant of dryer sites is only observational based on routine dry spells, not extreme drought situations.

Another common issue about tree selection is tolerance to wet soils. Due to poor irrigation system design, maintenance, and management, most home lawns are significantly over-watered. Some trees, such as crabapples and aspen, are rather intolerant of the excessive irrigation.

Management Concerns

Common management issues are a consideration in tree selection.

Pruning – Trees with a decurrent growth habit are more prone to storm and wind damage. Damage potential can be minimized if the trees are structurally trained while young.

Common insect and disease problems should be a consideration. What are the common pests of the tree? Which are only cosmetic, and which can affect tree health? How tolerant are you of cosmetic pests? Under what situations would management efforts become warranted? What is your interest and willingness to make pest management efforts?

For example, stressed ash trees are highly susceptible to lilac/ash borer that may kill trees. For gardeners unwilling to routinely treat for borers, ash would be a poor choice, particularly on a site with limited rooting area. Aspen are highly susceptible to poplar twig gall when planted in a heavily irrigated lawn. If you do not like this cosmetic damage, do not plant aspen in routinely irrigated sites. Honeylocust are highly susceptible to the honeylocust spider mite (which can defoliate the tree midsummer) when planted on dry sites or with restricted rooting areas. If you are not willing to treat for spider mites, do not plant honeylocust on dry sites or those with restricted rooting areas.

Other maintenance factors include:

- Fruiting habit
- Leaf litter nuisance
- Seed germination
- Root and basal suckering

Climatic Adaptation

Exposure to sun, wind, heat, and cold are considerations in tree selection. Issues related to winter hardiness and winter burn can be reduced with winter watering on susceptible species.

Hardiness zones are an indication of the expected minimum low winter temperature. However, in Colorado we occasionally have an extremely cold winter that challenges the hardiness zone data as we approach record lows.

Hardiness (the ability of a plant to withstand cold) comes from many interrelated factors:

Photoperiod and genetics – The length of night (photoperiod) is the first signal trees receive that winter is approaching. When parent materials are collected from the south and then moved north, they may not be adapted to the differences in photoperiod, and winter damage may be more pronounced. Growers are becoming aware of this important issue in selection of nursery stock.

Minimum temperatures that trees tolerate are set by the plants' genetics and influenced by recent temperatures.

Recent temperatures – A tree's tolerance to cold is heavily influenced by the temperature patterns of the previous few days. When temperatures gradually drop over a period of weeks, trees are generally tolerant of extreme cold. However, trees are less tolerant of extreme cold when it appears suddenly following moderate temperatures.

Rapid temperature change is a primary factor limiting our plant selection. In Colorado it is common to have a spring thaw followed by an "arctic express" back to winter. Temperatures readily drop more than 50°F in an hour.

Water – Woody plants going into winter with dry soil conditions lose approximately 20°F in hardiness. Colorado's dry fall and winter weather reduces plant hardiness. Fall watering, after leaves drop but before soils freeze, helps minimize hardiness issues.

Wind exposure is another factor reducing hardiness in open areas of the high plains. Winter watering helps manage this issue.

Exposure to sun, including reflected sun from snow or structures, contributes to winter bark injury and frost cracks.

Carbohydrate reserves – Plants under stress, with lower carbohydrate reserves, are more susceptible to winter damage. During the drought of 2002-2004, Colorado trees experienced extensive winter injury related to stress, even without extreme cold.

Microclimates – The typical yard has dryer and wetter sites, windy and less windy areas, and warmer and cooler areas. These microclimates may create a site that is more or less suitable for some specific plants.

Other Selection Criteria

- Potential damage to hardscapes (sidewalks, gutters, etc.) from root growth
- Utility right-of-ways for above-ground and below-ground utilities
- Vandalism in public-access sites
- Car damage along streets
- Turf competition and herbicide use
- Pesticide drift from adjacent properties
- De-icing salts

The majority of landscape management problems are traceable back to the design flaws. Care in tree selection and placement will help minimize management problems.

Size Considerations

Size and Establishment

To give the "instant tree" appearance, larger-caliper trees are often the choice for homeowners and public-access sites. However, the root systems of larger trees also take longer to redevelop in the establishment phase of the life cycle before the trees shift into the growth phase. During the establishment phase, canopy growth will be minimal. For this reason, smaller trees are recommended on sites where less than ideal growing conditions exist.

In Hardiness Zones 4 and 5, with good planting techniques and good soil conditions, it typically takes one growing season per inch of trunk caliper (measured at six inches above soil line) for roots to establish following transplanting. That is, a one-inch caliper tree will take one season for the roots to establish, while a three-inch caliper tree will take three seasons. In cooler regions with shorter growing seasons, it will take longer. With longer growing seasons, like the southern United States, the establishment phase will be measured in months.

On sites with poor soils and poor planting techniques, the establishment phase may be longer, and trees must live off carbohydrate reserves until roots become established. It is common to see trees planted with poor planting techniques and/or poor soil conditions that never establish, but rather decline over a period of time. In recent years, poor planting techniques have killed more trees than any insect or disease outbreak!

Moving Trees – A Weight Issue

Size (weight) is another factor in tree selection. It takes two people to move a two inch caliper tree (measured six inches above the soil line). Larger trees require mechanical help. Trees up to four inch caliper can be moved with front-end loaders used in landscape installation. For larger-caliper trees, special tree-moving equipment is required.

Minimum Root Ball Size

The minimum size of the root ball for trees and shrubs is set by the Colorado Department of Agriculture in the ***Rules and Regulations of the Colorado Nursery Act***. [Tables 1 and 2]

Maximum tree size to move with a spade is given in Table 3. It is common mistake to expect tree to live when moved with an undersized tree spade! [Table 3]

Table 1.
Minimum Root Ball Diameter for Nursery-Grown, and B&B Shade Trees

Tree Caliper*	Minimum Root Ball Diameter
½ to ¾ inch	12 inches
¾ to 1 inch	14 inches
1 to 1 ¼ inches	16 inches
1 ¼ to 1 ½ inches	18 inches
1 ½ to 1 ¾ inches	20 inches
1 ¾ to 2 inches	24 inches
2 to 2 ½ inches	26 inches
2 ½ to 3 inches	28 inches
3 to 3 ½ inches	32 inches
3 ½ to 4 inches	36 inches

*Measured 6 inches above soil line.

Table 2.
Minimum Root Ball Size for Coniferous Evergreens

Height	Caliper[1]	Minimum Root Ball Diamter[2]
1 to 2 feet	½ to ¾ inches	12 inches
2 to 3 feet	¾ to 1 inch	14 inches
3 to 4 feet	1 to 1¼ inches	16 inches
4 to 5 feet	1¼ to 1½ inches	18 inches
5 to 6 feet	1½ to 1¾ inches	20 inches
6 to 7 feet	1¾ to 2 inches	24 inches
7 to 8 feet	2 to 2½ inches	26 inches
8 to 9 feet	2½ to 3 inches	28 inches
9 to 10 feet	3 to 3½ inches	32 inches
10 to 12 feet	3½ to 4 inches	36 inches

[1] Measured at 6 inches above the ground
[2] Root ball size based on the larger of height or caliper.
Source, Colorado Department of Agriculture: Colorado Nursery Act

Table 3.
Maximum Size for Tree Spades

Spade Size	Deciduous Trees Caliper	Evergreen Trees Height
44-inch	2-3 inches	5-7 feet
60-inch	3-4 inches	7-9 feet
78-inch	4-6 inches	9-14 feet
85-inch	6-8 inches	14-18 feet

Types of Nursery Stock

Bare-Root Nursery Stock

Bare-root plants are sold without an established soil ball. Bare-root stock is generally limited to smaller-caliper materials. Some evergreen materials will not transplant well as bare-root stock.

The cost of bare-root stock is significantly lower than the same plant as a container-grown or B&B stock.

Roots dehydrate rapidly and must be protected. Bare-root stock is often marketed in individual units with roots bagged in moist sawdust or peat moss to prevent dehydration. Sometimes bare-root stock is temporarily potted to protect roots. Some nurseries maintain bare-root stock in moist sawdust. As plants are removed at sale, roots are packed in moist sawdust for transport to the planting site. These need to be planted within 24 hours of purchase.

Survivability drops rapidly once the plant leafs out. Some nurseries keep bare-root stock in cold storage to delay leafing.

Field-Grown, Balled and Burlapped Nursery Stock

Field-grown, Balled and burlapped (B&B) trees are dug from the growing field with the root ball and soil intact. In the harvest process, only 5-20% of the small roots are retained in the root ball, the other 80-95% is left behind in the field. This puts trees under water stress until roots can reestablish. [Figure 2]

Figure 2. Field-grown B&B nursery stock

To prevent the root ball from breaking, the roots are Balled and wrapped with Burlap and twine (knows as B&B). In nurseries today, there are many variations to B&B techniques. Some are also wrapped in plastic shrink-wrap, placed in a wire basket, or placed in a pot.

B&B stock is best transplanted in the spring or fall.

The weight of the root ball readily becomes an issue with larger-caliper trees. A two inch caliper tree is the largest size two people can expect to move. Equipment will be needed for larger trees.

In field production, the roots may be routinely cut to encourage a more compact root ball. While this process improves the transplantability of the tree, it slows growth, adding to production costs.

Container-Grown Nursery Stock

Container-grown nursery stock is grown in the container. Because the root system is not seriously disturbed, container-grown nursery stock can be readily transplanted throughout the growing season; spring, summer or fall.

Figure 3. Container-grown nursery stock.

Light textured potting mixes are generally used in container production to reduce weight and waterlogging potential in the pot. However, this can make the newly planted tree more prone to drought during the first two years.

Since the roots cannot spread, the root system of container-grown stock will be only 5-20% of that found in field-grown plants. Thus, growth rates in the nursery may be slower.

There are many variations of container production. In many systems, like “pot-in-pot” and “grow-bags,” the container is in the ground. This protects roots from extreme heat and cold and prevents trees from blowing over.

Selecting Plants – Don’t Buy Problems

There are several considerations in plant selection at the nursery, including the following:

- Because **codominant trunks** (trunks of equal size) account for the majority of storm damage, avoid purchasing trees with codominant trunks. A single-trunk tree should have one trunk to the top, and all branches should be less than 1/2 the diameter of the adjacent trunk. (Refer to pruning fact sheets for details.) [Figure 4]

Figure 4. Codominant trunks account for the majority of storm damage. Avoid purchasing trees with codominant trunks or correct the situation with structural pruning.

- Consider what other **corrective pruning** will be needed to structurally train the tree. (Refer to pruning fact sheets for details.) Avoid trees with poor branching structure.

- Any **pruning wounds or bark injury** should be less than one inch or less than 25% of the trunk circumference.

- Trees should have good **growth** the past 2-4 years and good **leaf color**.

- Evaluate the potential long-term impacts of any **insect or disease problems**. While some insect and disease problems are not an issue, others could seriously affect the tree’s health. Due to the water stress imposed by the harvest and planting process, young trees are less tolerant of most pests.

- **Planting depth of the tree in the root ball** – Generally, at least two structural roots should be within the top 1-3 inches of the soil surface, measured 3-4 inches out from the trunk. (Refer *CMG GardenNotes* #633, The Science of Planting Trees, for additional details and exceptions.)

  A visible trunk flare is another indication of proper planting depth in the root ball. However, on many small trees the trunk flair is hardly noticeable. A small gap between the trunk and soil indicates that the tree is planted too deep.

- **Healthy roots** are whitish, while dead roots are dark. **Girdling roots** can become a serious problem and will need to be cut in the planting process.

Shipment and Pre-Plant Handling

Pre-plant handling often predisposes new plantings to decline and death. Factors to pay attention to include the following:

- **Handle carefully.** The root ball is subject to cracking, killing the tree.
- **Lift by the root ball**, not the trunk. If lifted by the trunk, the roots may not be able to support the weight of the root ball soil, cracking the root ball.
- **Protect from mechanical injury** during shipment. The bark on young trees is tender and easily damaged by rubbing or bumping against the vehicle.
- **Protect from dehydration** during shipment. A shade cloth gives good wind protection. Many nurseries routinely wrap trees for shipment. Water upon delivery.
- **Protect from wind and heat** until planted.
- **Check water needs daily.**
- When possible, **plant immediately**.
- **Exposed roots** are readily killed by desiccation and should be cut off in the planting process.

Authors: David Whiting (CSU Extension, retired) with Carol O'Meara (CSU Extension).
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CMG GardenNotes #633

The Science of Planting Trees

Outline:

This *CMG GardenNotes* outlines research-based tree planting steps. The procedures apply to deciduous trees, evergreen trees, and shrubs planted in a landscape setting. As you review the content, pay attention to significant clarification in planting protocol. Based on the research consensus, it is not acceptable to plant a tree in a narrow planting hole with the burlap and wire basket left in place.

The Science of Planting Trees

Tree root systems are shallow and wide spreading. [Figure 1] Based on nursery standards, a field-grown, balled and burlapped (B&B) tree or container-grown tree has less than 5-20% of the fine absorbing roots of the same size tree in a landscape setting. This creates stress when the tree moves from the daily care in the nursery setting to the landscape**. The goal of the science of planting trees is promoting rapid root growth to reduce the water stress imposed by the limited root system.** *Post-planting stress* (transplant shock) describes the stress factors induced by the limited root system.

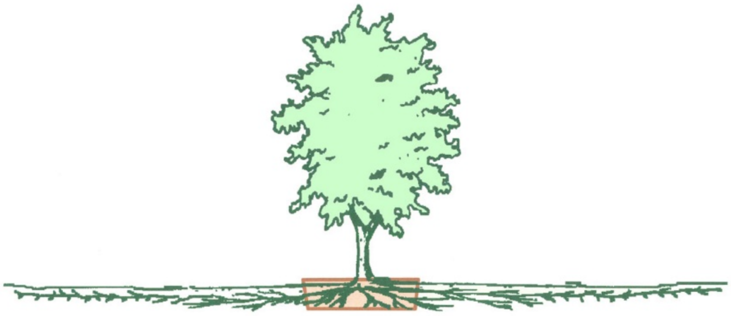


Figure 1. A tree's rooting system is shallow and wide spreading. Based on nursery standards, the container grown or field-grown, balled and burlapped tree has only 5-20% of the fine absorbing roots found on the same size tree in an open landscape. This places the new tree under stress.

Steps to Planting Container-Grown or Field-Grown B&B Nursery Stock

Note: Call before you dig. Whether you plan on planting the tree yourself or hiring the work done, the site needs to have underground utilities marked before digging to plant a tree. In Colorado, this is easy to do by calling the **Utility Notification Center of Colorado** at 1-800-922-1987 or 8-1-1.) It can also be done online at **colorado811.org**. The utilities will be marketed within 72 business hours, so plan ahead.

Step 1. Determine Depth of the Planting Hole

Planting trees too deep has become an epidemic leading to the decline and death of landscape trees. Trunk-girdling roots, caused by planting too deep, leads to more deaths of landscape trees than all other factors combined!

Trunk-girdling roots develop when a tree is planted too deep in the root ball and/or the root ball is planted too deep in the planting hole. Trunk-girdling roots may lead to decline and death some 12 to 20 years after planting. Trunk-girdling roots may be below ground.

To deal with this epidemic an industry-wide working group developed the following standards[1] for tree planting depth:

These standards have been adopted industry wide, including endorsement by the American Nursery and Landscape Association (ANLA), American Society of Consulting Arborists (ASCA), American Society of Landscape Architects (ASLA), Associated Landscape Contractors of America (ALCA), International Society of Arboriculture (ISA), and Tree Care Industry Association (TCIA).

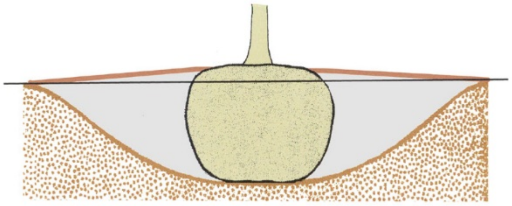
Depth of Root Ball in Planting Hole

In tree planting, **the root ball sits on undug soil**. This prevents the tree from sinking and tilting as the soil settles. If the hole is dug too deep, backfill and firm the soil on the bottom to the correct depth. (Roots grow out from the root ball, not down.)

To deal with the *soil texture interface* (actually the differences in soil pore space) between the root-ball soil and backfill soil, it is imperative that the root ball rise slightly above grade with no backfill soil over top of the root ball. For small (one-inch caliper) trees, the top of the root ball rises one inch above grade. For larger (two to four inch caliper) trees, the top of the root ball rises about two inches above grade. Backfill soil should cover the "knees" tapering down to grade. [Figure 2]

If backfill covers the root ball, water and air will be slow to cross the texture interface. In this situation, water tends to move around the root ball and is slow to soak into the root ball. Root health will be compromised by lower soil oxygen levels. [Figure 3]

Figure 2. Depth of root ball in planting hole – Top of root ball rises 1-2 inches above soil grade. No soil is placed over top of the root ball. Backfill soil covers the "knees" tapering downward to the original soil grade. Root ball sits on un-dug/firmed soil to prevent sinking.



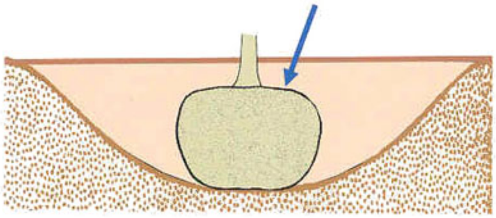


Figure 3. It is imperative that the root ball comes to the surface, with no backfill on top of the root ball. When backfill soil is placed over top of the root ball, the *soil texture interface* impedes water and air movement into the root ball.

Depth of Tree in the Root Ball

- Generally, at least two structural roots should be within the top one to three inches of the root ball, measured three to four inches from the trunk.
- On species prone to trunk-circling roots (crabapples, green ash, hackberry, littleleaf linden, poplar, red maple, and other species with aggressive root systems), the top structural root should be within the top one inch of the root ball.

Checking Depth of Tree in Root Ball

Check the depth of the tree in the root ball. Do not assume that it was planted correctly at the nursery.

- The presence of the root flare is an indication of good planting depth. However, small trees may have minimal root flare development, making it difficult to determine. Be careful not to mistake swelling of the trunk below the graft as the root flare.

- A good way to evaluate planting depth in the root ball is with a slender implement like a slender screwdriver, knitting needle, or barbeque skewer. Systematically probe the root ball three to four inches out from the trunk to locate structural roots and determine their depth. [Figure 4]

Figure 4. Systematically probe the root ball with a slender screwdriver. Generally, at least two structural roots should be found in the top 1-3 inches of soil, 3-4 inches out from the trunk. On species prone to trunk circling roots (crabapples, green ash, hackberry, littleleaf linden, poplar, red maple, and other species with aggressive root systems), the top structural root should be within the top one inch of the root ball.

If the tree is planted too deep in the root ball, excess soil should be removed from the top in the backfill step of the planting process. Adjust the depth of the planting hole to compensate. [Figure 5]

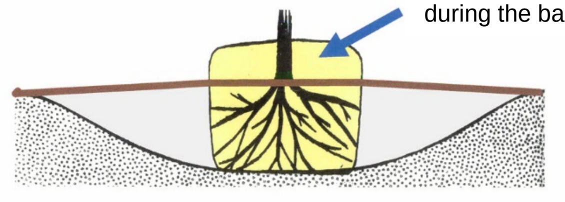


Figure 5. Adjust the depth of the planting hole to bring the root flare to the correct depth.

With trees planted too deep in the root ball, a better option is to not purchase the trees. In the root ball, the soil above the root flare generally does not contain roots so the total volume of roots may be too small to maintain tree health. In container-grown stock, trees planted too deep readily develop trunk-circling roots. [Figure 6]

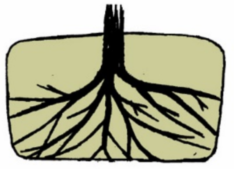


Figure 6. Another issue with soil levels above the root flare is root ball size. With roots only in a portion of the root ball area, the root ball may be too small for the tree to thrive following planting.

Summary: Depth of Planting Hole

Depth of the planting hole should be 1-2 inches less than the height of the root ball, adjusted (as needed) to correct the depth of the tree in the root ball.

For example, if a two-inch caliper tree has a root ball height of 16 inches, depth of the planting hole would be 14 inches. However, if the top structural roots are located five inches down in the root ball, between two to four inches of soil needs to be removed from the root ball in the backfill process. Depth of the planting hole would be adjusted to 10-12 inches.

Figure 7. In digging, measure the depth of the planting hole with a straight board (like rake handle) and a measuring tape.

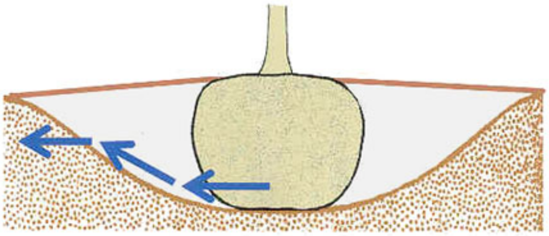
Figure 8. Checking depth of root ball in planting hole with a straight board (like a rake handle).

Step 2. Dig Saucer-Shaped Planting Hole Three-Times Root Ball Diameter

Saucer-Shaped Planting Hole

To support rapid root regeneration, research suggests a wide, saucer-shaped planting hole. If the roots have difficulty penetrating compacted site soil (due to low soil oxygen levels), sloped sides direct roots upward and outward toward the higher oxygen soil near the surface rather than being trapped in the planting hole. Roots that do not penetrate the site soil may begin circling in the hole, leading to trunk-girdling roots. [Figure 9]

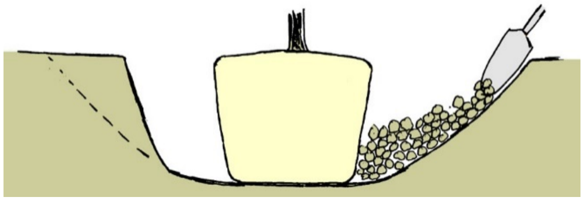
Figure 9. When roots cannot penetrate the site soil (due to low oxygen levels), the saucer-shaped planting hole directs the roots upward and outward into soils with higher oxygen levels.



Waterlogging concerns – The saucer-shaped planting hole actually gives the tree a larger margin for error in overwatering. In the saucer-shaped planting hole, three times the root ball diameter, the upper half contains 85% of the backfill soil, and the upper quarter contains 75% of the backfill soil. Water could saturate the lower 3/4 of the backfill soil and only affect 25% of the root system!

When the planting hole is dug with an auger, cut down the sides with a shovel to help eliminate the glazing and create the preferred sloping sides. An alternative is to rototill a 12-24" inch ring of soil around the planting hole after planting. [Figure 10]

Figure 10. When dug with an auger, cut down the sides into the saucer shape during backfill process.



Planting Hole Depth

Depth of the planting hole is determined in Step 1. To measure depth of the dug hole, place a straight board or shovel handle across the hole and measure from the board/handle height to the bottom of the hole.

For stability, it is imperative that the root ball sits on undug soil. If the hole is dug too deep, backfill and firmly pack the soil to the correct depth. Remember that the planting hole is shallow and wide. As a point of clarification, primary growth of roots is outward, not downward.

Planting Hole Width

Planting hole width is the key to promoting rapid root growth, reducing *post-planting stress.* In soils with great *tilth* (conditions supportive to ideal root growth), width is probably not a minor concern. However, in a compacted clayey soil, typical of much of Colorado, root growth slows when roots reach the undisturbed site soil beyond the backfill area. This is due to lower soil oxygen levels in the undisturbed soil.

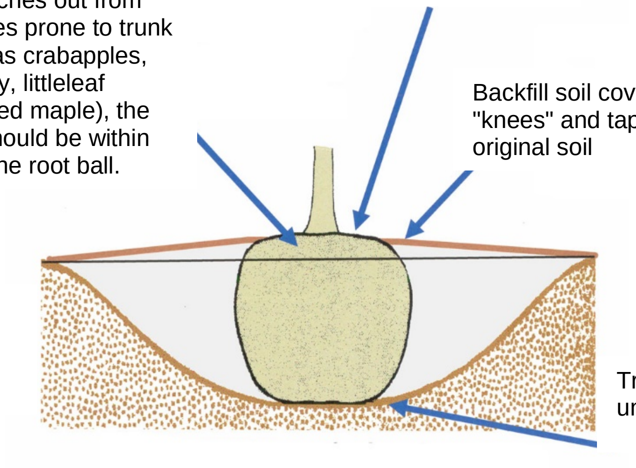
Twenty-five percent wider – A planting hole with vertical sides that is only twenty-five percent wider than the root ball hinders root growth. If the soil is compacted and difficult to penetrate, the roots circle inside the hole just as if the root system were in a container. Size of the root system (before growth is slowed by the lower oxygen levels of the site soil) is insufficient to reduce *post-planting stress.* Narrow planting holes are sometimes used as a labor saving technique. However, on less than idea soils, it will slow root establishment and may predispose the roots to circling.

Two times root ball – A saucer-shaped planting hole twice the diameter of the root ball will allow the root system to grow rapidly to 150% of the root ball size before growth is slowed by the lower oxygen levels of the site soil. This is not enough to avoid *post-planting stress* under normal conditions. A planting hole two times root ball diameter is common in commercial plantings as a labor savings technique. However, on less than idea soils, it may slow root establishment.

Three times root ball – A saucer-shaped planting hole three times the diameter of the root ball allows the root system to grow rapidly to 400% of the root ball size before being slowed by the lower oxygen levels of the site soil. This is enough to reduce *post-planting stress* under normal conditions. For example, a two-inch diameter tree with a 24 inch (two foot) wide root ball needs a 72 inch (six foot) wide saucer-shaped planting hole. To promote root growth, the planting hole is wide, shallow, and saucer-shaped!

The shallow but wide planting hole is the primary technique for encouraging rapid root growth, which is the objective in the *science of planting trees*. This is an important change in the mindset of many folks who have been planting into a narrow, deep hole.

Summary: Planting Hole Specifications [Figure 11]



Top of root ball rises 1-2 inches above grade. No backfill soil covers top of root ball.

Generally, at least two structural roots should be found in the top 1-3 inches of soil, 3-4 inches out from the trunk. On species prone to trunk circling roots (such as crabapples, green ash, hackberry, littleleaf linden, poplar, and red maple), the top structural root should be within the top one inch of the root ball.

Backfill soil covers root ball "knees" and tapers down to original soil

Saucer-shaped planting hole, three times root ball diameter.

Tree sits on undisturbed soil.

Figure 11. Planting hole criteria to promote rapid root establishment, reducing post-planting stress.

Modification for Wet Soils

On wet soils, raise planting depth so that one-third of the root ball is above grade. Cover root ball "knees" with soil, gradually tapering down to grade. Do not use mulch to cover knees, as roots will readily grow in moist mulch but will be killed when the mulch dries out. [Figure 12]

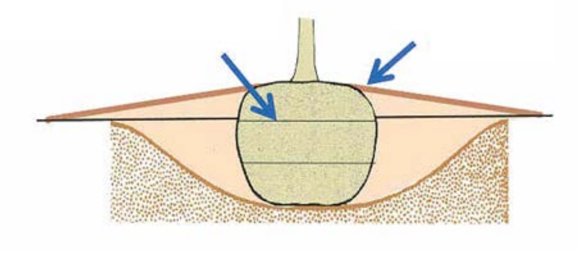


Figure 12. On wet soils, place root ball 1/3 above grade, covering knees with soil tapering down to grade.

Modification for Compacted Soils

On extremely compacted soils, rototilling a ring around the backfill area to a width of four, five, or more times the root ball diameter may be helpful. This should be done after planting is completed so the soil is not compacted by foot traffic during the planting process. [Figure 13]

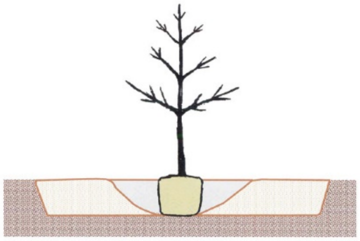


Figure 13. Rototilling a ring around the planting hole may help roots spread into compacted soil.

Planting on a Slope

When planting on a slope, plant "out-of-the-hill" by adjusting the grade around the planting hole as illustrated in Figure 14.

Figure 14. Planting on a slope:
Top row: When planting on a slope, adjust the grade to plant "out-of-the-hill."
Right: When planted "into-the-hill," roots on the uphill side will be too deep, slowing root establishment and growth.

Labor-Saving Techniques

A labor-saving technique is to dig the hole twice the root ball width with more-vertical sides. Place the tree in the hole, firm a ring of soil around the base of the root ball to stabilize it, remove wrappings, and check for circling roots. Then with a shovel cut the sides of the planting hole to form the saucer-shaped planting hole three times the root ball diameter. With this technique, part of the backfill soil does not have to be removed and shoveled back, but simply allowed to fall into the hole. Soil "peds" (dirt clods) up to the size of a small fist are acceptable. With this technique, it is not practical to mix in soil amendments, as amendments must be thoroughly mixed throughout the backfill soil. [Figure 15]

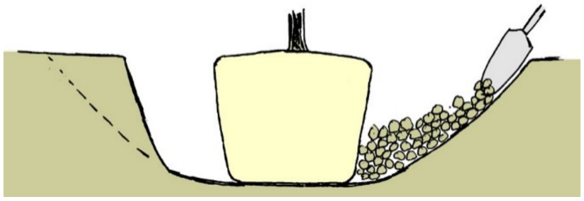


Figure 15. Planting hole widened into saucer-shape during the backfill process.

A small tiller or "garden weeder" makes for quick digging. Simply place the tiller where the hole will be and walk around in a circle. Stop periodically to remove the loosened soil from the hole, and continue walking and tilling in a circle. [Figure 16]

Figure 16. Digging the hole with a small tiller or "garden weeder."

Step 3. Set Tree in Place, Removing Container/Wrappings

In setting the tree in the planting hole, if the tree has a "dogleg" (a slight curve in the trunk just above the graft) the inside curve must face north to reduce winter bark injury. [Figure 17]

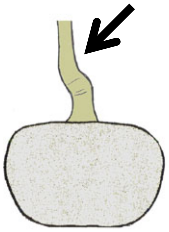


Figure 17. The inside curve of the graft crook or "dogleg" must face north to reduce winter bark injury.

Vertically align the tree with the top centered above the root ball. Due to curves along the trunk, the trunk may not necessarily look straight. It will appear straighter with growth.

In this step, techniques vary for container-grown trees and B&B trees.

Container-Grown Nursery Stock

"Container-grown" nursery stock refers to trees and shrubs grown in containers using a variety of production methods. Spread of the root system is limited to the container size. An advantage of container stock is that it can be planted in spring, summer, or fall. Smaller trees and shrubs are commonly grown in containers.

There are many variations of container production. In many systems, like "pot-in-pot" and "grow-bags," the container is in the ground. This protects roots from extreme heat and cold and prevents trees from blowing over.

In container-grown nursery stock, circling roots develop over time. These may be on the outside of the root ball (particularly at the bottom of the container) or just inside the root ball and not visible from the surface. Current research finds that the old standard of slitting the root ball on four sides does not adequately deal with circling roots. New standards call for the outer 1-1½ inch of the root ball to be shaved off with a knife, saw, or pruners in the planting process. This encourages roots to grow outward and does not affect tree growth potential.

Figure 18. Container-grown nursery stock is prone to developing circling roots that will girdle the trunk several years after planting if not corrected.

Techniques with Container-Grown Stock

Actual planting techniques in this step vary with the type of container and extent of **root** development. Generic steps include:

a) Lay the tree on its side in or near the planting hole.
b) Wiggle off or cut off the container.
c) Shave off the outer 1-1 ½ inch of the root ball with a knife, saw, or pruners. This step is important to deal with circling roots.
d) Tilt the tree into place. Remember that the inside curve of any dogleg faces north.
e) Check depth of the root ball in the planting hole. If incorrect, remove the tree and correct the depth, firming any soil added back to the hole.
f) Align vertically.
g) Firm a shallow ring of soil around the bottom of the root ball to stabilize it. [Figure 19]

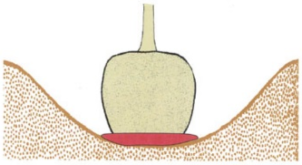


Figure 19. Stabilize the tree by firming a small ring of backfill soil around the base of the root ball.

- The ideal container-grown tree has a nice network of roots holding the root ball together. After the container is removed, the tree is gently tilted into place.
- If some of the soil falls off (often on the bottom), it may be necessary to adjust the depth of the planting hole. Backfill and pack the bottom of the planting hole to the correct depth.
- If most of the soil falls off the roots, the tree is planted as a bare-root tree (see below).
- Fabric grow bags must be removed from the sides. They are generally cut away after setting the tree in place.
- Generally, paper/pulp type containers should be removed. Most are slow to decompose and will complicate soil texture interface issues. Pulp containers often need to be cut off, as they may not slide off readily.
- In handling large trees (3-inch caliper and greater) it may be necessary to set the tree in place before removing the container.
- If the container is easy to cut, it may help to keep the root ball intact by first cutting off the bottom of the container, carefully setting the tree in place and tilting to align vertically, then cutting a slit down the side to remove the container.

Figure 20. If the container is easy to cut, many planters prefer to first cut off the bottom, then move the tree in place (helps hold root ball together) and then slit the container side to remove it.

Field-Grown, Balled and Burlapped Nursery Stock

Field-grown, balled and burlapped (B&B) trees and shrubs are dug from the growing field with the root ball soil intact. In the harvest process, only 5-20% of the feeder roots are retained in the root ball. B&B nursery stock is best transplanted in the cooler spring or fall season.

To prevent the root ball from breaking, the roots are balled and wrapped with burlap (or other fabrics) and twine (hence the name B&B). In nurseries today, there are many variations to B&B techniques. Some are also wrapped in plastic shrink-wrap, placed in a wire basket, or placed in a pot.

Larger plant materials are often sold as B&B stock. In field production, the roots may be routinely cut to encourage a more compact root ball. While this process improves the transplantability of the tree, it adds to production costs.

Depending on how long the tree has been held in the B&B condition, circling roots may begin to develop. If this has occurred, shave off the outer 1-1½ inches of the root ball as described previously for container-grown trees.

Figure 21. Field-grown, B&B nursery stock needs to have the wrappings that hold the root ball together taken off AFTER the tree is set in place.

Techniques with Balled and Burlapped Nursery Stock

An advantage of the wider planting hole is that it gives room for the planter to remove root ball wrappings AFTER the tree is situated in the hole.

Based on research, **standard procedures are to remove root ball wrapping materials (burlap, fabric, grow bags, twine, ties, wire basket, etc.) from the upper 12 inches or 2/3 of the root ball, whichever is greater AFTER the tree is set in place.** Materials under the root ball are not a concern since roots grow outward, not downward.

Actual planting techniques in this step vary with the type of wrapping on the root ball. Generic steps include:

a) Remove extra root ball wrapping added for convenience in marketing (like shrink-wrap and a container). However, do NOT remove the burlap (or fabric), wire basket and twine that hold the root ball together until the tree is set in place.
b) Set the tree in place. Remember that the inside curve of any graft crook faces north.

c) Check depth of the root ball in the planting hole. If incorrect, remove the tree and correct the depth, firming any soil added back to the hole.
d) Align vertically.
e) For stability, firm a shallow ring of soil around the bottom of the root ball. [Figure 22]

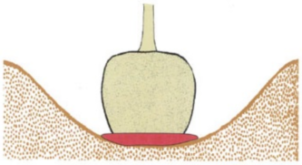


Figure 22. Stabilize the tree by firming a small ring of backfill soil around the base of the root ball.

f) Remove all the wrapping (burlap, fabric, twine, wire basket, etc.) on the upper 12 inches or upper 2/3 of the root ball, whichever is greater.
g) If circling roots are found in the root ball, shave off the outer 1-1½ inches of the root ball with a pruning saw and/or pruners.

Consensus from research is clear that leaving burlap, twine, and wire baskets on the sides of the root ball are not acceptable planting techniques.

- Burlap may be slow to decompose and will complicate soil texture interface issues.
- Burlap that comes to the surface wicks moisture from the root ball, leading to dry soils.
- Jute twine left around the trunk will be slow to decompose, often girdling the tree.
- Nylon twine never decomposes in the soil, often girdling trees several years after planting.
- Wire baskets take 30 plus years to decompose and may interfere with long-term root growth.
- With tapered wire baskets, some planters find it easier to cut off the bottom of the basket before setting the tree in the hole. The basket can still be used to help move the tree and is then easy to remove by simply cutting the rings on the side.

Optional Step 4. Underground Stabilization

One of the trends in tree planting is to use underground stabilization of the root ball rather than above-ground staking. Underground stabilization is out of the way and will not damage the trunk's bark. For information on underground stabilization, refer to *CMG GardenNotes* #634, Tree Staking and Underground Stabilization.

Staking became a routine procedure when trees were planted in deep holes and the trees sank and tilted as the soil settled. In the *Science of Planting Trees*, where trees are set on undisturbed soil and a ring of soil is firmed around the base before backfilling, staking or underground stabilization is not needed in many landscape settings.

Step 5. Backfill

In backfilling the planting hole, the best method is to simply return the soil and let water settle it. Avoid compacting the soil by walking or stamping on it. In the backfill process, the planting hole can be widened into the desired sauce shape.

No backfill soil goes on top of the root ball. Backfill soil covers the root ball "knees" tapering down to the original soil grade. [Figure 23]

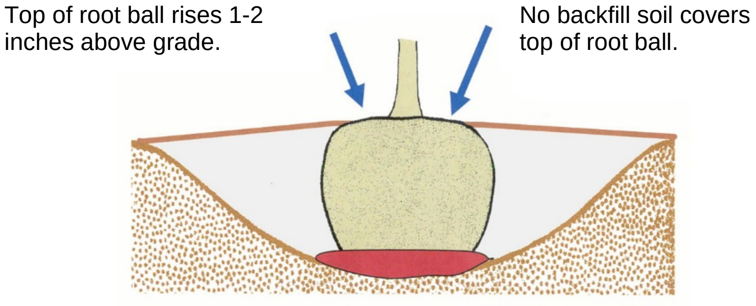


Figure 23. Backfill soil covers the "knees," tapering down to the original soil grade. It is imperative that no soil cover the top of the root ball.

In preparing any garden for planting, it is standard gardening procedure to ***modify*** the soil structure (i.e., loosen the soil) by cultivating. It is also routine to ***amend*** the soil by adding organic matter to improve the water-holding capacity of sandy soils or to increase large pore space in clayey soils. Modifying and amending, while related, are not the same process.

Ideally, soils in a tree's entire potential rooting area would be modified and amended to a 5% organic content.

Modifying the Backfill

When planting trees, soil in the planting hole is modified (loosened up) by digging the hole. The issue around “modifying the soil” is planting-hole width, as discussed previously. Due to lower levels of soil oxygen in the site soil, root growth slows as roots reach the undisturbed site soil beyond the backfill. A saucer-shaped planting hole three times the diameter of the root ball supports rapid root growth, reducing post-planting stress. Amending backfill soil in a narrow planting hole will not substitute for modifying soil in the wider saucer-shaped planting hole.

For backfill, soil “peds” (dirt clods) up to the size of a small fist are acceptable. The soil does not need to be pulverized. In clayey soils, pulverizing the soil will destroy all structure and may lead to excessive re-compaction with minimal large pore space.

A labor-saving technique is to dig the planting hole two times root ball diameter with rather vertical walls. Then in the backfill step, cut the hole to the three times root ball, saucer-shaped hole. In this method, part of the soil does not have to be moved twice. Peds (dirt clods) up to fist size are acceptable in the backfill (Figure 24).

Figure 24. A labor-saving method is to dig the planting hole two times the root ball diameter with more-vertical walls and ease the tree in place. Then cut the planting hole into the three-times-root-ball width and saucer shape during the backfill process. This way much of the soil does not have to be moved twice. Dirt clods up to fist size are acceptable in the planting hole.

Amending the Backfill

Amending the soil just in the planting hole is a complex issue. Too many soil-related variables play into this amended planting pit for a simple directive. In tree planting, it is a common procedure to amend backfill soil with organic matter. It is a good marketing technique for the nursery to recommend soil amendments with the sale of a tree.

Amending the backfill soil to five percent organic matter is standard procedure in garden soil management and may be supportive to root growth in the planting hole during the first two years.

However, amending the backfill to twenty-five to fifty percent is a common mistake! It helps containerize the roots and may also hinder root spread beyond the planting hole. It may hold excessive amounts of water, reducing soil oxygen levels. As the organic matter decomposes, the total volume of soil in the planting hole diminishes, allowing the tree to topple over.

If amending the soil, the organic matter needs to be thoroughly mixed with the backfill soil. Never backfill with organic matter in layers or clumps as this creates additional texture interface lines. Amendments should be well aged. Never use unfinished compost or fresh manure as it may burn tender roots.

Texture Interface

Changes in soil texture (actually changes in soil pore space) create a *texture interface* that impedes water and air movement across the texture change. There will always be a texture interface between the root ball soil and backfill soil and between the backfill soil and undisturbed site soil. **Amending the backfill soil will not diminish the interface** (Figure 25).

To deal with the interface, it is imperative that the root ball comes to the soil surface with no backfill soil over top of the root ball. If backfill soil covers the root ball soil, the interface between the root ball and backfill soil will impede water and air movement into the root ball.

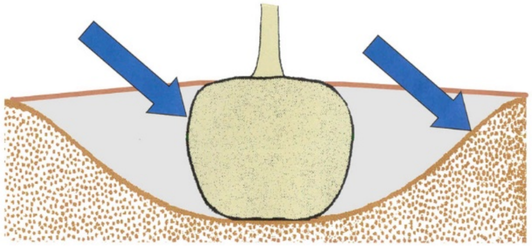


Figure 25. To minimize the texture interface, the root ball must come to the soil surface with no backfill over top of the root ball.

Changes in soil texture (actually soil pore space) create a texture interface that impedes water and air movement.

There will always be a texture interface between the root ball and backfill soil.

Summary: Modifying and Amending

For rapid root establishment, the focus needs to be on planting hole width and correct depth. In most situations, amending or not amending the backfill has little significance compared to other planting protocols.

Optional Step 6. Staking

Staking became a routine procedure when trees were planted in deep holes and the trees sank and tilted as the soil settled. In the *Science of Planting Trees*, where trees are set on undisturbed soil and a ring of soil is firmed around the base before backfilling, staking is not needed in many landscape settings.

In areas with extreme winds, "anchor staking" may be needed for improved wind resilience. In some landscapes, new trees may need "protection staking" to protect trees from human activities (like the football game on the lawn.

Step 7. Watering to Settle Soil

Watering is done after staking so the gardener does not compact the wet soil while installing the stakes. Watering is a tool to settle the soil without overly packing it. [Figure 26]

Figure 26. Water tree during planting; notice how soil has settled.

Step 8. Final Grade

In the wide, shallow planting hole, the backfill soil may settle in watering. Final grading may be needed after watering.

Figure 27. Final grade. Note how the root ball soil is visible on the surface, with no backfill covering the top of the root ball.

Step 9. Mulching

A mulch ring of bark/wood chips is suggested around all trees to help protect the trunks from lawnmower damage. On newly planted trees, organic mulch can increase fine root development by 400% compared to grass competition. This results in 20% faster canopy growth. The increase in growth is due to the lack of competition between the tree and grass and weeds.

Site-specific water needs should be considered regarding the use of mulch. Mulch over the rooting area helps conserve moisture and moderate soil temperatures. However, on wet sites the mulch may hold too much moisture, leading to root/crown rot, and may be undesirable. Wood/bark chips may blow in wind and therefore are not suitable for open, windy areas.

With newly planted trees, do NOT place mulch directly over the root ball. Rather mulch the backfill area and beyond. Never place mulch up against the trunk as this may lead to bark decay. Over the backfill area and beyond, 3-4 inches of wood chip mulch gives better weed control and prevents additional soil compaction from foot traffic. [Figure 28]

Figure 28. Do not make mulch volcanoes. Mulch piled up against the tree trunk may lead to bark decay and reduced trunk taper. Excessive mulch can reduce soil oxygen

Planting Bare-Root Trees

Bare-root nursery stock is sold without an established soil ball and is generally limited to smaller-caliper materials. Some evergreen materials will not transplant well as bare-root stock.

Cost for bare-root stock is significantly lower than the same plant as container-grown or B&B stock. Survivability drops rapidly once the plant leafs out. Some nurseries keep bare-root nursery stock in cold storage to delay leafing.

Roots dehydrate rapidly and must be protected. Bare-root stock is often marketed in individual units with roots bagged in moist sawdust or peat moss to prevent dehydration. Sometimes bare-root stock is temporarily potted to protect roots. Some nurseries maintain bare-root stock in moist piles of sawdust. At the time of sale, plants are pulled from the sawdust and the roots are wrapped with some moist sawdust for transport to the planting site. These need to be planted within 24 hours of purchase.

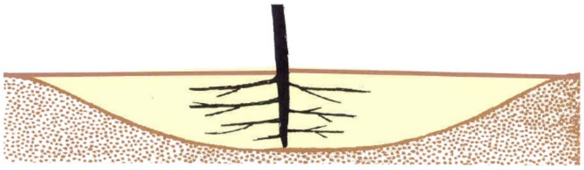
Techniques for Bare-Root Nursery Stock

Bare-root trees are planted with the same basic standards as container-grown or B&B stock, with the modification that the roots are spread out on a horizontal plane as the backfill soil is added. It is critical to minimize exposure of the roots as feeder roots dehydrate in minutes. Generic steps include the following:

1. Unpack roots to measure root spread. Cover or repack to protect roots while the hole is dug. Some gardeners like to soak the roots in a bucket of water for a couple of hours. However, do not leave them in the water for more than a half day.

2. Dig a shallow, saucer-shaped planting hole three times the diameter of the root spread. Depth of the planting hole should accommodate the planting depth standards mentioned previously. [Figure 29]

    - Top of backfill will be one inch above grade.
    - Generally, at least two structural roots should be within the top one to three inches of the soil surface.
    - On species prone to trunk circling roots (such as crabapples, green ash, hackberry, littleleaf linden, poplar, and red maple), the top structural root should be within the top one inch of the root-ball soil surface.
    - The bottom root should rest on undug soil.



Generally, at least two structural roots should be within the top 1-3 inches of the soil surface, measured 3-4 inches from the trunk. Noted exceptions include species prone to girdling roots, where the top structural root should be within the top 1 inch of soil.

Top of soil rises 1-2 inches above grade with backfill soil tapering away.

As backfill is added, spread roots out on a straight, horizontal plane.

Figure 29. Planting bare-root trees

Shallow, saucer-shaped planting hole 3 times root spread.

3. As backfill is added, spread roots out on a straight, horizontal plane.
4. Many bare-root trees will need staking.
5. Water the newly planted tree.
6. Final grade.
7. Mulch, as needed

Additional Information

Books: Watson, Gary W., and Himelick, E.B. ***Principles and Practice of Planting Trees and Shrubs***. International Society of Arboriculture. 1997. ISBN: 1-881956-18-0.

- Web: Dr. Ed Gilman's tree planting information at http://hort.ifas.ufl.edu/woody/planting.shtml.

Authors: David Whiting (CSU Extension, retired) with Joann Jones (CSU Extension, retired) and Alison O'Connor (CSU Extension). Photographs and line drawing by David Whiting; used by permission.

- *CMG GardenNotes* are available online at www.cmg.colostate.edu.
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CMG GardenNotes #634

Tree Staking and Underground Stabilization

Staking became a routine procedure when trees were planted in deep holes and the trees sank and tilted as the soil settled. In the *Science of Planting Trees*, where trees are set on undisturbed soil and a ring of soil is firmed around the base before backfilling, staking is not needed in many landscape settings.

Consequences of Staking

The consequences of staking with traditional methods that wrap and hold the trunk include the following:

- The tree grows taller, faster.
- Staking (the lack of tree movement) slows root spread.
- The tree has less growth in trunk caliper near the ground but more near the top support ties. Staking often produces a reverse trunk taper that increases the potential for storm damage.
- Staked trees experience more wind damage than unstaked trees of equal height (the top of the tree is not free to bend in the wind).
- Bark is often damaged by the ties. In a survey of 10,000 street trees, 90% were damaged by the ties.
- If the stake is close to the trunk, it can develop uneven xylem growth where the stake shades the trunk, making the trunk tilt to the side. Keep stakes at least 6 inches away from the trunk.

Purposes of Staking

<u>No Staking</u> – In most home landscape settings, no staking is necessary if the tree is set on undisturbed soil (where it cannot sink and tilt), with soil firmed around the base of the root ball before backfilling. Exceptions include the three types of staking below.

Protection Staking is used where the tree needs protection from human activities, such as the football game on the front lawn or from passersby along a street planting.

Protection staking may include standard staking techniques with three or four posts and straps or a structure surrounding the tree but not actually touching the tree trunk. [Figure 1]

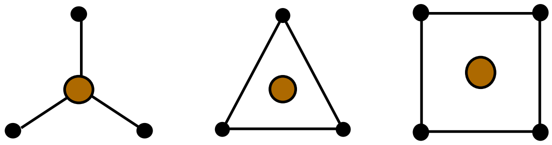


Figure 1. Configurations for protection staking

Anchor Staking – In areas of high winds, anchor staking may be needed. When anchor staking small trees, use two or three straps along the trunk about 18 inches above the ground. [Figure 2]

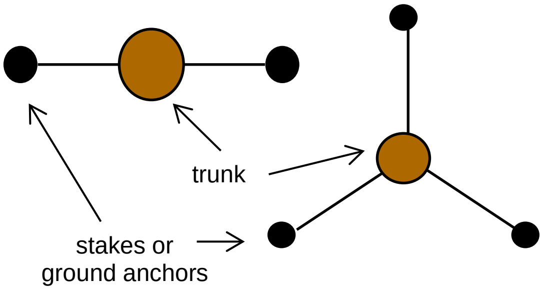


Figure 2. Configurations for anchor staking. Anchor staking may be needed in areas of high winds.

Support staking – If the tree has a floppy trunk that is not self-supporting, support staking will be needed. Straps would be located six inches above the point where the tree will stand upright, but at least three feet below the terminal leader.

Above Ground Staking Procedures

When staking, use flat, grommeted straps rather than ropes, wires or hose segments against the trunk. The straps spread the pressure over a wider area, reducing the potential for bark damage. Straps should lie flat against the trunk and should not be bunched up or twisted. Two or three straps are routinely used in tree staking.

Straps may tie back to wood or metal posts or to anchors in the ground. Plastic caps are available as a safety measure for the tops of metal posts. Place posts at least 15 to 18 inches out from the trunk. Never tie a post to the trunk, as the shading will cause the trunk to curve. [Figure 3]

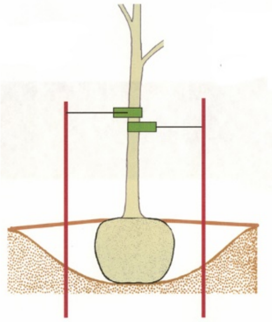
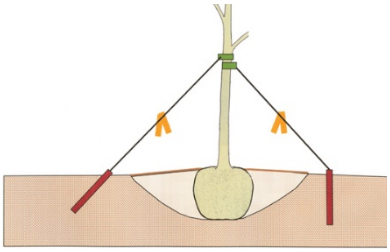


Figure 3. Routine staking includes two or three posts, at least 15-18 inches out from the trunk. Use flat straps to spread pressure over a wider area, reducing bark damage.

With guy-lines and ground anchors, place the guy-lines at a 45° angle. Flag the guy-lines to help people see them and prevent injury. In the illustration, the anchor on the left may be more secure than the anchor on the right. [Figure 4]

Figure 4. When staking with guy-lines, place guy-lines at a 45° angle. The ground anchor on the left is more secure than the anchor on the right.



In any staking system, it is best if the tree trunk has a little flexibility. Some wind movement encourages root growth and trunk taper development.

For 1-2 inch diameter trees, staking typically stays on for one to two seasons. On 3-4 inch diameter trees, staking may be needed for three to four seasons.

Underground Stabilization Methods

Several methods for underground stabilization are effective. They are applied prior to backfilling the planting hole. [Figure 5]

- **Two or three wood dowels** driven into the ground at the edge of the root ball. The dowels will decompose over time.
- **A 2×2 wood triangle over the top of the root ball is screwed into 2×2 wood stakes** driven into the ground at the edge of the root ball. The wood will decompose over time.
- **Two metal root "staples"** – Several brands are on the market. The long leg of the staple goes into the ground at the edge of the root ball. The short leg of the staple goes into the root ball. The metal staple may pose a problem if the tree stump needs to be ground out in the future.

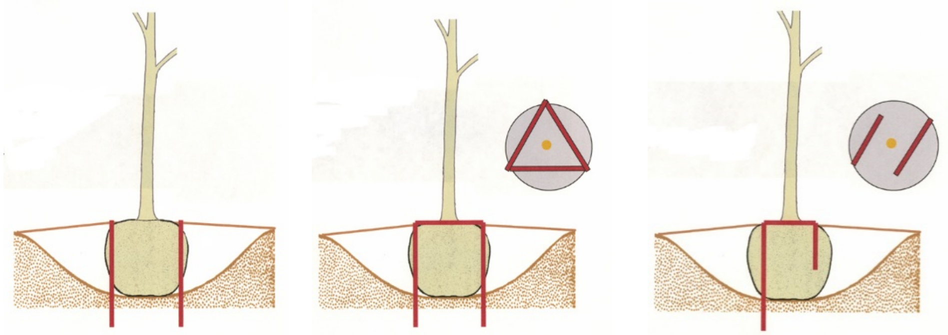


Figure 5. Methods for underground stabilization
Left: Two to three wood dowels are driven into the ground at the edge of the root ball.
Center: 2×2 lumber makes a triangle plate over the top of the root ball. It is screwed into wood stakes driven into the ground at the corners.
Right: Metal root "staples" are driven into the ground at the edge of the root ball and hook into the root ball.

Authors: David Whiting (CSU Extension, retired) with Carol O'Meara (CSU Extension).

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GardenNotes #635

Care of Recently Planted Trees

Root Establishment Phase

During the establishment phase in a tree's life cycle, primary growth occurs in the root system, with minimal growth in the canopy. The science of planting trees is aimed at encouraging this root growth, reducing *post-planting stress*. For additional information, refer to *CMG GardenNotes* #101, Plant Health Care, and #633, The Science of Planting Trees.

With good planting techniques and soil conditions, the establishment phase takes one growing season per inch of trunk diameter (in Hardiness Zones 4 and 5). On small trees (up to four inches in diameter), trunk diameter is measured at six inches above the soil line. That is, a one-inch caliper tree typically takes one year for roots to establish. A two-inch diameter tree typically takes two years. In cooler regions with shorter growing seasons, it will take longer. In warmer regions, like the southern United States, the establishment phase is measured in months.

With poor planting techniques and/or poor soil conditions, the establishment phase may take many years. It is common to observe trees that never establish, but rather simply hang on for a few years and gradually decline.

A significant increase in annual twig growth indicates that roots have become established and that the tree is shifting into the growth phase.

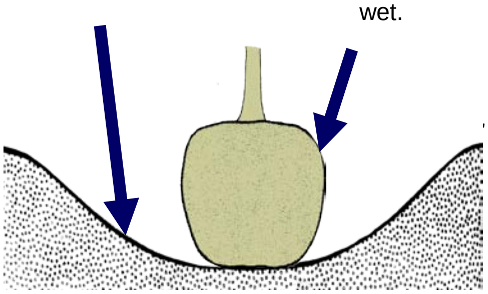
The purpose of this *CMG GardenNotes* is to summarize tree care during the establishment phase.

Watering

Regular irrigation after planting encourages rapid root development, for tree establishment. Under-irrigation often leads to slow establishment, canopy dieback, and bark splits (frost crack and sunscald) on the trunk. After the first couple of years, it is common to find under-irrigated trees that have minimal root growth. Recently planted trees and shrubs establish most quickly with light, frequent irrigation. For recently planted trees, primary water extraction is from the root ball and the root ball can become dry in just a day.

Larger volumes of water applied infrequently will not compensate for the need for frequent, light irrigation. On newly planted trees, soil amendments do not significantly reduce the need for frequent irrigation. Drought-tolerant species are not drought-tolerant until the root system becomes established. In sites without ideal irrigation management, smaller-sized nursery stock would be preferred because they establish faster.

When watering non-established trees, check the soil frequently, and water according to need. The soil could be dry in the root ball and wet in the backfill, or wet in the root ball and dry in the backfill. If the tree is planted in a newly sodded/seeded irrigated lawn, it is typically over-watered. [Figure 1]



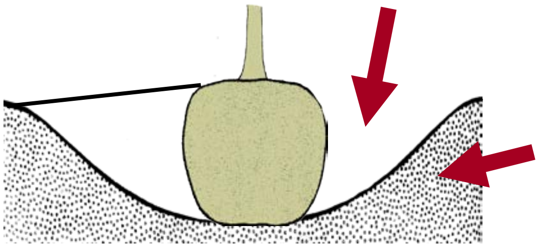
Compacted, undisturbed soil can create a basin that collects and holds water.

Depending on the texture interface between the root ball and backfill soil, one may be dry while the other is overly wet.

Figure 1. On non-established trees, check the water needs in the root ball and back fill soil frequently. Water according to observed needs.

The only way to know the watering needs of non-established trees is to check soil moisture levels. A useful tool for the home gardener is a houseplant water meter. While somewhat inaccurate, it can indicate wet or dry. (Note: If the fertility is high, it will read on the wet side. If fertility is low, it will read on the dry side.)

Check both the root-ball soil and the backfill soil. For a two-inch caliper tree in Hardiness Zone 5, it takes one growing season for the roots to extract significant amounts of water from the backfill soil, and two or more years for significant water extraction from the soil beyond the planting hole. [Figure 2]



With good planting techniques, it takes a growing season for significant water uptake from the backfill soils.

It takes two or more years for significant water uptake from the site soil beyond the planting hole.

Figure 2. Check water needs in the root-ball soil and the backfill soil.

Learn by carefully monitoring the amount and frequency of irrigation needed for each tree. Estimated irrigation needs are given in Table 1.

Table 1.
Estimated Irrigation of Newly Planted Trees and Shrubs (during the growing season) – **Check soil moisture and water as needed.**

Size of Nursery Stock	Irrigation Need for Vigor
<2-inch caliper	○ **Daily for 2 weeks** – Depending on temperature and wind, apply 1-2 gallons per inch of trunk diameter. ○ **Every other day for 2 months** – Depending on temperature and wind, apply 2-4 gallons per inch of trunk diameter. ○ **Weekly until established** (one to two or more seasons).
2-4-inch caliper	○ **Daily for 4 weeks** – Depending on temperature and wind, apply 1-2 gallons per inch of trunk diameter. ○ **Every other day for 3 months** – Depending on temperature and wind, apply 2-4 gallons per inch of trunk diameter. ○ **Weekly until established** (two to four or more seasons).
>4-inch caliper	○ **Daily for 6 weeks** – Depending on temperature and wind, apply 1-2 gallons per inch of trunk diameter. ○ **Every other day for 5 months**– Depending on temperature and wind, apply 2-4 gallons per inch of trunk diameter. ○ **Weekly** until established (four or more seasons).

- **Check the actual water need before watering**. A common mistake on compacted and clayey soils (with poor drainage) is to apply too much water per irrigation, waterlogging the planting hole. Never apply irrigation if soil is saturated.
- Trunk diameter on small trees is measured at six inches above the soil line.
- As a rule of thumb for Hardiness Zones 4 and 5, establishment takes one season per inch of trunk caliper.
- In Colorado winters without routine moisture, water newly planted trees monthly. However, do not water if the ground is frozen.
- In our dry, semi-arid climate, there is benefit from applying additional irrigation outside the root-ball area. This can be done with a ringed soil berm that allows water to percolate into the soil or a soaker-type hose running around the backfill area.

Mulch to Protect Tree from Lawnmowers, Weed Eaters, and Grass Competition

Wood/bark-chip mulch is highly recommended on newly planted trees. The mulch protects the trees from lawn mower and weed eater injury. Trees with a mulch ring typically have 20% more early growth compared to trees where grass grows up to the trunk. This is due to the lack of competition with the grass and/or weeds.

In a landscape setting, the mulch ring is typically two to four feet wide up to the width of the dripline (spread of branches). Wood chip mulch three to four inches deep gives better weed control and prevents additional soil compaction by foot traffic.

On newly planted trees, do not mulch over the root ball. On established trees, keep mulch back six inches from the trunk. Never pile wood/bark chips up against the

trunk. Wet chips can lead to bark decay. Never make mulch volcanoes!
On wet sites, mulching may help hold excessive soil moisture and may be undesirable. On open windy sites, wood/bark-chip mulch blows away.

Fertilization

During the establishment phase, fertilization needs are none to minimal on woody plants. High-nitrogen fertilization rebalances the canopy-to-root growth ratio, encouraging canopy growth at the expense of root growth.

In situations where soil fertility is low—but water and other growth factors are not limiting—very light fertilization with a time-release product may be acceptable. Never use a quick-release fertilizer on trees.

Never fertilize trees in the establishment phase that are showing signs of stress. When a nonestablished tree is under stress, nitrogen fertilizer can push out canopy growth that the root system cannot support in hot windy weather. Woody plants do not respond to “starter fertilizers” like herbaceous plants.

Pruning

In the establishment phase of a tree’s life cycle, pruning is undesirable. Pruning lowers the levels of auxin, a hormone produced in the canopy terminal buds that stimulates root growth.

Pruning should be limited to the removal of dead and broken branches and minimal pruning to maintain a single leader. In purchasing trees, select trees with good structure that will not require immediate pruning.

Structural training for the tree continues in the growth phase (after the roots have established and the canopy shows significant annual growth). For additional information on structural training, refer to *CMG GardenNotes* #614, Structural Pruning of Young Shade Trees.

In situations where trees will not receive any structural training while young, it may be desirable to correct structural major defects as part of the planting process. This is primarily removal of codominant trunks and spacing of secondary trunks. However, major pruning at planting will slow root establishment.

Author: **David Whiting**, Extension Consumer Horticulture Specialist (retired), Dept. of Horticulture & LA, Colorado State University. Artwork by David Whiting; used by permission.

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CMG GardenNotes #636

Tree Planting Steps

This publication summarizes the tree-planting process. For an in-depth discussion on tree planting, refer to *CMG GardenNotes* #633, The Science of Planting Trees.

The science of planting trees is aimed at promoting rapid root growth (regeneration) to quickly reduce the water stress imposed by the harvest and planting process. *Post-planting stress* (transplant shock) consists of the stress factors induced by the reduced root system.

Planting trees too deeply has become an epidemic leading to the decline and death of landscape trees. In the landscape, trunk-girdling roots account for 57% of all tree deaths. Trunk-girdling roots develop when a tree is planted too deeply in the root ball and/or the root ball is planted too deeply in the planting hole. Trunk-girdling roots may lead to decline and death some 12 to 20 years after planting. Trunk-girdling roots may be below ground.

Step 1.
Determine the depth of the planting hole

Depth of root ball in planting hole

To deal with the *soil texture interface* (differences in soil pore space) between the root-ball soil and backfill soil, it is imperative that the root ball rise slightly above grade with no backfill soil over top of the root ball. For small (one-inch caliper) trees, the top of the root ball should be about one inch above grade. For larger (2-4 inch caliper) trees, the top of the root ball should be about two inches above grade. Backfill soil should cover the “knees,” tapering down to grade. [Figure 6]

Depth of tree in the root ball

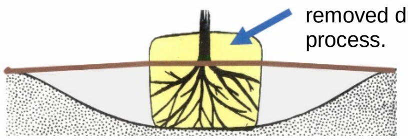
- Generally, at least two structural roots should be within the top 1-3 inches of the root ball, measured 3-4 inches from the trunk.
- On species prone to trunk-circling roots (Crabapples, Green Ash, Hackberry, Littleleaf Linden, Poplar, Red Maple, and other species with aggressive root systems), the top structural root should be within the top one inch of the root ball.

Checking depth of tree in root ball – Check depth of the tree in the root ball. Do not assume that it was planted correctly at the nursery.

- The presence of the root flare is an indication of good planting depth. However, small trees may have minimal root flare development making it difficult to determine. Be careful not to mistake swelling of the trunk below the graft as the root flare.
- A good way to evaluate planting depth in the root ball is with a slender implement like a slender screwdriver, knitting needle or barbeque skewer. Systematically probe the root ball 3-4 inches out from the trunk to locate structural roots and determine depth. [Figure 1]

Figure 1. Systematically probe the root ball with a slender screwdriver. Generally, at least two structural roots should be found in the top 1-3 inches of soil, 3-4 inches out from the trunk. On species prone to trunk-circling roots, the top structural root should be within the top one inch of the root ball.

If the tree is planted too deeply in the root ball, excess soil should be removed from the top in the backfill step of the planting process. Adjust the depth of the planting hole to compensate. [Figure 2]



Excess soil should be removed during the backfill process.

Figure 2. Adjust the depth of the planting hole to bring the root flare to the correct depth.

The depth of the planting hole should be 1-2 inches less than the height of the root ball. However, planting hole depth may need to be adjusted to correct the depth of the tree in the root ball.

Step 2. Dig a saucer-shaped planting hole three times the root ball diameter

- To maximize soil oxygen levels the top of the root ball rises 1-2 inches above grade (adjusted for proper rooting depth as determined in step 1).
- The root ball sits on undug soil, stabilizing the tree and preventing sinking and tilting.
- A saucer-shaped planting hole three times the root ball diameter with sloping sides allows the root system to grow rapidly to 400% of the root ball volume before being slowed by the lower oxygen levels in the site soil. This is enough to minimize *post-planting stress* in normal planting situations.
- The wide, saucer-shaped planting hole gives the tree more tolerance to over-watering problems and waterlogged soils.
- The wide planting hole allows for root ball wrappings to be removed after the tree is situated in the planting hole.
- A labor-saving technique is to dig the planting hole about two times the root ball diameter with somewhat vertical sides, then widen the hole into the desired saucer shape with the shovel during the backfill process. [Figure 3]

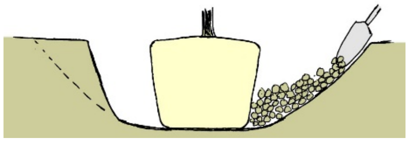


Figure 3. A labor-saving technique is to widen the planting hole into the desired saucer shape, three times the root ball diameter during the during backfill process.

Step 3. Set the tree in place, removing container/wrappings

In setting the tree into the planting hole, if the tree has a "dogleg" (a slight curve in the trunk just above the graft) the inside curve must face north to avoid winter bark injury. [Figure 4].

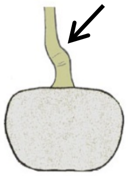


Figure 4. The inside curve of the graft crook or "dogleg" must go to the north to avoid winter bark injury.

Vertically align the tree, with the top centered above the root ball. Due to curves along the trunk, the trunk may not necessarily look straight. It will appear straighter with growth.

In this step, techniques vary for *Container-Grown Trees* and *Balled And Burlapped (B&B) Trees*.

Container-Grown Nursery Stock

"Container-grown nursery stock" describes a variety of production methods where the trees or shrubs are grown in containers (limiting root spread to the size of the container). In some systems, like "pot-in-pot" and "grow-bags," the container is in the ground. An advantage of container stock is that it can be planted in spring, summer, or fall.

Actual planting techniques in this step vary with the type of container and extent of root development. Generic steps include:

a) Lay the tree on its side in or near the planting hole.
b) Wiggle off or cut off the container.
c) Shave off the outer 1-1½ inches of the root ball with a pruning saw or pruners. This is to deal with circling roots.
d) Tilt the tree into place with the inside curve of any graft crook facing north.
e) Check the depth of the root ball in the planting hole. If needed, remove the tree and correct the hole depth.
f) Align vertically.
g) For stability, firm a shallow ring of soil around the bottom of the root ball. [Figure 5]

- The ideal container-grown tree has a nice network of roots holding the root ball together. After the container is removed, the tree is gently tilted into place.
- If most of the soil falls off the roots, the tree is planted as a bare-root tree.
- If some of the soil falls off (often on the bottom), it may be necessary to adjust the depth of the planting hole. Backfill and pack the bottom of the planting hole to the correct depth.
- Fabric grow bags must be removed from the sides. They are generally cut away after setting the tree into place.
- Generally, paper/pulp containers should be removed. Most are slow to decompose and will complicate soil texture interface issues. Pulp

containers often need to be cut off, as they may not slide off readily.
- In handling large trees (3-inch caliper and greater) it may be necessary to set the tree into place before removing the container.

Field-Grown, B&B Nursery Stock

Field-grown, balled and burlapped (B&B) trees and shrubs are dug from the growing field with the root ball soil intact. In the harvest process, only 5-20% of the feeder roots are retained in the root ball. B&B nursery stock is best transplanted in the cooler spring or fall season.

To prevent the root ball from breaking, the roots are balled and wrapped with burlap (or other fabrics) and twine (hence the name B&B). In nurseries today, there are many variations to the B&B technique. Some are also wrapped in plastic shrink-wrap, placed into a wire basket, or placed into a pot.

An advantage of the wider planting hole is that it gives room for the planter to remove root ball wrappings AFTER the tree is situated in the hole.

Based on research, **standard procedures are to remove root ball wrapping materials (burlap, fabric, grow bags, twine, ties, wire basket, etc.) from the upper 12 inches or 2/3 of the root ball, whichever is greater, AFTER the tree is set into place.** Materials under the root ball are not a concern since roots grow outward, not downward.

Actual planting techniques in this step vary with the type of wrapping on the root ball. Generic steps include:

a) Remove extra root ball wrapping added for convenience in marketing (like shrink-wrap and a container). However, do NOT remove the burlap (or fabric), wire basket and twine that hold the root ball together until the tree is set into place.
b) Set tree into place with the inside curve of any graft crook facing north.
c) Check the depth of the root ball in the planting hole. If needed, removed the tree and correct the hole depth.
d) Align vertically.
e) For stability, firm a shallow ring of soil around the bottom of the root ball. [Figure 5]

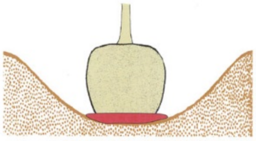


Figure 5. Stabilize the tree by firming a small ring of backfill soil around the base of the root ball

f) Removed all the wrapping (burlap, fabric, twine, wire basket, etc.) on the upper 12 inches or upper 2/3 of the root ball, whichever is greater.
g) If roots are found circling the root ball, shave off the outer 1-1½ inches of the root ball with a pruning saw or pruners.

The consensus from research is clear that leaving burlap, twine, and wire baskets on the sides of the root ball is not an acceptable planting technique.

- Burlap may be slow to decompose and will complicate soil texture interface issues.
- Burlap that comes to the surface wicks moisture from the root ball, leading to dry soils.
- Jute twine left around the trunk will be slow to decompose, often girdling the tree.
- Nylon twine never decomposes in the soil, often girdling the tree several years after planting.
- Wire baskets take 30-plus years to decompose and interfere with long-term root growth.
- Some planters find it easier to cut off the bottom of a tapered wire basket before setting the tree into the hole. The basket can still be used to help move the tree and is then easy to remove by simply cutting the rings on the side.

Optional Step 4.
Underground stabilization

When properly planted, set on undug soil, most trees in the landscape do not require staking or underground stabilization. Staking or underground stabilization may be needed in windy areas. For additional information on staking, refer *CMG GardenNotes* #634, Tree Staking and Underground Stabilization.

Step 5. Backfill

When backfilling, be careful not to over-pack the soil, which reduces large pore space and thus soil oxygen levels. A good method is to simply return soil and allow water to settle it when irrigated.

Soil "peds" (dirt clods) up to the size of a small fist are acceptable in tree planting. In clayey soils, it is undesirable to pulverize the soil, as this destroys large pore space.

Changes in soil texture (actually changes in pore space) between the root ball soil and the backfill soil create a *soil texture interface* that impedes water and air movement across the interface. To deal with the interface, the top of the root ball must come to the surface (that is, no backfill soil must cover the top of the root ball). Backfill soil should cover the root ball knees, gradually tapering down.

Optional Step 6. Staking

When properly planted, set on un-dug soil, most trees in the landscape do not require staking or underground stabilization. Staking may be desirable to protect the trees from human activities. Staking or underground stabilization may be needed in windy areas.

Install staking before watering so the planting crew does not pack down the wet soil. For additional information on staking, refer to *CMG GardenNotes* #634, Tree Staking and Underground Stabilization.

Step 7. Water to settle soil

Step 8. Final grade

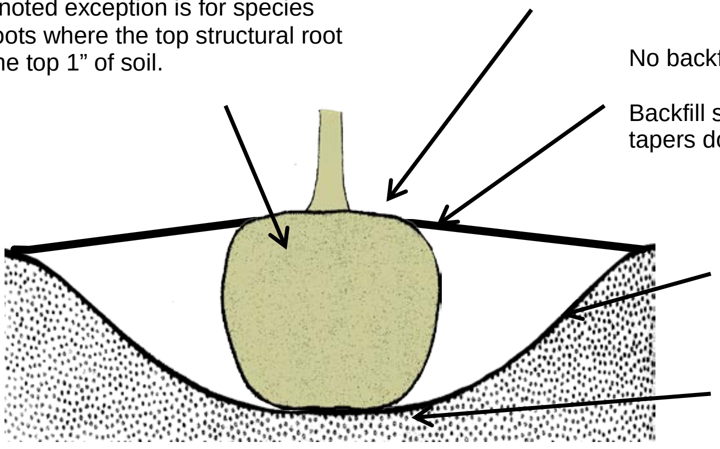
With the wide planting hole, the backfill soil may settle in watering. Final grading may be needed after watering.

Step 9. Mulch

Do not place mulch directly over the root ball on newly planted trees. As a rule of thumb, 3-4 inches of wood/bark chips gives better weed control and prevents soil compaction from foot traffic when placed over the backfill area and beyond. Additional amounts may reduce soil oxygen.

Do not place wood/bark chips up against the trunk. Do not make mulch volcanoes. On wet soils, mulch may help hold excessive moisture and be undesirable. Wood/bark chips are not suitable in open windy areas.

Figure 6. Planting Summary



Generally, at least two structural roots should be within the top 1-3" of the soil surface, measured 3-4" from the trunk. A noted exception is for species prone to circling roots where the top structural root should be within the top 1" of soil.

Top of root ball rises 1-2" above grade.

No backfill soil covers top of root ball.

Backfill soil covers root ball "knees" and tapers down to original soil grade.

For best root growth potential, make saucer-shaped planting hole three times root ball diameter.

Saucer-shaped planting hole

Tree sits on undisturbed soil

Author: David Whiting (CSU Extension, retired), with Alison O'Connor (CSU Extension). Line drawings by David Whiting; used by permission.

- Colorado Master Gardener *GardenNotes* are available online at www.cmg.colostate.edu.
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MASTER GARDENER
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CMG GardenNotes #651

Fertilizing Shade Trees

When gardeners fertilize lawns, they see a quick response as the lawn greens up within days. The response is different with trees; it happens over a period of months as a re-balance of canopy and root growth. When growth-limiting nutrients (nitrogen) become available through fertilization, the tree shifts more resources into canopy growth and correspondingly less into root growth.

Nitrogen is the nutrient most limiting to tree growth. Symptoms of nitrogen stress in woody plants are unlike those in lawns and herbaceous plants. Trees with nitrogen stress simply slow canopy growth rates, but do not show the characteristic yellowing of older leaves like lawns and herbaceous plants.

Nitrogen should be applied to trees only in a controlled release/slow release form.

A tree's need for phosphorous and potassium is rather low. Colorado (western) soils are typically adequate in phosphorous and potassium. Phosphate fertilizers have not been shown to increase tree growth even on soils marginal low in phosphorus. Excessive levels of phosphorus can aggravate an iron chlorosis problem.

Iron is a common deficiency in some tree species. Iron chlorosis is usually aggravated by spring- time overwatering and by trunk girdling roots (tree planted too deep).

Fertilizer Application Rates

The need for fertilizer varies with the tree's growth phase.

Establishment phase - recently planted trees

During the root establishment phase, the growth objective is root growth. Nitrogen fertilizer increases canopy growth with a corresponding decrease in root growth, which is undesirable in this phase.

As a rule-of-thumb for Hardiness Zone 4-5, the establishment phase for recently transplanted trees lasts one year for each inch of trunk caliper (measured at 6" above ground level). In other words, the establishment period for a one inch caliper tree is typically one year, and three years for a three inch caliper tree. The establishment phase may be longer on sites with poor soil tilth, limited irrigation, and with poor planting techniques.

Unlike herbaceous plants, woody plants do not respond to "rooting fertilizers" (water soluble fertilizers) applied at planting. During the root establishment phase, fertilizer applications should be kept to a minimum, as follows:

- If the soil organic content is moderate to high (3-5% organic matter), no additional fertilizer is warranted.
- If the soil organic content is low (1% or less), a light application of a controlled release (slow release) nitrogen may be beneficial. Application should not exceed 0.1 pound actual nitrogen per 100 square feet (based on the area off the planting hole). Do not apply fertilizer on a site with growth limiting factors such as a limited irrigation.

Growth phase

Significant branch growth indicates a shift from the root establishment phase into the growth phase. In this growth phase, fertilization can encourage faster growth if desired. Application rate is based on several factors:

1. Natural growth rate of the tree – Use higher rates on faster growing species if rapid growth is desired.
2. Growth limiting factors such as limited irrigation, severe soil compaction, or limited root spread potential – Do not force growth. Heavy fertilization can push canopy growth that the roots cannot support in summer heat and wind.
3. Soil organic content
4. Desired growth rate. If rooting and/or canopy space will be limited for the maturing tree, you may not want to push growth.

The table on page 3 illustrates rate adjustments based on these factors.

Mature maintenance phase

As trees reach a mature size and growth slows, the need for nitrogen drops. In the maturing maintenance phase the standard maximum rate is 0.2 to 0.4 pounds nitrogen per 100 square feet over a 4-year period. It may be applied annually or with multi-year applications using controlled release fertilizers. Over fertilization may push canopy growth that a limited rooting system cannot support in summer heat and wind, leading to early decline. The table below shows rate adjustments based on soil organic content.

Application rate based on growth phase and soil organic content

The fertilizer application rate should be adjusted according to soil organic content as indicated in the table below.

Tree fertilizer rates based on growth phase and soil organic content

	Nitrogen application rate[1 & 4] (Pounds nitrogen per 100 square feet)		
Soil organic content	**Low** (0-1%)	**Medium** (2-3%)	**High** (4-5%)
Establishment phase	0 to 0.1 lbs/year	0	0
Growth phase			
Faster growing species[2]	0.2 to 0.4 lbs/year	0.1 to 0.2 lbs/year	0
Routine rate	0.1 to 0.2 lbs/year	0.05 to 0.1 lbs/year	0
Mature phase[3]	0.2 to 0.4 lbs / 4 years 0.1 to 0.2 lbs / 2 years 0.05 to 0.1 lbs / year	0.1 to 0.2 lbs / 4 years 0.05 to 0.1 lbs /2 years 0.025 to 0.05 lbs / year	0

1 Do not exceed lower rates to trees with growth limiting factors (such as limited irrigation, severe soil compaction, or limited root spread potential).
2 Use high rate only on fast growing species without any growth limiting factors where rapid growth is desired.
3 For multi-year applications, use controlled/time release products.
4 In lawn areas, do not apply more than 0.1 pounds nitrogen per 100 square feet per application. When higher rates are needed, split the application.

Time of year

The best time of year to fertilizer is early spring (4-6 weeks before bud break) or late fall after leaves drop (and soil temperatures are above 40°). Avoid late summer and early fall fertilizations as they may interfere with winter hardiness.

Area to fertilize

Fertilizer application rate is based on the area of the ***Tree Protection Zone, TPZ***. To calculate a tree's TPZ area, first determine the ***Critical Root Radius,*** CRR, and then calculate the area in the TPZ using the CRR. The CCR typically extends a little beyond the drip line. The TPZ area is typically about 40% larger than the area in the drip-line for mature trees.

Calculating the CCR by the circumference method

1. Measure the circumference (inches around the tree) at 4.5 feet high.
2. Divide the number by 2.

3. Express the results in feet. This is the critical rooting radius.

Example:

1. Circumference = 24 inches
2. 24/2 = 12
3. CRR = 12 feet

Calculating the area (square feet) in the TPZ

To calculate the area in the TPZ, use the formula:

$CCR^2 \times 3.14 = TPZ$

Example: 12 feet x 12 feet x 3.14 = 452 square feet

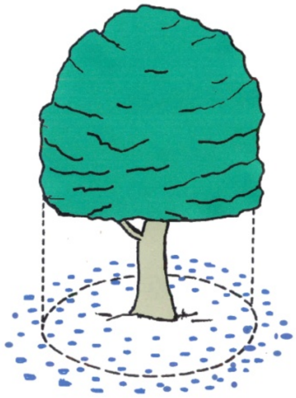
Unrestricted rooting area – For trees with an unrestricted rooting area (i.e., open lawn area) base the fertilizer application rate on the ***Tree Protection Zone, TPZ.*** This is the area where the fertilizer will be applied.

Trees with confined root zones – Calculate the fertilizer rate based on the **open** area within the TPZ, (i.e., the TPZ area not covered with sidewalks, driveways, streets, buildings, etc).

Fertilizer Application Methods

Broadcast applications are quick and easy. However, an actively growing turf takes up most of the soluble fertilizer within 48 hours.

An alternative is to apply the fertilizer in a series of holes or plugs drilled into the soil around the TPZ. Use caution to avoid hitting sprinkler lines and underground utilities.



Make plug holes:

- 1 ½ to 2 inch diameter
- 4-6” inches deep
- 2 foot intervals
- 2-5 rings around TPZ area
- Backfill with sand, compost, or vermiculite

Trees in Turf

In full sun, a healthy lawn has 20 to 400 times more root length than woody plants. The lawn will absorb most of a water-soluble nitrogen fertilizer applied within 48 hours. The following table summarizes the relationship to lawn fertilizer and tree fertilization.

Trees in Turf

	Tree Grow Phase	
Lawn Quality	**Growth Phase**	**Mature Maintenance Phase**
Routinely fertilized, actively growing, thick	Lawn fertilization adequate for trees If rapid growth is desirable on faster growing species, supplemental vertical fertilization may be beneficial. Do not force growth when limiting factors exist, such as limited water, severe soil compaction or limited root spread potential.	Lawn fertilization adequate for trees
Thin	Before fertilizing, evaluate why the lawn is thin and how this affects potential tree growth.	High nitrogen rates could push undesired tree canopy that roots cannot support in summer heat and wind.

Fertilizing Stressed Trees

When plants appear stressed, a common reaction is to fertilize. However, this can actually aggravate stress. Before fertilizing a stressed tree, evaluate whether or not a push of canopy growth with the corresponding decrease in root growth is desirable.

Nitrogen fertilization shifts the tree's balance of growth, favoring the canopy. If the stress is root related (i.e., soil compaction, restricted root spread, construction damage, extensive storm damage), this shift will aggravate it. Do not apply high levels of fertilizer to trees with root problems.

The tree invests energy reserves to take up nutrients. Thus, the short-term effects of a heavy fertilization will be an immediate reduction in a tree's carbohydrate levels, aggravating stress. If the tree shows severe stress, do not apply high levels of fertilizers. Work to alleviate stress factors to the extent possible.

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CMG GardenNotes #652

Tree Preservation During Construction

Outline:

In tree preservation, take steps to prevent construction damage, as little can be done to correct it!

This CMG GardenNotes was written as an overview of tree preservation issues in a construction site. For additional information refer to:

- ***Trees and Development, A technical Guide to Preservation of Trees During Landscape Development*** by Nelda P Matheny and James R Clark. International Society of Arboriculture. 1998. ISBN: 1-881956-20-2
- ***Up By Roots: Healthy Soils and Tree in the Build Environment*** by James Urban. International Society of Arboriculture. 2008. ISBN: 1-881956-65-2

Guiding Principles of Tree Preservation

1. **Goals in tree preservation include both *construction* AND *tree preservation.***

   - Both goals have to be valued.
   - Both sides have to make compromises.
   - Polarizations of attitudes include 1) that it is cheaper, easier and faster to remove all trees at the start and 2) that all trees need to be saved. For tree preservation, comprise must be found in the middle.
   - The goal is not to preserve trees just until occupancy occurs, but rather for twenty plus years.

2. Preservation requires commitment of all parties, as a team effort.

- Owners
- Engineers
- Architects and landscape architects
- Grading and demolition crews
- Construction and landscape crews
- Government agencies
- Arborists, who’s role includes
  - Technical resources and tree knowledge
  - Familiar with local regulations and regulatory staff
  - Familiar with local growing conditions

3. Tree preservation cannot wait until construction or afterwards.

- Tree preservation takes place in the planning phase.
- Construction crews then follow the plans.

4. All trees cannot and should not be preserved.

- Trees require that space be protected for their roots.
- Trees in poor health simply will not tolerate construction stress.
- Trees with poor structure have limited value.

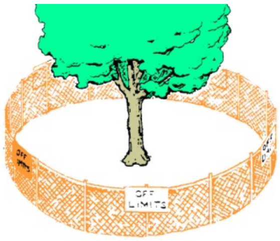
5. Tree preservation patterns must respect patterns of tree growth.

- All players in design and construction must respect the ***Tree Protection Zone, TPZ.*** .

Trees have a root plate system, shallow and wide spreading.

6. Tree preservation requires above and below ground space.

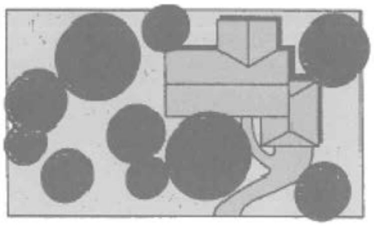
- Inside TPZ there is NO grading, trenching, parking, stock piling of building materials or dumping of waste products.



7. **Preservation focuses on preventing injury to trees, as little can be done to correct injury.**

8. **Construction impacts to trees are cumulative.** Small impacts add together for stress and tree decline.

9. **Tree preservation requires accurate site information.**



- Location of buildings, utilities and hardscape features
- Location of trees
- Species identification and tolerances to construction stress
- Evaluation of tree health and potential for preservation

10. **Arborists and design/construction professionals must communicate.**

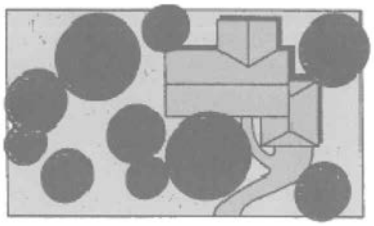
- Talk in technical terms.
- Both sides must be willing to compromise.

11. **Community attitudes and practices must support both tree preservation and development.**

- A compromise must be found between the polarizations of 1) aggressive tree preservation ordinances and practices that prohibit construction and 2) ignoring tree preservation in favor of construction.
- The same standards should apply to both private and public sector development.

Development Sequence

1. **Site design including *__tree report__***



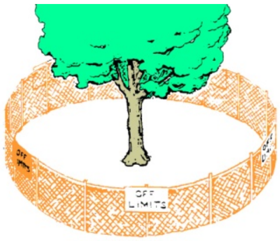
- Requires communication and compromise between all parties.
- This is the most important step in tree preservation.

2. **Review and approval by public agency**

- Conditions of approval
- Bonding: appraised value of trees preserved
- Permits

3. **Site work**

   1. **Tree work**



      - Tree work needs to be completed before other activities start.
      - Due to construction schedule, the time frame for tree work may be very short.
      - Tree protection needs to be in place during site work.

   2. Demolition and clearing
   3. Grading
   4. Utilities and roads

4. **Construction and landscaping**

   - Tree protection needs to be in place during site work.
   - Implement *tree maintenance during construction plan.*

      - How/who will the tree be protected during construction?
      - How/who will the tree be watered and cared for during construction?

5. **Occupancy**

   - Implement *post-construction maintenance plan.*
   - In tree preservation, it should be expected that the tree lives for twenty plus years, not just until site occupancy.

Tree Report

Step A – Inventory and Evaluation

- <u>Identify trees suitable for preservation</u>.

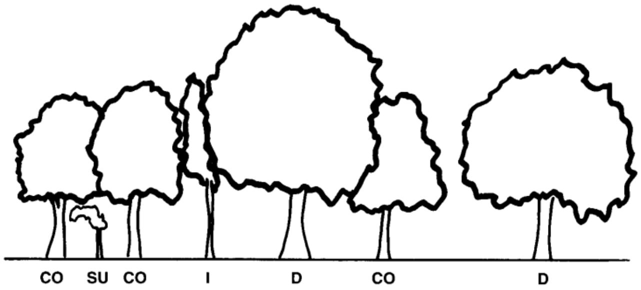
   - Species
   - Size
   - Health and vigor
   - Structural integrity
   - Age – Young trees are more tolerant of construction stress.

   - Species tolerance to construction stress
   - Maintenance requirements

   - Trees suitability to new use

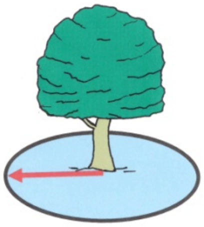
      - Group or specimen trees – Trees are often easier to preserve in a grouping rather than specimen trees.

- **Crown class**



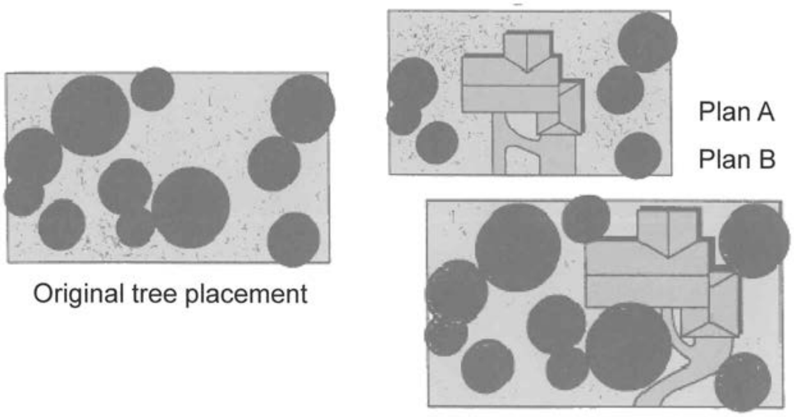
- ✓ ***Dominant trees*** make the best options for preservation.
- ✓ ***Co-dominant trees*** are best preserved in groupings.
- ✓ ***Intermediate trees*** make a poor choice for preservation.
- ✓ ***Subordinate trees*** make a poor choice for preservation due to inferior structure and sudden exposure.

Step B – Assess potential impacts by calculating the *Tree Protection Zones* for each tree.



- Trees under stress and/or decline are less tolerant of construction related stress and do not merit preservation.

Step C – Modify plan to accommodate TPZ and building plans



Step D – Identify tree work

- Work to be done by arborist not construction workers.
- There may be limitations on time of year for work to be done.
- There may have short time frame to complete work before construction begins.

Step E – Outline *Tree Maintenance During Construction Plan*

- Who and how will trees be protected during construction?
- Who and how will the tree be watered and cared for during construction?
- Who and how will the *tree protection plan* be communicated to all workers?
- Who and how will tree protection be monitored during construction?
- What penalties will be in place for individuals and companies who violate the tree protection plan?

Step F – Outline *Post-Construction Maintenance Plan*

- What will be done and who is responsible?
  - Soil management
  - Pruning: Cleaning
  - General care (watering, pest management)

Assessing Tree Tolerance

Species

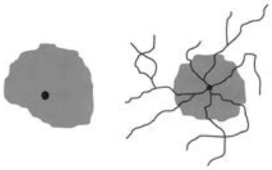
- For comparison, classify species as **good**, **moderate** or **poor** tolerance.
- There is no comprehensive list of species tolerances.
- Ask experts about their experience with specific species.

Age and longevity

- For comparison, classify as **good**, **moderate** or **poor** tolerance.
  - Young trees typically have good tolerance.
  - Medium age trees typically have moderate tolerance.
  - Over-mature and declining trees have poor tolerance and do not merit preservation.

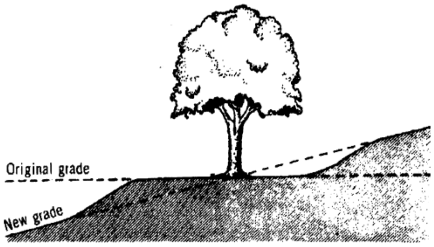
Health and vigor – Trees in poor health will not survive construction related stress.

Actual crown and rooting area may not be uniformly distributed.

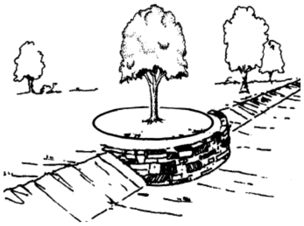


Structural stability – Preservation efforts are not warranted on structurally unsound trees.

Cuts and fills



- **Fills** are more tolerance on flooding tolerant species
- **Cuts** – more tolerance on drought tolerant species

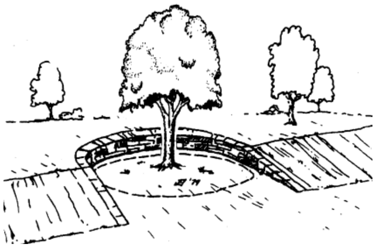


- **<u>Removing soil inside TPZ</u>**
  - On root severance **tolerant** species, may disturb up to **25% of TPZ <u>area</u>** (not diameter).
  - On root severance **sensitive** species, allow **extra space** beyond TPZ.

Root Severance Tolerance

Tolerant	**Intermediate**	**Sensitive**
<u>Up to 25% of TPZ area</u>	<u>TPZ area</u>	<u>Allow extra space in TPZ</u>
Ash: green, white, black	Birch: paper & yellow	Beech
Aspen: quaking & big-tooth	Buckeye: Ohio	Butternut
Birch: river	Catalpa	Ironwood
Boxelder	Cherry: black	Oak: white, northern pin and black
Cottonwood: eastern	Kentucky coffee	Walnut: black
Fir: balsam & white	Hawthorn	
Hackberry	Hickory: Bitternut	
Honeylocust	Maple: sugar	
Locust: black	Spruce: Colorado blue	
Maple: silver & red	Oak: bur & bi-color	
Mt. Ash		
Pine: white, jack, & red		
Spruce: black, white		
Willow		

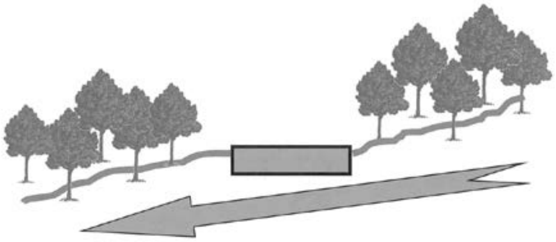
- **<u>Adding soil inside TPZ</u>**
  - If a compaction/flooding **tolerant** species, *may* successfully add **up to 6” *porous* fill**.
  - If a compaction-flooding **sensitive** species, **do NOT change grade**, and TPZ (as calculated with diameter method) may be too small.



Root Covering Tolerance

Tolerant	Intermediate	Sensitive
Add up to 6" porous soil	TPZ area	No change in TPZ
Ash: blue & green	Ash: white	Aspen: quaking & big-tooth
Cedar: northern white	Buckeye: Ohio	Basswood
Birch: river	Butternut	Beech: blue
Boxelder	Cherry: black	Birch: paper & yellow
Fir: balsam	Kentucky Coffee	Cedar: eastern red
Catalpa	Elm: American & slippery	Fir: white
Cottonwood: eastern	Hackberry	Ironwood
Maple: silver & red	Hawthorn	Locust: black
Spruce: Colorado blue & black	Hickory: bitternut	Maple: sugar
Tamarack	Honeylocust	Oak: red, white, black, & northern pin
Oak: bi-color	Mt Ash	Pine: white, jack, red, & scotch
Willow: black	Spruce: white	Plum: wild
	Oak: bur	
	Walnut: black	

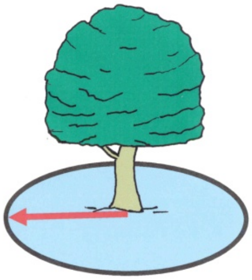
Changes in soil hydrology (soil water)



- **Ability to recover from stress factors**
  - Insects and diseases
  - Irrigation changes

Tree Protection Zone, TPZ

Trunk Diameter Method



The trunk diameter is probably the best method for general use on landscape trees. Size of the TPZ is based on the diameter of the trunk, increasing as the tree ages and become less tolerant of stress factors. It may be calculated by measuring the trunk circumference or diameter at DSH (diameter at standard height, 4.5 feet). For trees with a broad canopy in an open lawn, it is approximately 40% larger in area than the dripline method.

Trunk Diameter Method by Circumference

TPZ radius = 1 feet per 2 inches of trunk circumference

1. Measure the tree's circumference at DSH (4.5 feet) in <u>inches</u>.
2. Divide the number of inches by 2.
3. This is the radius, <u>in feet</u>, of the TPZ.

For example

1. Circumference = 24 inches
2. 24 / 2 = 12
3. TPZ radius = 12 feet

Trunk Diameter Method by Diameter

TPZ radius = 1.5 feet per inch of trunk diameter at DSH

1. Measure the tree's diameter at DSH (4.5 feet) <u>in inches</u>.
2. Multiply the diameter (in inches) by 1.5
3. This is the radius, <u>in feet</u>, of the TPZ

For example

1. Diameter = 8 inches
2. 8 x 1.5 = 12
3. TPZ radius = 12 feet

Area of the TPZ

The area of the TPZ can be calculated by the formula:

$[\text{TPZ radius}]^2 \times \pi$

For example - 12 foot radius:

12 feet X 12 feet X 3.14 = 452 square feet

<u>Stress Tolerance and Age Method</u>

This method is used in a construction site when compromise must be made to minimize the TPZ, allowing for construction activities.

1. Evaluate species tolerance to construction stress (good, moderate, poor)

- ✓ Transplant response
- ✓ Drought response
- ✓ Rooting pruning response
- ✓ Compartmentalization (decay response)
- ✓ Native range – tolerance to stress outside native ecosystem

2. Identify tree age

- Young = < ¼ life expectancy
- Mature = ¼ - ¾ life expectancy
- Over-mature = > ¾ life expectancy
- Older trees are less tolerant of stress and require larger TPZ

3. From the table, calculate minimum TPZ radius and area

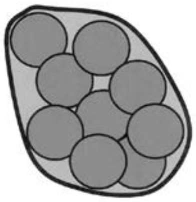
Stress Tolerance	Tree Age	Radius of TPZ* Feet/ inch trunk diameter
Good	Young	0.5
	Mature	0.75
	Over-mature	1.0
Moderate	Young	0.75
	Mature	1.0
	Over-mature	1.25
Poor	Young	1.0
	Mature	1.25
	Over-mature	1.5

- Additional space may be needed on compacted, clayey soils.

TPZ modifications

- Methods above are based on trees in open area with unlimited rooting space.
- Additional space may be needed for shallow rooted trees, like spruce and on compacted clayey soils.
- If low branches will interfere with work, extend the TPZ to include all the dripline area.

Trees in groupings



1. Calculate and plot the TPZ for each tree
2. Plot outer edge of tree group as the TPZ for the grouping

Multiple trunk trees

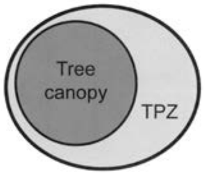
1. Calculate the trunk area for each trunk at DSH (4.5 feet).
2. Add the areas together.
3. Calculate the diameter of a tree that would have this size area in a single trunk.

Area = $\text{Radius}^2 \times 3.14$
Radius = $\sqrt{}\text{area} / 3.14$

4. Use this as the trunk size to estimate the TPZ

To accommodate site needs, the TPZ area may be

- Offset slightly
- Not necessarily round

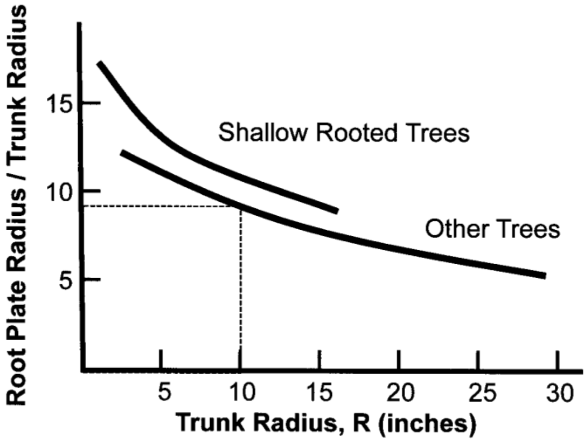


Sites with urban hardscape restricting root spread

- Methods, as described above, will need adjustments.
- Need to actually check for root location.
  - Backhoe (A good operator knows when he hits roots and will stop before cutting them.)
  - Hand digging
  - Air spade
- New sidewalks and parking areas are generally OK if they say inside the footprint of the old area without invading the rooting area.
- New buildings are generally OK if they say stay inside the footprint of the old building without invading the rooting area.

Tree Stability

- For wind stability, do not invade the root plate.
  - **General formula**: radius of root plate is 3-6 times DSH (trunk diameter at standard height, 4.5 feet)
  - **Bartlett Tree Lab Model**: radius of root plate is
    - 5 times DSH on one side AND
    - 3 times DSH on other three sides
  - **Mattheck Model**

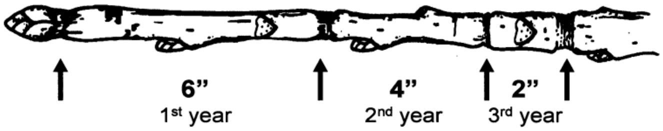


For example, a 10 inch trunk radius needs a root plate/trunk radius coefficient of 9. This would be 90” root plate radius (90”/10” = 9).

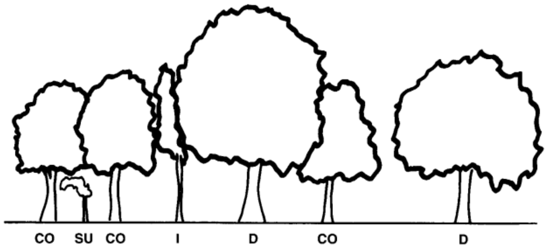
Symptoms of Construction Damage

Symptoms of construction damage include generic symptoms of stress and decline. Trees generally decline due to root decline and death.

- Reduced canopy growth – Compare how annual growth changes from year to year.



- Dieback on upper canopy
- Dieback of upper canopy on side related to root damage
- Small, poorly colored leaves
- Adventitious sprouting along trunk or lower scaffold branches
- Heavy seed set
- Mechanical injury to trunk and limbs
- New Edge” damage – Foliage and bark damage due to increased exposure to sun and wind.



Bottom line: Take steps to prevent construction damage, as little can be done to correct it.

Author: David Whiting, Extension Consumer Horticulture Specialist (retired), Department of Horticulture & LA, Colorado State University Extension.

- Colorado Master Gardener *GardenNotes* are available on-line at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.
- Extension programs are available to all without discrimination.
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October 2014

CMG GardenNotes #653

Wrapping Trees For Winter

Why Use Wrap

Tree wrap is used to protect young, thin-barked trees during the winter months. Wrapping trees helps protect against sunscald and frost cracks, both of which are temperature related. Not all trees need to be wrapped. Species such as linden, maple, ginkgo, crabapple and redbud will benefit from tree wrap. Trees with thick, corky bark, like bur oak, do not need to be wrapped.

Sunscald

Sunscald is also known as "southwest injury" since it tends to occur on the south or southwest side of the tree. During the winter, the south/southwest side of the tree is warmest, due to the location and angle of the sun during the winter months. Sunny warm winter days "wake up" cells in the cambium (the living tissue in the tree), causing them to move water and nutrients. As temperatures drop at night, the cells freeze and burst, causing bark splitting. Sunscald creates a jagged wound along the trunk that can take a long time to seal over and be an entry point for disease and insects.

Figure 1 Sunscald damage

Frost Cracks

Frost cracks are vertical cracks in the trunk or stems of trees. Warm winter days cause the cells to warm up and expand. As the sun sets, the outer bark temperature cools quickly, but the inside of the tree remains warmer, which results in splitting. Younger trees are most susceptible. Frost cracks are usually not as detrimental to tree health as sunscald.

The rules for using tree wrap are as follows:

1. Wrap trees at the end of November and removed in early spring (mid-April). Tree wrap should not be left on all year.
2. Use a light-colored crepe-paper type wrap; using plastic, dark colored materials or burlap can result in tree damage. Crepe-paper wrap has some elasticity to it and sheds water, keeping the trunk dry.
3. Start wrapping at the bottom of the tree, overlapping by 1/3 until you reach the first branch. Tape the wrap to prevent it from slipping at the top of the tree. Or consider stapling the wrap to itself around the first branch. Do not staple the wrap into the tree!

Once the bark of the tree has hardened and become furrowed, it is not necessary to wrap trees. Trees should only be wrapped for the first one to three years following planting. It cannot be emphasized enough that wrapping is only a seasonal treatment.

Figure 2 Tree wrap

Using Latex Paint

Latex paint is often used in nurseries and orchards since it is a cheaper and less labor-intensive option to wrapping trees individually. Paint is not as aesthetically pleasing and will take time to wear off. Only use water-based latex paint and not oil-based, as it can damage trees. Apply the paint in late fall when temperatures are above 50 degrees F so it can dry quickly.

Watch this short video on tree wrapping:
https://www.youtube.com/watch?v=B_KOaHXETb4

Author: Alison O’Connor, Colorado State University Extension. Photos courtesy Alison O’Connor.

- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.
- Extension programs are available to all without discrimination.

July 2017

CMG GardenNotes #654

Staking Trees

Outline: When to stake, page 1
Staking straps, page 2

Many gardeners believe that tree staking during the planting process is necessary, but it is really only required in certain situations. More important than staking a tree is to ensure it is planted properly. Refer to the Colorado Master Gardener Garden Notes #633 or the shortened version #636 at www.cmg.colostate.edu.

When to stake

Staking is only necessary in the following situations:

1. Windy sites: When a tree is planted in a wind tunnel or in an area that is perpetually prone to wind and/or damage from wind, then staking can be justified.
2. Protecting the newly planted tree from people or activities: If the tree is planted in a public space that gets high amounts of traffic or is prone to vandalism, stakes may be used to help protect the tree. Sometimes just having posts (without staking straps attached) around the tree may divert vandals or harmful activity.
3. Supporting the weight of the tree because the tree cannot stand on its own. In this situation, the tree should not be planted, since quality of nursery stock is an important component when planting trees. However, if the tree was planted but cannot stand on its own, staking straps should be attached six inches above the point where the tree can support itself, but at least three feet below the terminal leader. Again, there is a responsibility of consumers to demand quality nursery stock—planting inferior trees should not be a standard practice.

Staking Straps

Always use wide canvas straps with grommets at either end to attach staking wires to trees. These wide straps help distribute the pressure evenly. Wire threaded through hose concentrates the pressure, causing girdling and other damage.
For details about staking trees properly, refer to the Colorado Master Gardener Garden Notes #634 at www.cmg.colostate.edu.

Staking can lead to increased tree height at the expense of caliper (diameter) development. It can also lead to a smaller root system, since the tree may not have the ability to sway/move with wind (which builds caliper and roots). Staking has also been found to damage the trunk as soon as six months after planting, causing girdling and compression injury to the trunk.

When stakes are used, they should be removed after **one growing season**. Stakes are often forgotten if left on the tree longer, leading to long-term damage. Materials can girdle or grow into the tree, creating weak points and potential failure.

Author: Dr. Alison O’Connor, Colorado State University Extension. Photos courtesy Mary Small, Colorado State University Extension

August 2017

MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #655

Dealing with Leaves in the Landscape

Outline: Uses for Leaves, page 1

Many gardeners find that raking and clearing leaves from their landscapes in the fall is tedious and never-ending task. Depending on the age of the neighborhood, the size of trees and the number planted in or near the property, it can take a fair amount of time and energy to manage them.

Uses For Leaves

Leaves are a valuable resource in the landscape. While they are not considered a fertilizer replacement, (it would take 100 pounds of leaves per 1000 square feet of turfgrass to apply one pound of nitrogen if the leaf nitrogen value was 1%), they do have other benefits. Try to avoid sending the leaves to a landfill and use them in the landscape.

1. ***Mow the leaves into the lawn.*** Set the lawnmower deck to the highest setting. Remove the bagging attachment and make at least two passes over the lawn, chopping the leaves into small pieces. As long as you can see some grass through the leaves, the layer is not too thick. Research has found that mowing leaves into the lawn will return nutrients to the soil, provide food for earthworms, increase moisture for the turf roots and reduce weeds. ***Leaves do not lead to thatch accumulation***.

Research at Purdue University found that mulching leaves into the lawn at high rates did not affect turf quality, color or soil pH. A study at Michigan State University found that mulching leaves into the lawn reduced perennial weed populations like dandelions and annual weeds like crabgrass after three years. The small leaf pieces sift down onto the turf surface and prevent weed germination from bare soil. It is important that the leaves are shredded or mulched and not left whole on the lawn.

2. ***Add leaves to compost bins***. Tree leaves are "brown" material and can be added to compost bins in combination with "green" materials. For more information on composting, refer to the Colorado Master Gardener Garden Notes #246 at www.cmg.colostate.edu.

3. ***Add leaves to garden beds or raised beds.*** Consider leaves a free source of organic matter. You can add up to six to eight inches of leaves (best if chopped by the lawnmower) into the vegetable garden. Water the surface, add some fertilizer to kick-start decomposition and let microbes break down the leaves through the winter. In the spring, till them into the soil or directly plant into the area. Be cautious about over-amending garden soils and consider having your soil tested first.

4. ***Use as mulch in the landscape.*** Leaves can be used as mulch around tender plants or those that are newly planted. Place a wire cage around the plant and pile three to six inches of shredded leaves inside the cage, next to the plant. As growth begins in the spring, remove the cage and leaves.

Author: Dr. Alison O'Connor, Colorado State University Extension. Photos from csu.cohorts.blogspot.com (Dr. Tony Koski) and (compost) farm3.staticflickr.com/2435/4022031843_65a2086098_z.jpg

August 2017

MASTER GARDENER
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CMG GardenNotes #656

Herbicide Use Around Landscape Trees

Outline: How herbicides can damage trees, page 1
Herbicides safe to use around trees, page 2

There are times when using pesticides around trees is necessary and it is important to understand how they can potentially affect tree health. The most common pesticides used around trees in the home landscape are herbicides.

How herbicides can damage trees

1. Direct "hits" to the canopy, suckers or trunk that contact live tissue.
2. Absorption through the root system, which can extend several times the width of the canopy and can be extensive. Depending on soil type, tree roots are generally located within the top 12" of soil. In compacted or mostly clay soils, more than half of tree roots can be located in the top six inches of the soil.
3. Drifting or volatization (become a gas) with movement to sensitive tree tissue when conditions are too windy, too hot or when the relative humidity is low.

Figure 1 Volatilization Injury to Ash Leaves

It is critical to read and follow all directions on the label of a pesticide product before using it. Reading the label in its entirety helps the homeowner determine if the product can cause damage to woody landscape plants. Some trees are more sensitive to certain herbicides than others.

It is also important to understand the herbicide's mode of action (how it works). Some may be contact herbicides, some may be root absorbed and some may be systemic.

Table 1. Post-emergence Herbicides that are Safe to Use Around Trees

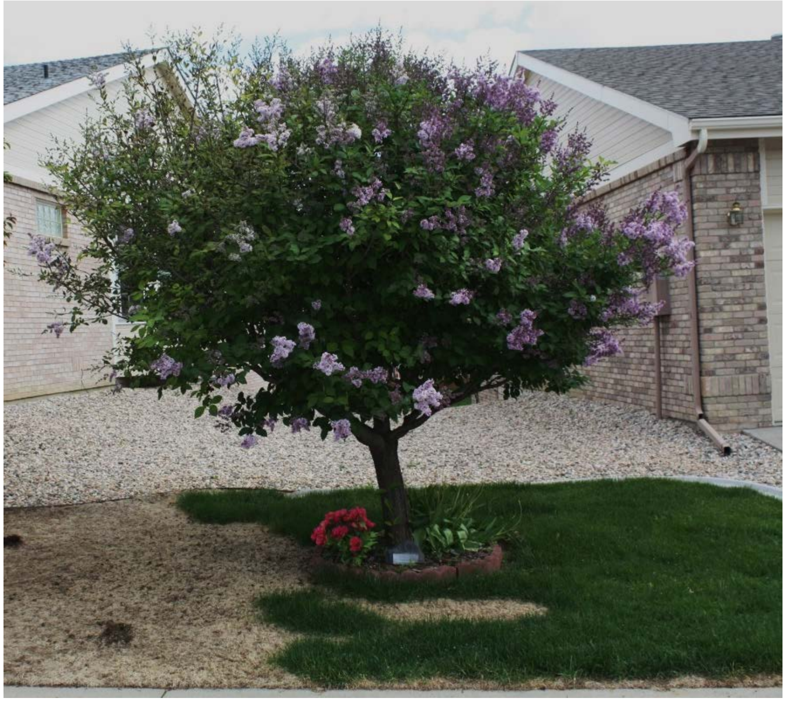
Class of Herbicide	**Products**	**Mode of Action**
Amino Acid inhibitors	• glyphosate (Roundup, Kleenup)	Foliar (systemic), but can be mixed with sterilants
Burndown products (non-selective)	• Diquat • Essential oil herbicides • Glufosinate (Finale) • Horticultural vinegar (20%) • Pelargonic acid (soaps) (Scythe)	Foliar (contact)
Phenoxys	• 2,4-D • Clethodim (Grass Out) (grasses only) • dichlorprop • Fluazifop (Grass B Gon) (grasses only) • MCPA • MCPP	Foliar (systemic)

Table 2. Preemergence Herbicides Safe for Use Around Trees.

Chemical Name	**Trade Name**
Isoxaben	Gallery
Oryazlin and trifluralin	Snapshot
Oryzalin	Surflan
Prodiamine	Barricade
Trifluralin	Preen

Weed and grass growth at the base of the trees is one area where herbicides may be applied frequently. In this situation, consider using mulch, mowing, hand pulling the weeds and grass, using glyphosate or burndown products (i.e. horticultural vinegar). When using glyphosate, only apply to the weeds or grass and do not spray the trunk, suckers or exposed roots of trees. Pre-emergence weed control products may be used under trees in spring.

Figure 2 Accidental root absorption of herbicide applied to rock mulch.



Author: Dr. Alison O’Connor, Colorado State University Extension. Photos courtesy Mary Small and Alison O’Connor, Colorado State University Extension.

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MASTER GARDENER
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CMG GardenNotes #657

Watering Mature Shade Trees

Why Trees Need Water

All living things need water to survive and trees are no exception. Trees use water for physiological functions and growth processes. In the landscape, water moves from soil in three ways.

1. Available water is *absorbed* through plant root systems, transported upward and lost via transpiration from leaves and bark.
2. Water *evaporates* from the soil surface.
3. Water *drains* through soil due to gravitational forces.

As soils dry, water molecules are held more and more tightly by soil particles. These water molecules become unavailable for plant use, resulting in the *permanent wilting point* of plants (the point of "no return"). As drought and desiccation increase, normal plant functions may cease. During drought stress, normal physiological functions of plants are interrupted, including:

1. Reduction in photosynthesis; water is an important component of photosynthesis and the process is negatively affected during dry periods.
2. Stomata, which regulate water and gas exchange in the leaf, may close. This prevents water vapor and oxygen from leaving the plant, as well as carbon dioxide entering the plant (which is essential for photosynthesis).
3. There is likely a reduction in carbohydrate production and storage (due to reduced photosynthesis).
4. Plant growth is reduced (leaves, shoots, roots, fruit, etc.)

Plants under drought stress also have weakened defense systems, which can lead to problems with certain insects and diseases. Fortunately, trees can tolerate *some* drought and dry conditions. It is very difficult to detect short-term drought stress in trees. Prolonged drought stress, however, may result in wilting, early leaf drop, smaller-than-normal leaf size, early fall leaf color, scorch on leaf margins, purpling or browning of leaf tissue and increase in disease or insect pressure.

Tree Establishment

Established trees in the landscape don't require water as frequently as those that are recently planted. (Trees generally take a season to establish for each inch of trunk caliper; a 2" tree will take two years to establish). In Colorado's dry climate, trees will need supplemental irrigation during dry periods in the summer and during fall and winter. Keeping your trees well-watered will contribute to their overall health and survivability in the landscape. A general rule of thumb is that the bigger the tree, the more water it will need.

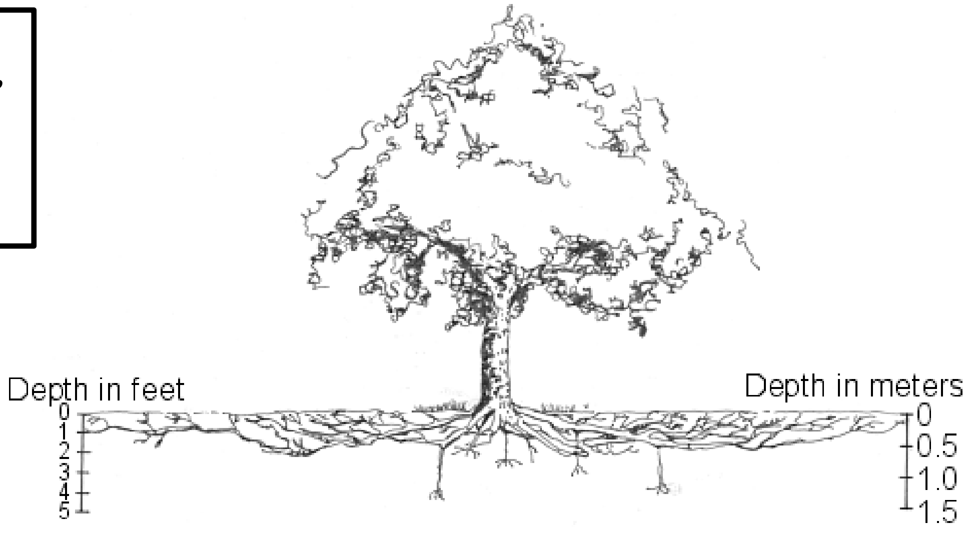
Tree Roots and Their Location

Tree roots tend to be shallow and most are located within the top 36" of soil. In compacted clay soils, up to 50% of roots may be located in the top six inches of the soil with nearly all roots located in the top 12 inches.

Tree roots can extend several times the width of the canopy. Trees planted near or in a lawn will share water with turf roots. Whichever was planted first has the advantage. New trees in an established lawn will have fewer roots to compete; mature trees with an extensive root system will outcompete turf grass.

In compacted or clay soils:

- **90-95% of roots in top 12"**
- **50% of roots in top 4-6 "**
- **Spread up to 5x canopy width**



Determining When to Water

It is difficult to look at a tree and determine if it needs water. Instead, take a slender screwdriver and poke it into the soil in several places around the tree, both inside and outside the dripline (where the canopy extends). If the screwdriver can easily penetrate the soil to a depth of six to eight inches, there is no need to apply water.

Amount of Water

The amount of water to apply will vary depending on the size and age of the tree, the time of year, soil type, watering method and other factors. Aim to apply one to two inches of water every two weeks during the growing season. If you prefer to measure in gallons, apply 10 gallons of water for each inch of trunk caliper - diameter- (e.g. a 4” caliper tree needs 40 gallons of water). These amounts are *recommendations only*. Adjust as necessary for your local situation and precipitation.

Methods of Watering

In general, it is easier to apply the entire amount slowly over one period of time instead of over a period of days. However, if your soil is very dry and cannot absorb the water - resulting in runoff - consider watering over several days to allow for absorption.

Trees growing in sandy soils will need to be watered more frequently than trees in clay soils, since sand drains more quickly and doesn’t hold water well.

It is much easier to keep soil continually moist throughout the season than to rehydrate dry soils. Dry soil often become hydrophobic and rewetting it takes a long time with multiple applications of small amounts of water.

There are many ways to water mature trees in the landscape: lawn irrigation, hose and sprinkler, drip irrigation, soaker hoses and self-watering devices.

<u>Lawn Irrigation</u>

When mature trees are planted in/near the lawn, using a lawn sprinkler system is an easy and effective way to water them. (Figure 1) Remember that the turf and tree roots are located in the shared rooting area and both are using the applied water. A good goal is to apply enough water to the lawn to compensate for evapotranspiration (ET); this is the amount of water used by the plants and lost from evaporation. The amount will

Figure 1

vary throughout the season. A typical bluegrass lawn may need one inch of water early in the summer (May-June), up to two inches during July and August and one inch in September and October. You can consider running additional cycles (perhaps a couple times per month) to supply additional water to tree roots. To measure how much water you are actually applying in an irrigation cycle, place several cups in the area and measure the amount of water in them. Multiply this by the number of days the system runs per week:

0.5 inches applied/cycle x 3 days per week = 1.5 inches of water applied per week
1.5 inches of water applied per week x 4 weeks/month = 6” of water per month

Hose and Sprinkler

Figure 2

A hose and sprinkler is an effective way to water trees. (Figure 2) A hose and sprinkler should always be used when the lawn irrigation system is turned off. Place several cups in the pattern of the sprinkler to collect output, or attach a water meter to the hose to determine how much water was applied. The most effective place to water mature trees is just outside the dripline (NOT at the trunk). Depending on the type of sprinkler, it may take 30-60 minutes of run time to apply one inch of water.

Drip Irrigation

Drip irrigation is often used to water newly planted trees. One mistake many homeowners make is leaving the drip irrigation in the original location for years. Emitters must be moved out and additional ones added as the tree grows or drought stress may occur. Depending on the location and tree species, drip irrigation may be eliminated after the tree matures. When using drip, understand the systems’ emitter size and output to calculate the amount of gallons applied during each irrigation cycle. For example:

2 gallons/hour emitters x 4 emitters x 30 minutes per irrigation cycle = 4 gallons per cycle

Soaker Hoses (“leaky pipe hose”)

Soaker hoses are probably most effective on smaller trees, but can be used on larger trees if there is enough hose available to apply in the tree’s dripline. Soaker hoses apply water very slowly and need to run for long periods of time. It may take several hours to apply one inch of water, depending on pressure and hose size. A small container could be placed beneath the hose (or dug in a shallow hole) to collect water and determine total irrigation output. Do not coil soaker hose around trunks of mature trees.

Self-watering Devices

These systems, sometimes known as “Gator Bags”, are best used *only* on newly planted trees. They are not an effective or practical way to water mature trees. Even with newly planted trees there are some potential problems. First, the bag must be monitored to ensure that it is filled with water. Second, bags are often dark in color and when left around the trunk of the tree, can trap excess heat. Third, bags may keep the trunk and surrounding soil overly moist, leading to disease and insect problems. Self-watering devices may be used for the short term, but are not a reliable way to irrigate.

Deep Root Watering Devices

Since the majority of tree roots are not located deep within the soil profile, deep root waterers are not an effective method of irrigating. In addition, the device must frequently be moved around the tree, which is time consuming. A hose and sprinkler is a better option.

Following your method of irrigation, stick a slender screwdriver into the soil. If you cannot penetrate to a depth of six to eight inches, water again. Repeat this process until you have adequate soil moisture.

Fall and Winter Watering

Watering trees in Colorado’s dry fall and winter months is extremely important. Moist soils hold more heat than dry soils, leading to additional growth in the fall and increased time for establishment. Adequate soil moisture also leads to better plant hardiness and ability to survive cold, dry winters. Aim to water trees and other woody landscape plants monthly when natural precipitation between October and April is less than an inch per month.

Precipitation can be in the form of snowmelt or rain, but snow moisture can vary. Water on days when the temperature is above 40 degrees. Apply an inch of water early in the morning to allow it to soak into the soil before freezing at night. For additional information, refer to CSU Extension Fact Sheet #7.211 at www.extension.colostate.edu

Figure 3 Snow holds varying amounts of water

Obey All Ordinances

Be smart when watering and avoid irrigation during the hottest part of the day (10am to 6pm), when evaporation can occur more readily. Follow all HOA guidelines and town/city restrictions.

Authors: Dr. Alison O’Connor and Eric Hammond, Colorado State University Extension. Figure 1 source: By M.O. Stevens (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons; Figure 3 courtesy of Mary Small, Colorado State University Extension

August 2017

CMG GardenNotes #658

Mulching Trees

Mulch Importance and Benefits

Mulch is important to the long-term health of trees.

- It helps protect them from string trimmer and lawn mower damage.
- It helps retain soil moisture and reduces evaporation from the soil surface by 25-50%.
- Mulch helps moderate soil temperature extremes and controls erosion.
- It enables tree roots to outcompete grass roots for available nutrients and water.
- Fine root hairs of trees develop 400% more under mulch than under grass. This is important because root hairs absorb most of the water and nutrients for the tree.
- Mulch suppresses weed growth and gives landscapes a finished, polished look.

Mulch Disadvantages

While mulch has many benefits, there are some disadvantages.

- Used in moist areas, organic mulch can create conditions ideal for trunk or root rot, especially when placed too close to the trunk. Rot in this part of the tree leads to instability and makes a tree more susceptible to wind throw.
- Organic mulches may be attractive to voles that use it as shelter and then chew on tree bark for food.
- Lighter-weight mulch materials can blow away in very windy areas,
- Herbicides directed at weeds emerging through mulch may accidentally touch roots, green bark and sucker sprouts, leading to tree injury.
- When mulch is applied too deep around a tree stem- girdling root problems often follow and may kill a tree several years after planting.

Mulch Options

There are many options when it comes to choosing mulch, but not all mulch is best for tree health. Plastic mulch/sheets suppress weed growth, but might overheat the soil and damage roots. In addition, plastic mulch doesn't allow for proper oxygen flow to the tree root systems so roots tend to grow directly under the plastic, leading to potential problems. Large rocks do a poor job of suppressing weed growth and can overheat the soil and tree roots. Rock mulch may also have increased weed growth, as soil settles between rocks, providing ideal conditions for weed germination. Rubber mulch can lead to drainage problems and leach toxic metals into the soil. When choosing a tree mulch that is attractive, beneficial, and convenient it is hard to beat bark chunks, shredded bark, wood chips, and pine needles.

Mulch Application

Properly applying mulch is just as important as selecting it. Keep the mulch at least 6 inches away from the bark of the tree. This helps keep the lower trunk dry and reduce the likelihood of bark decay and rot.

Never apply mulch directly over the newly planted root ball since this encourages roots to grow up into the mulch and around the trunk or each other. This growth can girdle the tree within several years. Instead, mulch the backfill area and beyond if possible, to a 3 to 4 inch depth. Excessively mulched trees, sometimes called "mulch volcanoes", reduce the amount of available oxygen to tree roots, causing oxygen starvation and tree decline or death.

Figure 1. Keep mulch away from the trunk and off the root ball.

Authors: Tyler Mason, PhD candidate, Colorado State University Department of Horticulture and Landscape Architecture: Dr. Alison O'Connor and Mary Small, Colorado State University Extension. Photos courtesy Alison O'Connor, Colorado State University Extension.

October 2017

MASTER GARDENER
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CMG GardenNotes #659

Understanding Tree Roots

Functions of Tree Roots

Support\anchorage

A tree's root system keeps its trunk and canopy upright against the forces of wind and gravity. The strength of anchorage provided by a tree's root system depends on a variety of factors including soil type, soil moisture levels, tree species, root health and the depth and width of a tree's root plate. Sandy and overly wet soils provide worse anchorage.


Upended tree shows extent of root plate

The "root plate" is the area close to the trunk that contains the primary structural roots
The root plate occupies an area ~3 to 6 times the diameter of the trunk at DSH\DBH (Diameter at 4.5ft).

Absorption of water and mineral nutrients

Roots absorb water and nutrients for use by the plant. Mineral nutrients are only absorbed from forms dissolved in the soil solution. In some species, the architecture of the tree's vascular system is such that specific roots supply correspondingly specific branches with water and nutrients. For example, in ring porous species such as the oaks (*Quercus* spp.), a given root or suite of roots supplies a specific branch or suite of branches which are often on the same side of the tree as the root. Similarly, in many conifers, water and nutrients move up the trunk in a spiral pattern supplying branches along the way. In this case damage to a root manifests in branches along the spiral the root supplied. The specific vascular architecture of many species is not known.

Production of plant growth hormones

Cytokinins, gibberellins and abscisic acid are all produced by roots. Cytokinins are involved in cell division, cell differentiation, axillary bud growth and leaf senescence.

Gibberellins are involved in stem elongation, bud break and other processes. Abscisic acid is involved in drought stress response, maintaining apical dominance, suppressing stem elongation and promoting dormancy.

Storage of energy as sugars and starches

Energy created through photosynthesis can be transported to the roots of a tree as sugars, and then is stored as starch.

Describing Tree Roots

Types of tree roots

Woody roots (also called transport roots)

There are larger roots that may be up to 1 cm to 30 cm (.4 to 12 inches) or more in diameter in some cases. These roots provide anchorage, serve as storage sites for starches and sugars and are part of the system that transports water, nutrients and other compounds through the tree from fine feeder roots to leaves. They absorb very little water or mineral nutrients from the soil.

Example of woody roots

Specialized Woody Roots

1. **Tap Root**- A primary root that grows downward from the seed radical. Some species exhibit taproots when younger but by the time they reach maturity few trees have a true deep taproot due to low soil oxygen levels deeper in the soil.
2. **Sinker Roots**- Roots that grow downward from lateral woody roots. Formation of these roots is species and soil dependent. They are not common in landscape trees.

Fine feeder roots (absorptive roots)

These are smaller roots that are 2 mm (.4 to .008inches) or less in diameter.
These roots are the primary sites of water and mineral nutrient absorption. They are often short lived and can been killed or suppressed by low soil oxygen levels, drought or

fluctuations in soil temperature. Such events are stressful but healthy trees rapidly reproduce fine feeder roots.

Fine feeder roots are commonly colonized by symbiotic fungi. These fungi can help extend the reach of the root system, aid in the mineralization of plant nutrients, increase the trees' drought tolerance and help it to resist some diseases.

It is common for fine feeder roots to form grafts with the fine feeder roots of other members of the same species.

Size and extent of the root system

Width

A mature tree's root system often occupies a much wider area than its canopy. Depending on the species of tree and soil conditions the spread of a trees' root systems may be 2 to 5 times the width of its canopy or even greater in some cases.

Depth

The depth of a trees root system is governed by the availability of water, mineral nutrients, soil oxygen and the species of tree. In clayey, compacted or perpetually wet soils (soils with a shallow water table) roots tend to be shallower due to low soil oxygen levels in the deeper layers of such soils. In sandy soils, roots also tend to be massed near the soil's surface. Sandy soils have low levels of mineral nutrients and having a large concentration of roots near the surface allows trees to capture nutrients released from decomposing leaf litter. In loamy soils, tree roots tend to be deeper as there is sufficient oxygen and nutrients to support their growth.

The rule of thumb for estimating rooting depth in clayey, compacted or perpetually wet soils (soils with a high water table) is that 90-95% of roots will be in the top 12 inches and 50% will be in the top 4 inches of soil. In favorable soils conditions 90-95% of roots will be in the top 36 inches and 50% will be in the top 12 inches of soil.

Surface area

The surface area of a root system is likely larger than that of the plants' leaves BEFORE you take into account symbiotic fungi.

Conditions that adversely affect roots

Soil Compaction

Heavy equipment traffic compacts soils

Soil compaction occurs when soil is compressed, pushing soil particles closer together. This reduces the overall volume of pore space in a soil and particularly reduces the volume of larger air holding pores.   In landscapes, compaction can be caused by foot traffic, maintenance equipment or other vehicle traffic and other factors. Many soils are compacted during construction.

Compaction affects tree roots in a several negative ways. It can lower soil oxygen levels which adversely affect root and tree health (see below). Compaction also increases the strength of soil making it physically harder for roots to grow through it. This can slow the establishment and growth of a tree.

Low soil oxygen levels

Roots require oxygen to perform respiration (the process that turns the products of photosynthesis into usable energy). As roots (and other soil life) consume oxygen it is replenished though diffusion from the atmosphere.   When adequate oxygen is not in the soil, root growth slows. Low soil oxygen levels also leads to stomata (located on plant leaves) closing which reduces water and nutrient uptake, reduces translocation of water, nutrients and hormones within the plant and can potentially led to wilting. Low soil oxygen can also lead to root cells “self- poisoning” due to accumulation of the byproducts of anaerobic respiration.

Conditions leading to low soil oxygen levels

Overwatering\Waterlogged Soils

In soils that are perpetually wet, soil pores are mostly filled with water (soil solution). Relatively few pores are filled with air. There also may be few clear contiguous pathways from the air-filled pores to the soil surface, slowing the rate of diffusion of oxygen between the atmosphere and the soil.

Compaction

Compaction reduces the overall volume of pore space in a soil and especially reduces the volume of “large” pore spaces. The “large” pores are those that tend to be filled with air after gravitational water has drained. They are also the easiest pathways for diffusion of gasses. So, compaction reduces the volume of air-holding pores in soil and can reduce the rate of diffusion between the atmosphere and the soil.

Improper mulching

Appling organic mulch too thickly can slow diffusion of gasses, including oxygen, from the atmosphere into the soil. Generally, no more than four inches of organic mulch should be applied to avoid this. Plastic sheet or fabric mulches limit the exchange of gasses between the atmosphere and the soil.

Grade Changes

Adding soil over the top of an established root system can have the same effect as adding a mulch layer that is too thick.

Other common root issues

Girdling Roots

Girdling roots are roots that are wrapped around other parts of the plant. Stem girdling roots are roots wrapped around or growing across the stem of a tree. Root girdling roots are wrapped around another root (somewhat less of a concern).

Stems girdling roots compress newly produced phloem (and eventually xylem) which impairs the ability of the tree to move material through these tissues. This leads to stress and potentially, decline.

Symptoms

i. Flat sections of a tree's trunk where it enters the soil (non-flared).
ii. Swelling above and below the girdling root.
iii. Generally poor health or dieback without any obvious cause.

Girdling roots

Causes of Girdling Roots

i. Root deflection and circling at the edge of a container.
ii. Root deflection at edge of planting hole.
iii. Trees placed too deeply in nursery containers. This leads to roots growing upward and potentially to circling roots in a container above the root flare.
iv. Upward growing roots as the result of low soil oxygen due to deep planting, root pruning in the field during nursery production or combination of the two.
v. Mulch over the root ball or root flare.

Dealing with girdling roots

A root collar excavation, which is the process of removing the soil from the base of the tree, can be performed to expose the root flare and any girdling or potentially girdling roots. Girdling roots can then be removed, preferably back to a point where they will grow outward from the trunk. Some roots may be too in-grown to remove and may result in greater damage to the tree if removal is attempted.

Proper management and pruning of root systems in nurseries and at planting as well as proper planting practices can prevent girdling roots from forming.

Surface roots


Surface roots

Trees roots may develop at or partially above the soil surface creating a nuisance in turf and a potential health risk for the tree as exposed roots are often wounded by mowers or other landscape maintenance activities.

Some trees are prone to developing surface roots. However, their formation is encouraged by low soil oxygen levels that are caused by compaction or overwatering or both.

Once surface roots develop, little can be done. A soil of courser texture can be added over the surface roots but it is **likely a short term solution**. As roots increase in diameter they will surface again. Adding too much soil or too fine a soil can reduce soil oxygen levels and harm the tree. Mulching the area so that it no longer needs to be maintained as intensively is the best management option.

Installation and maintenance practices that promote better soil aeration can help prevent surface roots. Such practices include amending soil with organic matter and regular core aeration of turf.

Suckering


Suckers growing around base of tree

Roots may produce adventitious shoots known as suckers. Suckers arise from adventitious or latent buds along a trees' root system. (They are different from seedlings with are the result of seeds created through sexual reproduction.) Production of suckers is partially species dependent and some species are more prone to suckering. Damage to roots from trenching, flooding or other causes can also in courage suckering. Removing a tree can cause its remaining root system to sucker. Suckering can also be a response to general stress.

What can be done?

ii. Avoid planting species that are prone to suckering.
iii. Avoid damaging tree root systems.

iv. Try “Sucker Stopper” which is an artificial plant growth hormone that prevents buds from opening. Read label directions before using as it works better on some species than others.
v. Try herbicides - if you do not care about the health of the tree that is producing the suckers, herbicides can be used.
vi. Tolerate suckers.

Key Points for Talking With Clients about Tree Roots

☐ Tree root systems are much wider than their canopies, if space permits.
☐ Tree root systems are relatively shallow.
☐ Proper planting practices and species selection are the best way to avoid common root issues.

Author: Eric Hammond, CSU Extension.

- *CMG GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the *Colorado Garden Show, Inc.*
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

October 2017

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

Vegetables

Learning Objectives

At the end of this unit, the student will be able to:

- Describe block style layout in a raised bed garden design.
- Describe garden planning and planting times.
- Describe soil preparation and fertilization for the vegetable garden.
- Describe routine garden care including mulching, irrigation, and water conservation.
- Describe routine care for tomatoes.
- List hints for growing other vegetables.
- Describe frost protection and microclimate modification.

Vegetables Curriculum developed David Whiting (CSU Extension, retired), Carol O'Meara (CSU Extension, Boulder County) and Carl Wilson (CSU Extension, retired)

- Colorado Master Gardener Training is made possible, in part, by a grant from the ***Colorado Garden Show, Inc.***
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

Revised October 2014

References / Reading

Colorado State University Cooperative Extension

CSU Extension Fact Sheets

- Eggplants – Peppers and Eggplant – #7.616
- Flea Beetle – #5.592
- Grasshopper Control in Yards and Gardens – #5.536
- Herbs – Growing, Preserving and Using Herbs – #9.335
- Horticultural Oils – #5.569
- Insects – Flea Beetle – #5.592
- Insects – Grasshopper Control in Yards and Gardens – #5.536
- Insects – Greenhouse Whitefly – #5.587
- Insects – Potato or Tomato Psyllids – #5.540
- Insects – Squash Bug Management - #5.609

- Peppers and Eggplant – #7.616
- Potatoes Seeds – Saving Seeds – #7.602
- Preventing E. coli From Garden to Plate – #9.369
- Psyllids – Potato or Tomato Psyllids – #5.540
- Seeds – Growing Plants from Seed – #7.409
- Seeds – Home Storage of Vegetable and Flower Seeds – #7.221
- Storage of Home-Grown Vegetables – #7.601
- Tomatoes – Recognizing Tomato Problems – #2.949
- Vine Crops – Cucumbers, Pumpkins, Squash, and Melons – #7.609

Review Questions

1. Describe how adding organic matter improves a sandy garden soil. A clayey garden soil.
2. List techniques to manage soil compaction in the vegetable garden.
3. What are the limitations on using manure and compost made with manure in the vegetable garden?
4. Describe the pros and cons of homemade compost, of commercial compost.
5. Describe the standard application rate for compost. How does it change with incorporation depth and potential for salts in the product?
6. If the soil is low in organic matter, will a routine application of compost and/or manure supply the nitrogen needs for crops? Explain why.
7. How the fertilizer application rate change based on soil organic content?
8. What is the purpose of a starter fertilizer? List examples of common fertilizers that could be used as a starter fertilizer.
9. What is nitrogen side dressing? List examples of common fertilizers that could be used for side-dressing.
10. In Colorado, what types of soils will likely have deficiencies of phosphorus and potassium?
11. Why are the advantages of a block style garden layout? Of raised bed gardens?
12. Describe how to design a garden in block style layout.
13. Describe how to make a raised bed garden. How high should the beds be raised? In routine raised bed gardening, where are the crop's roots?
14. Explain "double digging".
15. Describe how to set up a soaker hose drip irrigation system in a raised bed garden.
16. Describe procedures and limitations on using grass clipping mulch in the vegetable garden.
17. Can wood/bark chip mulch be used in the vegetable garden? Explain.
18. List gardening techniques to conserve water in the vegetable garden. What happens to vegetable quality with inadequate water supplies?
19. What is the critical water period for various vegetables?
20. Describe the ideal tomato transplant. How should tall, leggy transplants be planted?
21. What are the advantages of trellising tomatoes? How far apart should tomatoes be spaced? Give examples of trellising methods.
22. What are the advantage and limitations on using black plastic mulch on tomatoes, peppers, eggplants and vine crops? Describe techniques for using plastic mulch.
23. Tomatoes are often referred to as being a "low nitrogen" crop. More correctly stated, they are fussy about nitrogen levels. Explain the fertilizer needs at planting and as the crop nears harvest.

24. Explain the management option for early blight on tomatoes. Will a fungicide stop the disease when leaves have turned yellow late summer?

25. Why will vine crops bloom but not set fruit?

26. When should beans be planted?

27. Beans have a higher water use than other vegetables. What happens when they get a little dry? How can you tell when bean plants need irrigation?

28. Explain the growing techniques for quality cole crops.

29. *Bacillus thuringiensis*, *Bt*, is the standard biological control approach for worms in cole crops. Describe the criteria in using *Bt*. (See fact sheet #5.556.)

30. What is isolation required in growing Super Sweet corn varieties?

31. Gardeners often list “poor quality” as the reason most don’t grow leafy vegetables. What are the keys to great quality lettuce, spinach, chard, and other leafy vegetables?

32. What cultural practices are needed to compensate for the onion family’s poor, inefficient root system?

33. What is the difference between English peas, snow or sugar peas, and snap peas?

34. Describe how to get potatoes off to a great start.

35. What are the different temperature requirements of hardy, semi-hardy, tender, and very tender vegetables?

36. How does a gardener know when to plant various crops?

37. In covering plants for frost protection, what is the heat source, i.e., where is the heat stored?

MASTER GARDENER
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CMG GardenNotes #711

Vegetable Gardens:
Soil Management and Fertilization

Outline:

In the garden, managing soils to improve ***tilth*** and garden ***fertilization*** are related but not necessarily the same process. For example, compost or manure may be added as a soil amendment to improve tilth; however, they may add nominal amount of plant nutrients. A manufactured fertilizer may be added to supplement soil fertility levels, but it will not improve a soil's tilth. For optimum yields and quality, gardeners need to pay attention to both soil management for improving tilth and soil fertilization.

> ***Tilth*** is a term related to the suitability of a soil to support plant growth. Technically speaking, tilth is "the physical condition of soil as related to its ease of tillage, fitness of seedbed, and impedance to seeding emergence and root penetration".

Soil Amendment or Fertilizer

The term ***soil amendment*** refers to any material mixed into a soil. By law, soil amendments make no legal claims about nutrient content or other helpful (or harmful) properties. Compost and manure are common soil amendments used to improve soil tilth. They may also supply nominal amounts of plant nutrients. Some of the nutrient effect seen from adding soil amendments is likely due to their effect on soil microorganisms. The organic material in soil amendments is a food source that allows microorganisms to multiply. The larger numbers increase the conversion of nutrients in the soil to plant usable forms.

Mulch refers to a material placed on the soil surface.

By law, the term ***fertilizer*** refers to a material that guarantees a minimum percentage of nutrients of nitrogen, phosphate, and potash. An ***organic fertilizer*** is derived from natural sources and guarantees the minimum percentages of nitrogen, phosphate, and potash.

Soil Amendments

In the vegetable garden, the routine addition of organic soil amendments such as compost will optimize potential yields and quality. The goal in soil management is to increase the organic content to 4-5%, over a period of years.

Common amendments include compost, manure, compost made with manure, fall leaves, straw, and peat moss. Home compost has the advantage that the gardener controls what goes into the compost, reducing problems with salts, weed seeds, and plant diseases.

In climates with long growing seasons, another method to add organic matter is to grow green manure crops in between the vegetable growing season. In some areas, this would be a winter crop, in hot areas of the south this would be a summer heat crop. In areas like Colorado, where the entire growing season is used for vegetable production, a green manure is less practical. For additional information, refer to *CMG GardenNotes* #244, **Cover Crops and Green Manure Crops**.

How Organic Amendments Improve the Soil

On clayey soil, organic matter (over a period of years) glues the tiny soil particles together into larger aggregates, increasing pore space. This increases soil oxygen levels and improves soil drainage, which in-turn increases the rooting depth thereby allowing roots to reach a larger supply of water and nutrients.

On sandy soils, organic matter holds over ten times more water and nutrients than sand.

Organic matter also encourages the beneficial activity of soil organisms and helps remediate soil compaction.

Application

General application rates for compost or other organic soil amendments are based on the salt content of the materials and soil and on the depth to which it is cultivated into the soil. Ideally, cultivate the soil amendment into the top six to eight inches of the soil. On compacted/clayey soils, anything less can lead to a shallow rooting system with reduced plant growth, lower vigor, and lower stress tolerance.

Table 1 gives the standard application rate for compost. Compost made solely from plant residues (leaves and other yard wastes) is basically free of salt problems, and higher application rates are safe.

Compost, which includes manure or biosolids as a component, has a potential for high salt. Excessive salt levels are common in many commercially available products sold in Colorado. In compost made with manure or biosolids, the application rate is limited unless a soil test on that batch of product shows a low salt level. An amendment with up to 10 dS/m (10 mmhos/cm) total salt is acceptable if incorporated six to eight inches deep in a low-salt garden soil (less than 1 dS/m or 1 mmhos/cm). Any amendment with a salt level above 10 dS/m (10 mmhos/cm) is questionable.

> Note: dS/m or mmhos/cm is the unit used to measure salt content. It measures the electrical conductivity of the soil.

Table 1. Routine Application Rates for Compost

Site	**Incorporation Depth**[2]	**Depth of Compost Before iIncorporation**[1]	
		Plant Base Compost and other compost known to be low in salts[3]	**Compost Made with Manure or Biosolids** for which the salt content is unknown[4]
One-time application—such as lawn area	6-8 inches	2-3 inches	1 inch
	3-4 inches	1-1½ inches	½ inch
Annual application to vegetable and flower gardens – **first three years**	6-8 inches	2-3 inches	1 inch
	3-4 inches	1-1½ inches	½ inch
Annual application to vegetable and flower gardens – **fourth year and beyond**	6-8 inches	1-2 inches	1 inch
	3-4 inches	1 inch	½ inch

1 3 cubic yards (67 bushels) covers 1,000 square feet approximately 1 inch deep.

2 Cultivate compost into the top 6-8 inches of the soil. On compacted/clayey soils, anything less may result in a shallow rooting depth predisposing plants to reduced growth, low vigor and low stress tolerance. The 3-4” inch depth is shown as an illustration of how application rates need to adjust when the deep cultivate is not practiced.

3 Plant based composts are derived solely from plant materials (leaves, grass clippings, wood chips and other wards wastes). Use this application rate also for other compost known, by soil test, to be low in salts.

4 Use this application rate for any compost made with manure or biosolids unless the salt content is known, by soil test, to be low. Excessive salts are common in many commercially available products sold in Colorado. Based on soil tests of commercially available compost, this application rate may be too high for products extremely high in salts.

Compost needs to be thoroughly mixed into the upper six to eight inches of the soil profile. Do not leave compost in chunks, as this will interfere with root growth and soil water movement.

As the soil’s organic content builds in a garden, the application rate should be reduced to prevent ground water contamination issues. A soil test is suggested every four to six years to establish a base line on soil organic matter content.

If using a green manure cover crop, till the cover crop in before it reaches four inches in height.

In the vegetable garden, do not plow in woody materials such as bark or wood chips. They may interfere with seedbed preparation and may result in soil nitrogen depletion.

Precautions When Using Compost and Manure

Manure, compost made from manure, and bio-solids may be high in salts that will interfere with crop growth. Do not add more than one inch per season without conducting a soil test to evaluate potential salt build-up.

Due to a health issue (*E coli* contamination), fresh manure additions should be made at least four months prior to the harvest of any edible crops. In other words, apply fresh manure only in the fall after crops are harvested.

Fresh manure or unfinished compost products may be high in ammonia. Avoid application of products with an ammonia smell; they could burn roots and leaves. Manure and compost may be source of weed seeds.

Nutrient Release Rates from Compost and Manure

Gardeners need to understand that the nutrient release from compost and manure is slow, taking years. Adding compost or manure to improve soil tilth is not the same as fertilizing.

The typical nitrogen release rates from manure is only 30 to 50% the first year (fresh manure), 15 to 25% the second year, 7 to 12% the third year, 3 to 6% the fourth year, and so on. With compost and composted manure, the release rate is even slower, 5 to 25% the first year, 3 to 12% the second year and 1 to 6% the third year.

Because the nitrogen percentage of compost and manure products is typically only 2 to 4%, the amount of actual nitrogen release to support crop growth is very small.

For soil with 4 to 5% organic matter, the mineralization (release) of nitrogen from soil organic matter will likely be sufficient for crop growth.

For soils with 2 to 3% organic matter, the mineralization of nitrogen from soil organic matter will not likely be sufficient for heavy feeding vegetable crops. Supplement with 0.1 pound nitrogen fertilizer per 100 square feet.

For the typical garden soil with 1% organic matter or less, the mineralization of nitrogen for soil organic matter will be minimal. Add 0.2 pounds of nitrogen fertilizer per 100 square feet.

Fertilization

Soil fertilization is the addition of soil nutrients to support crop growth. While some soil amendments add small amounts of nutrients, amending the soil to improve soil tilth is not the same as amending the soil to provide nutrients.

Manufactured fertilizers are popular with gardeners because they are readily available, inexpensive, easy to apply, and generally provide a quick release of nutrients for plant growth. Application rates for any fertilizer depend on the content and the amount of nutrient to be applied. **In products containing multiple nutrients, the application rate is always based on the nitrogen content.**

Nitrogen Applications

Nitrogen is the nutrient needed in largest quantities by plants and the one most frequently applied as fertilizer. It is annually applied in the form of manufactured fertilizer, organic fertilizers, and/or organic soil amendments. **Application rates are critical, because too much or too little directly affects crop growth**.

The standard annual application rate for home vegetable gardens is 2 pounds actual nitrogen per 1,000 square feet (0.2 pound actual nitrogen per 100 square feet). When organic matter is supplied, adjust the rate accordingly to account for nitrogen released by the organic matter. [Table 2]

Table 2. Standard Nitrogen Fertilizer Application Rates for Gardens

	Soil Organic Content		
	Typical garden soil low in organic matter (<2% organic matter)	Moderate level of organic matter (2-3% organic matter)	High level of organic matter (4-5% organic matter)
Nitrogen needed	**0.2 lb. actual N per 100 sq. ft.**	**0.1 lb actual N per 100 sq. ft**	**0**
Fertilizer examples			
Ammonium sulfate 21-0-0	1 lb. fertilizer per 100 sq. ft (approx. 2 cups)	0.5 lb. fertilizer per 100 sq. ft (approx. 1 cup)	0
OR			
Ammonium nitrate 34-0-0	0.6 lb. fertilizer per 100 sq. ft. (approx. 1 1/3 cups)	0.3 lb. fertilizer per 100 sq. ft (approx. 2/3 cup)	0
OR			
Urea, 45-0-0	0.4 lb. fertilizer per 100 sq. ft. (approx. 1 cup)	0.2 lb. fertilizer per 100 sq. ft (approx. ½ cup)	0

Manufactured nitrogen fertilizer can be broadcast and watered in, or broadcast and tilled into the top few inches of soil. It can be banded 3-4” to the side of the seed or plant row. Do not place the fertilizer in the seed row or root injury will occur. Some soluble types are applied in the irrigation water. “Organic” nitrogen fertilizers are typically tilled in or some can be applied in irrigation water.

Starters Fertilizers

In setting out transplants, starter solutions often promote early growth. Because transplants have been hardened-off (growth slowed to prepare the plant for movement to the exposed, windy, outdoor environment), the nitrogen in the starter solution gives the signal to resume active growth. Because phosphorus is less available in cold soils, phosphate may also be helpful in spring and before soils have thoroughly warmed.

A starter fertilizer is any water-soluble fertilizer added to the irrigation water. Common examples include MiracleGro, Peters, Schultz Plant Food, Fertilome Root Simulator, and Plant Starter Solution, etc. They generally contain ammonium nitrate since it is readily usable by the plant. Some products claim that vitamins or hormones promote plant growth. These claims are not supported by research findings.

Nitrogen “Side Dressing”

Plant need for nitrogen varies. Beans, peas, tomatoes, and vine crops (cucumbers, squash, pumpkins, and melons) are examples of vegetables with a lower need for nitrogen. High nitrogen promotes excessive growth of the plant at the expense of fruiting.

Crops such as potatoes, corn, and cole crops (broccoli, cauliflower, cabbage, and kale) use large amounts of nitrogen and need supplemental applications during the growing season (referred to as ***side dressing***). For example, home garden potatoes often show nitrogen deficiency from August into fall. Symptoms start as a yellowing of lower leaves and progress into a general browning and dieback of the vine. When nitrogen stress hits, potatoes become more susceptible to diseases, including early blight and Verticillium wilt. [Table 3]

Fertilizers commonly used in the home garden for side dressing include ammonium sulfate, ammonium nitrate, and water-soluble fertilizers such as MiracleGro, Peters, etc. Phosphate and potash fertilizers are best added in the spring or fall, when they can be cultivated into the soil.

Table 3. Nitrogen Side Dressing of Vegetable Crops

Vegetable	Timing	Application Rate (Based on rate of 0.1 lbs. actual N per 100 square feet)		
		Ammonium sulfate 21-0-0	Ammonium nitrate 34-0-0	Water soluble fertilizers
Asparagus	1) Early spring 2) At end of harvest season	0.5 lbs. fertilizer per 100 sq. ft. (approximately 1 cup) Sprinkle over soil and water in, OR place in furrow to side of plant. CAUTION: an over application will burn roots, stunting or killing plants.	0.3 lbs. fertilizer per 100 sq. ft. (approximately 2/3 cup) Sprinkle over soil and water in, OR place in furrow to side of plant. CAUTION: an over application will burn roots, stunting or killing plants.	See label of specific product. Water soil with fertilizer added to water. Low burn potential, but significantly more expensive.
Sweet Corn	1) 12 inches tall 2) One month later			
Leafy green vegetables	3-4 weeks after emergence			
Onions	3-4 weeks after emergence			
Potatoes	Late-July to early-August			
Tomatoes, peppers, and eggplants	First fruits 1" diameter			
Cole crops (broccoli, cabbage, cauliflower)	1) 2-3 weeks after transplanting 2) 4-5 weeks after transplanting			See label for specific product.

Phosphorus and Potassium Applications

A soil test is the best method to determine the need for phosphate and potash. With a fertilizer containing nitrogen and phosphate and/or potash, the application rate is always based on the nitrogen percentage because nitrogen is most critical to plant growth.

Phosphate and potash fertilizers are best applied in the spring or fall, when they can be tilled into the soil

Phosphorus

Phosphorus levels are adequate in the majority of established Colorado soils. Deficiencies are most likely to occur in new gardens where the organic matter content is low and in soils with a high pH (7.8 to 8.3). Excessive phosphorus fertilizer can aggravate iron and zinc deficiencies and increase soil salt content.

Routine application of compost or manure will supply the phosphorus needs in most Western soils.

Where phosphorus levels are believed to be low, the standard application rate without a soil test is ¼ to 1-pound triple super phosphate (0-46-0) or ammonium phosphate (18-46-0) per 100 square feet.

Potassium

Potassium levels are naturally adequate to high in most Colorado soils. Deficiencies occasionally occur in new gardens low in organic matter and in sandy soils low in organic matter. Excessive potash fertilizer can increase soil salt content.

Routine applications of compost or manure will supply the potassium needs for most Western soils.

Where potash levels are believed to be low, the standard application rate without a soil test is ¼ to ½ pound potassium chloride (0-0-60) or potassium sulfate (0-0-50) per 100 square feet.

Managing Soil Compaction

On clayey soils, soil compaction is a common problem limiting crop growth potential. Soils are typically compacted in the construction process. Walking on wet soils, cultivating wet soils, and the impact of rain are other common forces compacting soils.

The following are suggested to help minimize soil compaction in the garden:

- Add organic matter to clayey soils.
- Avoid cultivating or working a clayey soil when wet. To evaluate, squeeze a handful of soil. Then try to crumble it. If it will crumble, it can be worked. If it will not crumble but stays in mud balls, it is too wet to be worked.
- Avoid cultivating other than to prepare a seed bed or till in organic matter and fertilizers. For weed control, use a mulch, hand removal, or shallow cultivation only.
- Use a raised bed with established walkways, and avoid walking on the growing bed.
- Mulch the soil, year round, to minimize the compaction forces of rain and sprinkler irrigation. Winter rains on bare soil are a major compaction force. This also helps manage weeds and reduces irrigation need.

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CMG GardenNotes #712

Sample Vegetable Garden Seed Catalogs

Baker Creek Heirloom Seed
2278 Baker Creek Rd.
Mansfield, MO 65704
417-924-8917
www.rareseeds.com

Burpee Seed
300 Park Ave.
Warminster, PA 18974
800-888-1447
www.burpee.com

Gurney Seed
110 Capital St
Yankton, SD 57079
513-354-1492
www.gurneys.com

Harris Seed
P.O. Box 24966
Rochester, NY 14624
800-544-7938
www.harrisseeds.com

Irish-Eyes
Garden Seed
5045 Robinson Canyon Rd.
Ellensburg, WA 98926
509-933-7150
www.irisheyesgardenseeds.com

Johnny's Selected Seeds
955 Benton Ave
Winslow, Maine 04901
1-877-564-6697
www.johnnyseeds.com

Jung Seed
335 S High St
Randolph, WI 53956
800-247-5864
www.jungseed.com

Park Seed
3507 Cokesbury Road
Hodges, S.C. 29653
800-845-3369
www.parkseed.com

Stokes Seed
Box 548
Buffalo, NY 14240-0548
800-396-9238
www.stokeseeds.com

Territorial Seed
PO Box 158
Cottage Grove, OR 97424
800-626-0866
www.territorialseed.com

Twilley Seed
121 Gary Road
Hodges, SC 29653
800-622-7333
www.twilleyseed.com

Tomato Growers Supply
PO Box 60015
Ft. Meyers, FL 33906
888-478-7333
www.tomatogrowers.com

- *CMG GardenNotes* are available online at www.cmg.colostate.edu.
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.
- Extension programs are available to all without discrimination.
- No endorsement of products mentioned is intended nor is criticism implied of products not mentioned.

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GMG GardenNotes #713

Block Style Layout in Raised Bed Vegetable Gardens

Block Style Garden Layout

Block style garden layout (also called ***close-row*** or ***wide-row*** plantings) ***increase*** yields five fold compared to the traditional row-style garden layout, and 15-fold for the smaller kitchen garden vegetables. The compact design reduces weeding and is ideal for raised bed gardening.

The basic technique used in close-row, block planting is to eliminate unnecessary walkways by planting vegetables in rectangular-shaped beds or blocks instead of long single rows. For example, plant a block of carrots next to a block of beets, followed with a block of lettuce and so forth down the bed area.

Plant crops with an equal-distance space between neighboring plants in both directions. For example, space a carrot patch on 3-inch by 3-inch centers. It may be easier to visualize this plant layout as running rows spaced 3 inches apart across the bed, and thinning the carrots within the row to 3 inches. A 24-foot long "traditional" row of carrots will fit into a 3 foot by 2-foot bed. [Figure 1]

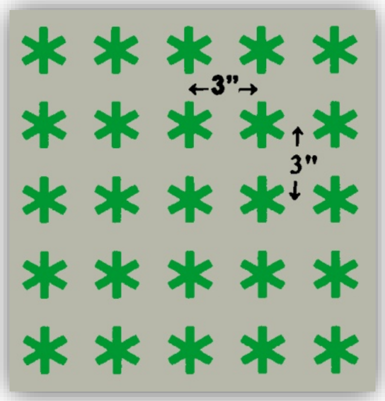

Figure 1. Carrots planted on 3-inch centers

Design the planting beds to be 3 to 4 feet wide and any desired length. This width makes it easy to reach into the growing bed from walkways for planting, weeding and harvesting.

Limiting foot traffic to the established walkways between planting beds reduces soil compaction. Design walkways to 18-24 inches wide. Mulch walkways with dry grass clippings, wood chips, or other organic mulch.

As the vegetable foliage grows together, the shade cast suppresses weed germination.

After harvesting a row of radishes, beets, lettuce, or spinach, replant for continual summer production.

Due to the higher plant density, block plantings require a weed-free, fertile, well-drained soil that is rich in organic matter. Give extra attention to watering and frequent, light fertilization to nourish the dense plant population. Avoid over-crowding vegetables; the reduced air circulation can increase disease problems.

Figure 2. Kitchen garden in block-style layout with (top to bottom) spinach, assorted lettuce varieties) and Swiss chard. Note that rows run across the four-foot wide bed. As a row of lettuce is harvested, it is replanted for continual production or neighboring crops fills in the space.

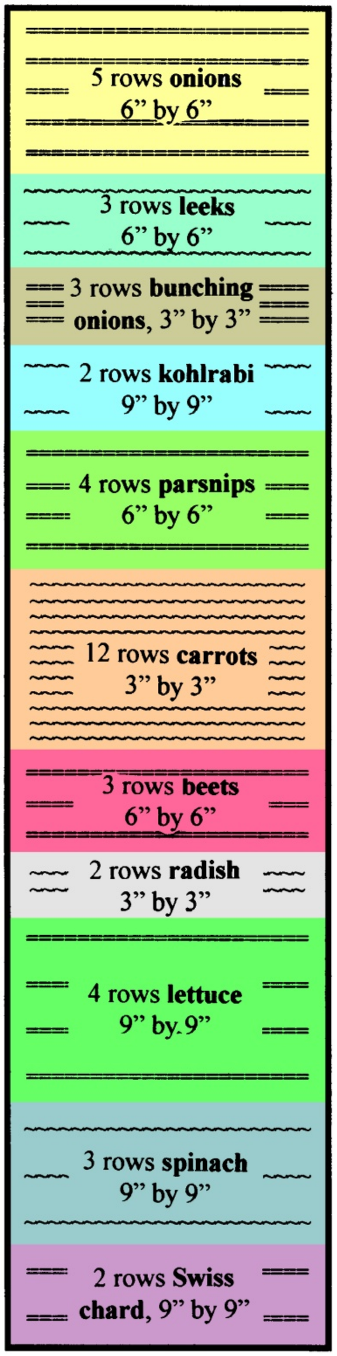

Figure 3. Sample layout of kitchen garden vegetables.

Suggested Spacing

Suggested spacing for kitchen garden vegetables: (Start with the wider spacings, reducing spacing with experience and as soil improves in fertility and tilth.)

- Beets: 4-6” by 4-6"
- Carrots: 2-3" by 2-3"
- Celery: 7-9" by 7-9"
- Garlic: 4-6” by 4-6"
- Kohlrabi: 7-9" by 7-9"
- Leeks: 4-6” by 4-6"
- Lettuce, head: l0-l2” by 10-12"
- Lettuce, leaf: 7-9" by 7-9"
- Onions, bunching” 2-3" by 2-3"
- Onions, dry: 4-6" by 4-6”
- Parsnips: 5-6” by 5-6"
- Radishes: 2-3" by 2-3"
- Spinach: 4-6” by 4-6”
- Swiss chard: 7-9” by 7-9”
- Turnips: 4-6”by 4-6"

Other vegetables suited to block planting

Cole crops (broccoli, cabbage, Brussels sprouts and cauliflower) – Spaced at 18 by 18-inches', or three plants across a 4-foot bed.

Corn – Always plant in a block to facilitate pollination. Five rows wide is recommended for the best “pollen shower" to maximize kernel set; three rows wide is minimum. Space at 12” by 24” or four rows across two, four-foot wide beds.

Eggplant – Space at 18-24 by 18-24 inches (or two or three plants across a four-foot wide bed).

Peppers – Space at 15 by 15 inches (or three plants across a four-foot wide bed).

Potatoes – Space at 12-15 by 12-15 inches (or three plants across a four-foot wide box).

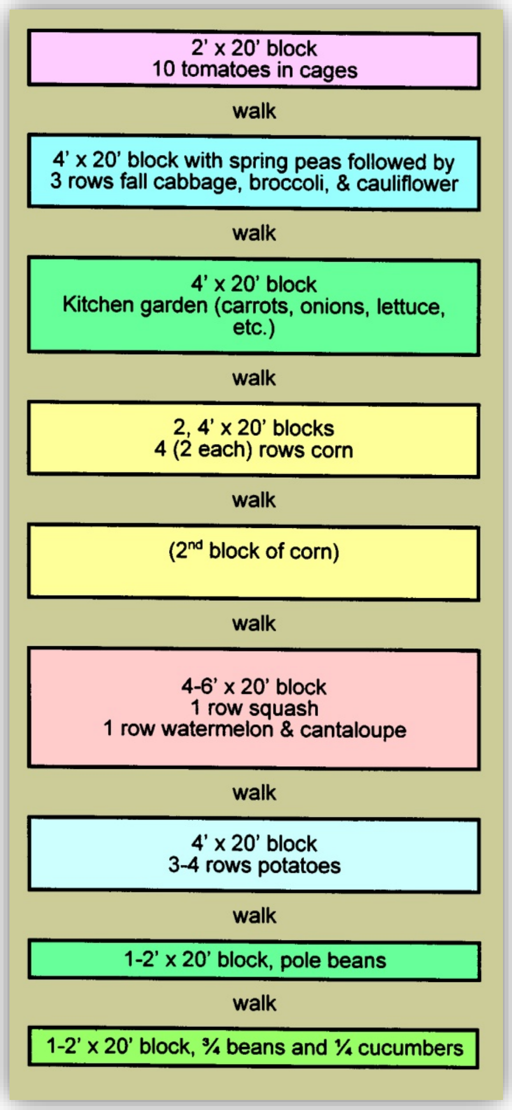

Figure 4. Sample block-style garden

Vine crops (squash, cantaloupes, pumpkins, and watermelons) – Place a single row down the center of a 4-foot wide box. They may also be planted in larger blocks, several rows wide. Place the winter squash and pumpkins in the center of the block and cantaloupes, watermelons, and summer squash around the edge where they can be reached for summer harvest.

Trellis tomatoes and cucumbers to save space and make harvest easier. The increased air circulation around trellised tomatoes helps suppress tomato blight. Space trellised tomatoes a minimum of 24 inches apart down a single row, in a block two to three feet wide. Plant cucumbers along a trellis at 9-12 inch spacings.

Beans and peas may be easier to pick and are less disease-prone if planted in single or double rows, rather than block style planting. Space beans 12 inches between rows and 4 inches between plants. Plant a double row down a block 2 to 3 feet wide.

Figure 5. Raised bed garden with chard, lettuce varieties, spinach, beets, and onions. Because even water distribution is needed for this bed with a heavy plant population, the drip irrigation hose is run up and down the bed four times on a 12 inches spacing. The bed will be mulched with dry grass clippings to conserve water and control weeds in summer. Wood chips make an excellent mulching material for the walkways.

Raised Bed Gardening

Raised bed gardens with block style layout have many advantages, including the following:

Higher yields and less area to weed – The block style layout, eliminating unnecessary walkways increases yields by five-fold over the traditional row-path-row garden layout.

Reduced soil compaction – Established walkways keep foot traffic off the growing bed, reducing soil compaction.

Earlier planting – The raised bed facilitates better runoff and drainage allowing soil to warm faster in the spring. Beds can be covered with plastic during spring rains, allowing for early planting even in rainy years.

Frost protection – The block-style layout is easy to cover for spring and fall frost protection. It can also be shaded in the hot summer.

Soil improvement – The raised bed is a clearly defined area where the gardener can concentrate on soil improvement techniques, (e.g., the addition of soil organic matter). In situations where the soil is poor, and limits plant growth, good planting soil may be added to the box.

Architectural interest – Raised beds become an architectural feature of the landscape design.

Accessible gardening – The raised bed is ideal for enabling persons with limited mobility to garden.

Constructing a Raised Bed Garden

Size – A bed 4 feet wide is ideal for most vegetable crops, allowing the gardener to reach the entire bed from the side without ever stepping on the soil in the growing bed. Length can be whatever works for the space.

Tomatoes are well suited to a bed 24 to 36 inches wide, with one row of plants down the middle. Beans and peas are easier to pick in a single or double row down a bed rather than in the block-style planting. Here a bed 24 inches wide would be ideal.

Depth / Height – The height of the beds is generally of no consequence, assuming that crops can root down into the soil below the bed. For most home garden situations, the role of a raised bed is to define and separate the growing bed from the walkway. Here a four-inch height would be adequate. Variations in heights (4”, 6”, 8”, and 10”) among different beds may help create an appealing landscape feature.

In situations where the soil below is not suitable for crop growth, 8 to 12 inches of soil is considered minimal. Deeper beds would make management easier.

To accommodate gardeners with special needs, bed height may be raised to minimize bending or to allow gardening work from a chair or wheelchair. Plan walkway space between beds wide enough to accommodate specialized equipment or mobility.

For ease of irrigation, beds should be reasonably level, both across and lengthwise.

Orientation – For frost protection, an east-west orientation has a slight advantage of collecting heat. For summer crop growth, a north-south orientation has a slight advantage of sunlight on both sides of the plant row each day. Because there is no clear advantage, orient the beds in whatever direction work best for the landscape design. Often beds are best arranged to be an appealing landscape feature of the property.

Construction materials – A simple way to construct a raised bed garden is to use construction lumber (2 by 4s, 2 by 6s, 2 by 8s, and 2 by 10s). Untreated lumber will last for several years, except in high salt areas or wet sites. Treated lumber will last longer. Simply cut two pieces the width of the bed (typically 4 feet) and two others to the desired bed length. Using 3½ to 4 inch decking screws, screw the corners together to make a four-sided box. Place the box-like frame on the soil and fill.

Various landscaping timbers may also be used in like fashion. Cooper treated lumber is safe for garden boxes. However, do not use railroad ties (creosote cancer concerns) or CCA pressure treated lumber (removed from the market several years ago due to arsenic concerns). Brick or other building materials may also be suitable.

Raised beds may also be made without sides. Here, organic matter is mixed as the garden is tilled. Walkways are dug down with the soil thrown up on the bed. Beds are 4 feet wide at the base and three feet wide at the top. The entire bed is covered with organic mulch like dry grass clippings to prevent soil erosion and reduce compaction from rain and sprinkler irrigation. [Figure 6]

Figure 6. Raised bed garden without sides. Beds are 4 feet wide at the base and t3 feet wide at the top. Walks were dug down with soil placed on the beds.

Adding soil – In the typical garden setting where crop roots will spread down into the soil below the bed, it is best to use similar soils. It may be beneficial to double-dig the beds. In ***double-digging***, the top 6 inches of soil is moved from one side of the bed to the other side of the bed. Mix organic matter into the soil below the excavated side. Return the soil to the top, mixing in organic matter. Then repeat the process for the other side of the bed.

When adding soil, avoid creating a situation where one type of soil ends and another begins. This creates a line between soil types that impedes water and air infiltration and slows, or even stops, root penetration. If the soil being added to the bed is different from the soil below, mix some of the two together before adding the remainder to avoid a distinct line of change.

In situations where the entire rooting zone will be in the raised bed, a soil on the sandy side with 4-5% organic matter would be preferred.

When purchasing soil, be aware that there is no legal definition of topsoil or planting soil. Just because it is commercially available in bulk or sold in bags, does not necessarily mean that it is good for gardening. Many bagged and bulk soils and soil amendments are prepared with compost made with manure and may be high in salts.

Figure 7. A recently planted raised bed garden. Corn boxes to left, kitchen garden in center, strawberry patch on right, tomato patch in back with black plastic mulch. Growing beds are mulched with grass clippings; wood chips were used between beds.

Gardening in a Raised Bed

Due to the high plant population, raised beds require better than average soils, and more frequent irrigation and fertilization. Concentrate on improving soils with routine applications of organic matter. For details on soil improvement and fertilization, refer to the various *CMG GardenNotes* #711, **Vegetable Garden: Soil Management and Fertilization**.

Mulching – Mulch beds to control weeds, conserve soil moisture, and regulate soil temperatures. Grass clippings make great mulch when applied in thin layers (up to ¼ inches thick). Allow each layer to dry between applications. Do not use clippings from lawns treated with weed killers or other pesticides for at least four weeks after application. Wood/bark chips are great for mulching between the beds. Three to four inches of chips will minimize the compaction forces of foot traffic. However, do NOT mix wood/bark chips into the growing bed, it will interfere with seedbed preparation. For additional information on mulching, refer the to the *CMG GardenNotes* #715, **Mulches for the Vegetable Garden**.

Watering a raised bed – Drip irrigation is well suited to raised bed gardening. It is rather easy and inexpensive to add a water tap at the end of each box. Alternatively, simply move a garden hose in turn to each box and connect the drip hose. Sprinkler irrigation is also suitable, but less desirable due to potential disease problems. For details on irrigation, refer the *CMG GardenNotes* #714, **Irrigating the Vegetable Garden**.

As a point of clarification, raised bed gardening is a water conservation technique. It does require more frequent irrigation due to the higher plant density. However, it is more efficient resulting in higher yields for the amount of water applied compared to the larger areas watered in traditional row-walkway-row culture. Raised beds become even more efficient when watered with drip irrigation or soaker hoses on timers.

Frost protection – An advantage of raised bed, block style layout is that the bed is easy to cover for protection from springs rains and frost, allowing for early planting.

Figure 8. Frost protection covering adds two to six plus weeks to the growing season.

This picture illustrates a Quonset-type cold frame covering made of concrete reinforcing mesh covered with plastic. This style of frost protection adds two to six plus weeks on both ends of the growing season for cool season vegetables. Any type of covering must be opened during the day to prevent overheating.

Authors: David Whiting (CSU Extension, retired), Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Artwork by David Whiting; used by permission.

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MASTER GARDENER
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CMG GardenNotes #714

Irrigating the Vegetable Garden

Outline:

Garden Irrigation

In vegetable production, an adequate supply of water during the growing season is directly related to produce quality and yields. Many vegetables become strong-flavored or stringy with water stress.

Several gardening techniques (including soil preparation, mulching, and efficient irrigation) help conserve water in the vegetable garden.

As a rule of thumb, vegetables use around ¼ inch of water per day during typical summer weather. If the garden is watered every four days, apply one inch of water per irrigation. Hot, windy weather will increase water demand significantly. Beans and corn will be significantly higher in water demand during blooming or tasseling/silking.

Checking Soil Moisture Content

Check soil moisture regularly. Irrigate when the top two to four inches of soil is dry to the touch. This is especially important if using mulch, where surface evaporation is reduced.

Evaluating when the soil needs irrigation is rather subjective. The "stick" method (judging moisture by the relative easy or difficulty of pushing a stick or screwdriver into the soil) is an old farmer's standard. It will be easier when wet than when dry. However, this very subjective method is specific to soil types and can be misleading to the novice. On compacted clayey soils, it may be somewhat difficult when moist and very difficult when dry. On sandy soils, it may be somewhat easy wet or dry.

To check moisture levels, a soil probe is a useful tool to pull up soil samples from the rooting zone at a six to eight inch depth. A small garden spade could be used.

Houseplant watering meters are helpful in evaluating the soil moisture content under mulch. Realize however, that these inexpensive meters are somewhat inaccurate. If the fertility level is high, the meter will read on the wet side. If the fertility is low, the meter will read on the dry side. Learn to interpret the meter reading for a specific soil by trial and error. [Figure 1]

Figure 1. Although somewhat inaccurate, a houseplant water meter is a tool to evaluate water needs in the garden.

Automate the System with Controllers

Sprinkler or drip systems can be easily automated with a multi-zone controller like the lawn. A small garden could be connected to the lawn's controller as a separate zone and run on a different program. However, do not have the lawn and vegetable garden on the same zone, as water needs are not the same.

Single zone controllers connect to the garden hose. Some simple models are manually turned on and automatically turn off after the set number of minutes or gallons. More elaborate battery operated models turn the water on and off at the day and time interval set by the gardener. [Figure 2]

Figure 2. Single zone controllers connect to the hose line. Left: This style is manually turned on and automatically turns off the water flow after the set number of minutes. Right: This battery powered controller turns water on and off at the day and time intervals set by the gardener.

Furrow Irrigation

For gardeners who have irrigation water from a ditch, furrow irrigation in the traditional row-style garden layout may be most practical. As a rule of thumb, adjust water flow for the furrow so that the water reaches the end of the row 1/3 of the time into the irrigation period. For example, if the irrigation period is 15 minutes, the water should reach the end of the row in five minutes. Soil erosion and runoff are major disadvantages of furrow irrigation.

Sprinkler Irrigation

Sprinkler irrigation is considered more efficient in water delivery than furrow irrigation. It is easy to measure the amount of water applied and easy to manage. Because it wets the entire soil surface, weed seed germination may be high.

Sprinkler irrigation is discouraged on vegetables prone to foliar diseases such as Early Blight (tomatoes, peppers, and potatoes). The splashing water spreads disease organisms and water on the leaves creates favorable conditions for disease development. Tall crops, such as corn and pole beans may interfere with water delivery patterns.

As a rule of thumb, vegetables use around ¼ inch of water per day, depending on temperature, wind, and stage of crop development. For example, if the garden is watered every four days, apply one inch of water per irrigation. The gardener can quickly learn how long to run the sprinklers by measuring the amount of water in several straight-sided cans placed around the garden.

Delivery rates depend on the type of sprinkler heads used, pressure, and the spacing of heads in the garden. For example, pop-up spray heads deliver around 1½ inches per hour and would typically run 40 minutes to apply 1-inch of water. Rotor type heads deliver around 1/2 inch per hour and would typically run for 120 minutes to apply 1-inch of water.

Because the water needs of the vegetable garden are different from a lawn, it should be on a different irrigation zone than the lawn. Water use will be low in the spring when crops are small and temperature are cool and will increase as the temperatures rise and crops come into bloom.

Drip Irrigation

Drip irrigation is well suited for the block-style garden layout and raised beds. Several different types of drip systems are available including:

- **In-line drip tubing** – Emitters are found in the tubing every 6, 12, or 24 inches; 12 inches is most common in the home garden trade.
- **Soaker hose** and **soaker tubing** – Emits water along the entire length of the hose.
- **Bubblers** and **drippers** – Emitter or drippers are placed to water individual plants.

A disadvantage of a drip system is that they require relatively clean water. Systems readily plug with dirt, algae, or salts in the water. This is generally not a problem when using drinking quality municipal water supplies. Depending on water quality, drip irrigation may not practical for many non-potable water sources. The filtering system required may be expensive and high maintenance.

Ideally, an in-line drip hose or soaker hose is placed on the soil surface under the mulch. The soaker hose may also be buried a couple of inches into the soil to protect the hose from breakdown by sunlight.

On a raised-bed box, space the drip line/soaker hose at 12-inch spacing. A four-foot wide box would have four runs of the drip line/soaker hose up and down the box (as illustrated in Figure 1). For larger vegetables like corn, squash, and cole crops (three plants across a four-foot wide bed) make three runs up and down a four-foot wide box. On a two-foot wide raised bed box for tomatoes or beans, the drip line/soaker hose runs down and back. [Figure 3]

Figure 3. On this four-foot wide box, the drip line or soaker hose makes four runs up and down the box at 12-inch spacing. Carrot rows are running across the box.

Drip systems are designed to run on low pressure. High pressure may split the hose and pop connections. The desired low pressure is easy to achieve with pressure regulators that have hose-end fitting (found with the drip system supplies). If the garden has changing elevations, a pressure regulator will be needed for every couple of feet change in elevation. [Figure 4]

Figure 4. With irrigation pipe, it is easy to plumb a tap at each raised bed box. Here a pressure regulator with hose-end fittings reduces pressure to 25 psi. It is connected to a ½-inch soaker hose.

Determine the run time by examining the soil moisture content. Run time will vary with the brand of hose, water pressure, and spacing.

Soaker Hose and Soaker Tube

The soaker hose and soaker tube type of drip system allows water to seep out the entire length of the hose. It is easy to use in traditional row style or raised-bed gardens. [Figure 5]

Figure 5. Soaker hose seeps water out along the length of the hose.

It can be connected by manually connecting the garden hose to each line at each irrigation session or by connecting a series of dedicated garden hoses to a series of lines. On raised-bed gardening, it is easy to run a water line with a tap to each box. Several small boxes may run together on the same zone. [Figure 4]

For uniform water delivery, keep runs short, generally 25 feet or less. With long lengths, water delivery will be higher at the top of the hose line and less at the bottom. The ground must be reasonably level. On slopes, run several short lengths.

Several brands and styles are available in the home garden trade.

- **Half-Inch Soaker Hose** – Some brands (like *Swans Soaker Hose*) are a ½-inch hose that connects with standard hose fitting. These are found the garden hose section. It can be cut to any length and connected with garden hose fittings.

  A small plastic disc fits inside the female hose connection as a pressure regulator (actually a flow regulator). With the reduced water flow, it may need to run for around an hour to adequately water the garden. It works better to use the pressure regulators with hose-end fittings found with the drip irrigation supplies (figure 4). With this type of regulator, the drip line runs 10-20 minutes to adequately water the garden. Without a pressure regulator of some type, the soaker hose tends to rupture sending out steams of water at spots rather than dripping along the line.

  This half-inch hose style is more tolerant of small amounts of dirt, algae, or salts in the water than other types of drip systems, and may be successful on some nonpotable water sources. Periodically, open up the end of the hose and flush out soil deposits.

- **Quarter-inch Soaker Tubing –** A ¼ inch soaker tubing is availble in the drip irirgaiton section at garden stores. Cut the soaker tubing to desire length and connect with drip system components. An in-line pressure regulator (figure 4) is required; otherwise, the fitting may pop or leak.

  Because the soaker tubing has a higher delivery rate, it can not be on the same zone as other in-line drip hoses, button emitters, or bubblers.

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MASTER GARDENER
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CMG GardenNotes #715

Mulches for the Vegetable Garden

Benefits

The benefits of mulch depend on the material used and depth to which it is applied. In general, mulching minimizes evaporation of water from the soil surface, reducing irrigation need by around 50%. It helps stabilize soil moisture levels, thereby improving vegetable quality and encouraging the beneficial activity of soil organisms.

Mulching helps reduce soil compaction forces from rain and traffic. Some may later be plowed into the garden as a soil amendment, adding organic matter to the soil. Mulching may cool or warm soil temperatures. It may control weeds.

Grass Clippings

Grass clippings make excellent mulch for the vegetable garden. Apply fresh clippings in thin layers (up to 1/4 inch thick) and allow each layer to dry before adding more. The clippings quickly dry down and additional layers can be added weekly. A few layers will stop weed seed germination. Do not place fresh clippings in thick piles, as they will mat, reducing water and air infiltration, stink, and may become hydrophobic. Do not use clippings from lawns that have been treated with herbicides or other pesticides in the past month. [Figure 1]

Figure 1. Grass clippings being applied to garden directly from lawn mower bag. Apply only in thin layers, allowing the grass layers to dry between applications.

Around lettuce and other leafy vegetable, mulch by carefully hand placing the grass at the base of the plants. Grass sticks to wet lettuce, creating a problem in food preparation.

A couple of sheets of newspaper may be used under the clippings to help control weeds. The newspapers blow away with a light wind. It must be covered immediately with grass to hold it in place. It shuts out the light preventing seed germination. Do not apply newspapers more than a couple of sheets thick or a soil carbon to nitrogen imbalance may occur. Do not use glossy print materials; their inks may not be soy-based like newspapers. The grass and newspaper mulch may be cultivated into the soil in the fall adding small amounts of organic matter. [Figure 2]

Figure 2. Corn bed being mulched with newspapers (only a couple of sheets thick) covered with grass clippings.

Wood or Bark Chips

Do not use wood or bark chips in the growing beds since they will interfere with future seedbed preparation. It takes several years for chips to decompose in the soil.

In a raised-bed garden, wood or bark chips make excellent mulch between the boxes. Apply three to four inches deep to control weeds. At this depth, chips also prevent soil compaction from foot traffic, allowing crop roots to spread out under the walkways. [Figure 3]

When placed on the soil surface as mulch, wood/bark chips do not tie-up soil nitrogen. Does not use fine sawdust for mulch because it could create carbon to nitrogen imbalance.

Figure 3. Wood or bark chips make excellent mulch between raised-bed boxes.

Do NOT put wood or bark chips on the growing bed. The chips take years to breakdown and will interfere with seedbed preparation.

Black Plastic

Black or colored plastic mulch is extensively used in commercial tomato, pepper, and melon production in Colorado. It merits consideration for the tomato family (tomatoes, peppers, eggplant) and the vine crops (cucumbers, summer and winter squash, pumpkins, watermelons, cantaloupes and other melons). Because it warms the soil, it is undesirable for other crops.

Put the plastic on the growing bed early in the season to start the soil warming. **Crops must be planted early so plant growth shades the plastic before summer heat arrives.** Otherwise, the plastic can be too hot for crops and must be removed.

The plastic warms the soil allowing for earlier crop growth. Along the Colorado Front Range, crops average 2-3 weeks earlier production and produce higher yields. In cooler locations, crops could be three to over four weeks earlier in production.

The black plastic mulch also controls weeds and reduces the need for irrigation. Because there is no surface evaporation of water, it is easy to over-irrigate crops.

Applying plastic mulch

1. Prepare the soil and irrigation system. Drip irrigation with a soaker-type hose works well. Slightly mound the soil so the plastic makes direct contact with the ground.
2. Cover the growing bed with the plastic. Bury all edges two to four inches. On a raised-bed box made with lumber, staple the plastic on the <u>sides</u> of the box.
3. Cut holes to plant or transplant into. Do not cut “X’s”— the hot plastic touching tender plants can burn.

Figure 4. Tomatoes planted down a 30-inch wide raised-bed box. Plastic mulch is stapled to side of box. Plants are spaced at 24 inches in the center of 24-inch wide cages.

Figure 5. Trellised tomatoes in raised-bed box with black plastic mulch.

With plastic mulch, crops must be planted early so plant growth shades the plastic before summer heat arrives.

The plastic fluttering in the wind pumps air into the soil. However, covering the plastic with organic mulch like grass clippings or chips could reduce soil oxygen levels.

In the fall, do NOT plow in the plastic, rather remove and put it in the trash. Polyethylene plastic will never decompose in the soil. Because it breaks down with sunlight, it generally can be used only for a single season. Chemists are working on biodegradable plastics for horticultural uses. It will be a few years before they are available.

Some gardening magazines talk of colored plastics. For example, red plastic is reported to increase tomato yields in cloudy climates. It also makes the fruits softer in texture. With Colorado's high light intensity, color is insignificant.

Warming the soil for other crops – Plastic may also be used to warm the soil for other crops, being applied early and **removed prior to planting**. For maximum soil warming, clear plastic is most effective. However, it will also encourage weeds to grow under the warm, greenhouse-like covering.

Straw

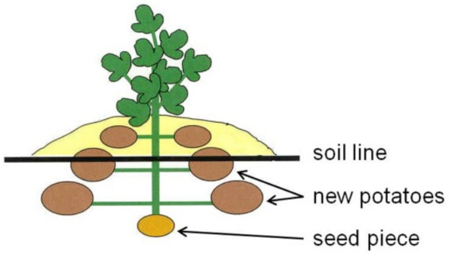
Weed free (seed free) straw makes excellent mulch for potatoes. When purchasing straw, look for certified weed (seed) free products. Otherwise, the potato patch may be thick with oats!

The straw protects tubers growing near the surface from sunlight, so the potato plants do not have to be mounded. (When a potato tuber is exposed to sunlight, it turns green, becoming mildly poisonous.) [Figure 6]

Certified weed (seed) free straw is also a good organic source for clayey soils. After using it as a summer mulch, thoroughly cultivate it into the soil as a soil amendment in the fall.

Figure 6. The new crop of potatoes grows above the seed piece.

To shield growing tubers from sunlight (which turns them green), soil is "hilled" (mounded) around the base of the plant. Straw mulch may be used as an alternative to hilling.



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CMG GardenNotes #716

Water Conservation in the Vegetable Garden

In vegetable production, an adequate supply of water during the growing season is directly related to produce quality and yields. Many vegetables become strong flavored with water stress. Unlike bluegrass and other landscape plants, vegetables cannot go dormant when the water supply is inadequate. However, there are several techniques that will significantly reduce the water requirements of the home vegetable garden.

Always follow efficient irrigation practices. The following practices will allow gardeners to have a productive vegetable garden and still reduce water consumption.

Water Conserving Techniques

Amend Garden Soil with Coarse, Decomposed Organic Matter

In the vegetable garden, the routine addition of organic soil amendments, such as compost, will optimize potential yield- and produce quality. The goal in soil management is to increase the organic content to 4-5%, over a period of years.

On sandy soils, organic matter holds over ten times more water and nutrients than the sand. On clayey soil, organic matter glues the tiny soil particles together into larger aggregates, increasing pore space. This process takes place over time. This increases soil oxygen levels and improves soil drainage, which in turn increases the rooting depth allowing roots to reach a larger supply of water and nutrients.

Organic matter also encourages the beneficial activity of soil organisms and helps remediate soil compaction

Manure and compost made from manure may be high in salts that will interfere with crop growth. The standard application rate for plant-based compost (free of salts) is two to three inches per year, cultivate into the soil six to eight inches deep. After a few years, the application rate should be cut back to avoid excessive soil salts, phosphorus, and potassium.

Manure and manure-based compost may be high in soil salts. The standard application rate is one-inch maximum per year, cultivated into the soil six to eight inches deep. Do not add more unless a soil test on the specific batch indicates low soil salt levels. Soil testing on many commercially available products available in Colorado markets found extremely high salt levels in some products. For high salt products, the one-inch application rate may be too high.

Be sure that the organic matter is thoroughly cultivated into the soil. Leaving chunks of organic matter will interfere with seeding, root spread, and water movement through the soil profile.

In the vegetable garden, do not plow in woody materials such as bark or wood chips, as they may interfere with seedbed preparation and may result in soil nitrogen depletion. Wood chips take several years to decompose in the soil.

Due to a health issue (*E coli* contamination), fresh manure additions should be made at least four months prior to the harvest of any edible crops. In other words, apply fresh manure only in the fall after crops are harvested.

Another method to add organic matter is to replant the fall garden with a green manure crop such as winter rye or Austrian peas. For details, refer to *CMG GardenNotes* #244, **Green Manure and Cover Crops.**

For additional details, refer to *CMG GardenNotes* #711, **Vegetable Garden: Soil Management and Fertilization**.

Reducing Water Need with Drip Irrigation and Mulching

Use of a drip system on a mulched garden reduces water need by around 50%.

Other Water Saving Techniques

Plant in blocks, rather than rows. This creates shade for roots and reduces evaporation. For details, refer to the *CMG GardenNotes* #713, **Block Style Layout in a Raised Bed Garden**.

Control weeds that compete with vegetables for water.

Group plants with similar water needs in the same section of the garden for easy irrigation. Cucumber, zucchinis, and squash, for example, require similar water applications.

Protect plants and soil from wind with windbreaks to reduce evaporation.

Critical Water Periods for Vegetables

You can target the timing and amount of water to add. As a rule of thumb, water is most critical during seed germination, the first few weeks of development, immediately after transplanting, and during flowering and fruit production. The critical watering periods for selected vegetables follow:

Asparagus needs water most critically during spear production and fern (foliage) development. Less water is needed after ferns reach full size.

Cole crops (broccoli, cabbage, cauliflower, collards, Brussels sprouts, kale, and kohlrabi) need consistent moisture during their entire life span. The quality of cole crops is significantly reduced if the plants get dry anytime during the growing season. Water use is highest and most critical during head development.

Beans have the highest water use of any common garden vegetable. During blossoming and fruit development, beans use 0.25-inch to over 0.50-inch of water per day (depending on temperature and wind). Blossoms drop with inadequate moisture levels and pods fail to fill. On hot, windy days, blossom drop is common. When moisture levels are adequate, the bean plant is a bright, dark, grass-green. As plants experience water stress, leaf color takes on a slight grayish cast. Water is needed at this point to prevent blossom drop.

Carrot and other root crops require consistent moisture. Cracking, knobby, and hot flavored root crops are symptoms of water stress.

Corn water demand peaks during tasseling, silking, and ear development. Water stress delays the silking period, but not tasseling. Under mild water stress, the crop may tassel and shed pollen before silks on ears are ready for pollination. The lack of pollination may result in missing rows of kernels, reduced yields, or even eliminate ear production. Yield is directly related to quantities of water, nitrogen, and spacing.

Lettuce and other leaf vegetables need water most critically during head (leaf) development. For quality produce, these crops require a constant supply of moisture.

Onion family crops require consistent moisture and frequent irrigation due to their small, inefficient root system.

Peas need water most critically during pod filling.

Potato tubers will be knobby if they become overly dry during tuber development.

Tomato family (tomatoes, peppers, and eggplant) needs water most critically during flowering and fruiting. Blossom end rot (a black sunken area on the bottom of the fruit) is often a symptom of too much or too little water. The tomato family has a lower water requirement than many vegetables and plants are often over-watered in the typical home garden.

Vine crops: cucumbers, summer and winter squash, and assorted melons need water most critically during flowering and fruiting. Vine crops use less water than many vegetables and are often over-watered in the typical home garden.

Vegetable Gardening When Irrigation Interval Is Restricted

- Restrictions that allow for thorough watering only twice a week should not have a major effect on the vegetable garden. With adequate soil organic content, a standard in vegetable production, the garden should be able to go two to seven days between irrigations. Follow recommendations listed above.
- Avoid heavy water use crops such as beans and sweet corn.
- Grow only what you need. Consider that one tomato plant can yield over 20 pounds of fruit.

Vegetable Gardening When No Watering Is Allowed

- When water restrictions prohibit outdoor watering, do not plant a vegetable garden. Vegetables do not go dormant like Kentucky bluegrass lawn. If water restrictions allows, consider planting containers with vegetables and consider planting non-irrigated or minimally-irrigated cover crops in the vegetable garden area.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired).

- Colorado Master Gardener *GardenNotes* are available o-line at www.cmg.colostate.edu.
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MASTER GARDENER
COLORADO STATE UNIVERSITY
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CMG GardenNotes #717

Growing Tomatoes

Variety Selection

There are over 2,000 cultivars of tomatoes grown worldwide. Ask neighbors, local gardeners, and garden center staff about local favorites.

Hybrid tomatoes are popular in the United States to reduce problems with *Verticillium* and *Fusarium* wilt, common soil-borne pathogens. Early hybrids were developed for their yields and disease resistance. Flavor became a driving factor in the breeding of newer hybrids. Some gardeners prefer to trade off the disease protection of hybrids for the rich “tomato-ey” flavors of heirloom varieties.

For early production, *Early Girl* is a popular variety with mid-size fruits. *Celebrity*, *Big Boy*, and *Better Boy* are examples of popular main season varieties. Many gardeners prefer the rich tomato flavor of heirloom *Brandywine* or the large beefsteak types. Pear tomatoes and yellow types are gaining popularity.

Cherry and the new grape-type tomatoes are popular for salads and snacking. Many, but not all, have small size vines suitable for container gardening. [Figure 1]

Figure 1. ***Sweet 100*** is the most popular home garden cherry-type tomato. On a large vine, it produces hundreds of sweet, cherry sized fruits with very tender skins.

Requiring less time to cook down, paste types such as *Roma* and its descendents are preferred for making salsa, chili sauce, and other tomato products. Be aware that paste types and standard varieties are not directly interchangeable in recipes.

Where the growing season is short, select *Early Girl* and other cultivars that will mature in 50 days or less. In many mountain communities, tomatoes may only be successfully grown in a structure or adjacent to the south side of a building to provide frost protection and warmer growing temperatures.

Whatever type you prefer, VFN resistant hybrid varieties are recommended. The abbreviation VFN indicates resistance to *Verticillium* wilt, *Fusarium* wilt, and nematodes. Verticillium and Fusarium wilts are common soil-borne fungal diseases. Nematodes are not an issue in Colorado due to cold soil temperatures. Researchers have found multiple strains of *Verticillium* and *Fusarium*, so if you are having problems with these diseases, try <u>other</u> VFN varieties.

<u>Vine types</u> – There are two types of vines: *indeterminant* and *determinant*. Most popular home garden varieties are indeterminant. The vine keeps growing through the growing season, extending fruit production until frost kills the vine. Plant size is typically large. Determinant types are common in commercial production as vine growth stops when flowering begins; plants will typically be moderate in size. Determinant types put on a large single crop. They may be suitable for container planting where trellises are not possible.

Planting

Planting Time

For optimal growing, tomatoes need warm temperatures: above 52ºF at night and above 60ºF during the day at transplant. They are readily killed by a light frost. A week of cool daytime temperatures (below 55ºF) will stunt plants, reducing yields.

With these warm temperature requirements, planting time along the Colorado Front Range is typically late May. Do not plant tomatoes out into a cold spell and make sure soil temperatures are warm.

To get a head start on the season, gardeners use a variety of frost protection techniques. The Wall-of-Water® provides protection into the mid teens, or lower. Cool soil temperatures also inhibit early growth. When using a Wall-of-Water, also use black plastic mulch to help warm the soil. Be cautious in filling the Wall-of-Water not to splash water around, as a wet soil will be slow to dry and warm in the spring. [Figure 2]

Figure 2. Wall-of-Water protects individual plants down to the mid-teens.

Notice that black plastic mulch was also used to warm the soil. Cool soil temperatures are also a growth-limiting factor with early plantings.

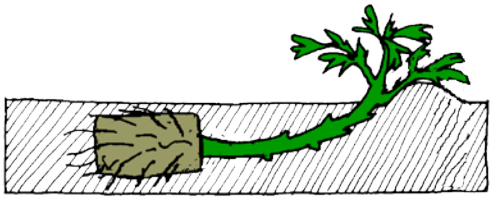
Selecting the Ideal Plants

The ideal tomato transplant is dark grass green and six to eight inches tall. The stem is about pencil size in diameter and the plant has not been pruned or cut back. Transplants are hardened-off (growth rate slows so the plant is more tolerant of the move the greenhouse environment to the bright, windy outdoors) by withholding water and/or nutrients or by exposure to cooler temperature.

Plant leggy transplants horizontally – When gardeners are shopping for transplants in the warm greenhouse conditions of May, tomato plants quickly grow from ideal size to tall and leggy. The white bumps along the leggy tomato stem are roots beginning to form.

Plant these taller leggy transplants horizontally. Dig a trench a two to three inches deep. Place the plant horizontal with only the top two to three sets of leaves showing above the soil. Pinch off other lower leaves below the soil line before planting. These leggy plants readily root out along the stem in the warm soil near the surface, supporting rapid growth. [Figure 3]

Figure 3. Plant tall leggy tomatoes horizontal in a shallow furrow.



Space and Trellis Plants

To minimize Early Blight, space and trellis plants to allow for good air circulation and promote rapid drying. Trellised tomatoes are easier to pick and less preferred by tomato psyllid insects. Trellising eliminates problems with fruit rotting where they touch the ground.

The minimal spacing for trellised tomatoes is two feet apart in a hedgerow. Research has demonstrated that crowding plants will not increase yields, but will increase disease problems.

Cages – The American Society for Horticultural Science suggests a trellis two feet in diameter by four to five feet tall. It is easy to make from a 6½-foot length of concrete reinforcing mesh. Cut off the bottom ring of wire so the cages can be pushed into the ground. When a branch sticks out of the cage, simple tuck it back in. [Figure 4]

For the smaller-vined, determinant types, two cages may be made from a 6½-foot length, cutting the height in half. Cages will be two feet diameter but only 3-feet tall.

Commercially available cages are too small for most popular tomato varieties grown on good soils.

Figure 4. Tomatoes planted in a raised bed with black plastic mulch and cages made from concrete reinforcing mesh.

Cages are six feet around, two feet across, and five feet tall. On improved soils, tomato vines will loosely fill the cage, allowing for good air circulation and easy picking.

Tender transplants are rather sensitive to cool winds. Wrapping the cages with a plastic sheet or newspapers to provide wind protection for the first week helps plants acclimate.

Figure 5. Wrapping the tomato cage with plastic or newspapers protects tender plants from cold winds.

Single pole trellis – Some gardeners prefer to trellis tomatoes on a single pole or stake. To do this, prune plants to a single trunk by removing all side shoots. This requires constant removal of side shoots.

Figure 6. Tomatoes trellised to a single pole.

Fan trellis – Another method, which produces larger fruit, is to trellis to a three-trunk, fan shape, removing all other side shoots. This requires a sturdy frame to support the weight of the vine and fruit.

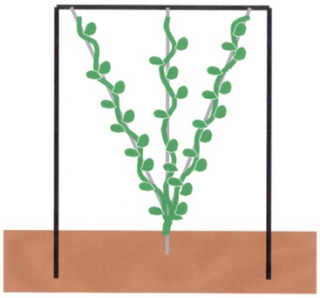


Figure 7. Tomatoes trellised into a fan shape.

Mulching

As with any crop, surface mulch is recommended to conserve soil moisture and manage weeds. Mulching helps reduce the splashing of Early Blight fungal spores from the soil onto the leaves. It also helps stabilize soil moisture levels, reducing the incidence of blossom end rot.

Black plastic mulch is popular for tomatoes, warming the soil and pushing production two to three weeks earlier. When using black plastic mulch, crops must be planted early so plant growth covers and shades the plastic before summer heat sets in. .

Irrigation

Avoid overhead sprinkling on tomatoes. Fungal spores are easily water-splashed from one leaf to another, and water on the leaves creates a favorable environment for disease development. Watering in the morning, allowing plants to dry before nighttime, may also be helpful.

Fertilization

Tomatoes have a low nitrogen requirement. Under high nitrogen conditions, vines grow excessively large at the expense of fruit production. More correctly stated, tomatoes are a fussy nitrogen feeder. On soils low in organic matter, tomatoes typically run out of nitrogen in mid-summer, reducing yields and predisposing the plants to Early Blight.

At transplanting, apply one to three applications (depending on soil organic content) of a water-soluble, “plant starter” fertilizer. This includes any of the water-soluble products like MiracleGro, Peters, RapidGro, Schults, etc. Transplants would have been “hardened off” (growth slowed) in the greenhouse. Water-soluble fertilizers stimulate renewed growth.

If the weather turns cold late spring after tomatoes are out (that is a week with daytime temperatures below 55°F), use water-soluble fertilizers to stimulate growth when warm temperatures return. A week with daytime temperatures below 55 °F stunts tomato growth, reducing yields.

Mid-summer – On low organic matter soils, tomatoes typically run out of nitrogen in mid to late summer. Yellowing of the foliage, starting with lower leaves, is the typical symptom of nitrogen stress. Low nitrogen in the plant allows Early Blight disease to spread like wildfire. Keeping nitrogen levels up in mid to late summer is a primary means of Early Blight control and significantly improves yields.

Fertilize tomatoes lightly as the first fruits reach two-inches in diameter. Water-soluble fertilizers (such as MiracleGro, RapidGro, and Peters) used according to label directions make a good summer fertilizer supplement. Make applications every two to four weeks, depending on soil organic content.

If using a dry granular fertilizer, apply 21-0-0 (ammonium sulfate) at the rate of one level tablespoon per plant. Sprinkle the granular fertilizer in a wide circle 12 to 20 inches out from the plant, and water in. Dry granular fertilizers can easily kill tomatoes if over-applied.

Pollination and Summer Temperatures

Tomato pollination is temperature dependant. If nighttime temperatures drop below 55ºF, pollen fails to develop and flowers that open the following morning will not set fruit. Cool nights often interfere with fruit set for early tomatoes and in higher elevations. Blossom set sprays help set fruit even with cool nights.

If the daytime temperature reaches 90ºF by 10 a.m., blossoms that opened that morning abort. Blossom set sprays are not effective under high temperatures.

In July and August along the Colorado Front Range, night temperatures have a 50/50 probability of staying above 55ºF any given night. In unusually warm seasons, tomato fruit set may be unusually high. When poor soil conditions and/or watering problems limit plant growth potential, fruit may ripen while small. With good soil tilth and water conditions, fruit size may be unusually large.

Garden Sanitation

Control weeds. Common weeds harbor many garden insect and disease problems. Volunteer potatoes and tomatoes could be a source of Early Blight infection. [Figure 8]

For Early Blight management, some references suggest removing lower leaves showing symptoms. Symptoms start as tiny black spots on lower leaves. Spots enlarge to light and dark target-like rings. Leaves yellow and the disease progresses from lower leaves up the plant.

If removing lower leaves, focus on leaves with the tiny black spots. Removing just the lower yellow leaves will not be adequate. Wash hands with soap and water immediately after touching diseased leaves to prevent spreading spores to other plants. Avoid working with the plants when they are wet.

Another disease, tobacco mosaic virus (TMV) can readily spread from tobacco smoke residues on the hands and clothing to tomatoes. Prevent TMV infections by washing hands after smoking or handling tobacco products.

Figure 8. Early blight leaf spots [Photo: USDA]

Rotation

Since the common tomato diseases (Early Blight, Verticillium and Fusarium wilt) are soil borne, crop rotation is an effective management tool. However, this may not be practical in most home garden situations, particularly since rotation allows no tomatoes, peppers, potatoes, eggplants, vine crops (cucumbers, squash, pumpkins, and melons), strawberries, or raspberries in the same growing area for at least four years. In a garden bed, moving the tomatoes a few rows to the left or right is not an effective rotation.

Fall Clean Up

Remove all tomatoes and potato debris in the fall. Dispose of debris in municipal trash or by burial. Do not compost unless the compost heats to at least 145ºF and the pile is turned occasionally. Most home compost piles do not heat adequately to kill pathogens.

Common Disorders

- CSU Extension fact sheet #2.949, **Recognizing Tomato Problems**

Figure 9. Blossom end rot on tomato is caused by water imbalance between the fruit and soil. The soil could be too wet, too dry, or root could be cut by cultivation. It could be aggravated by soil compaction and poor soil preparation.

Ripening Fruit at the End of the Season

To speed fruit ripening in the fall, hold back slightly on watering.

Ripening Fruit Indoors

With the forecast of a light frost, tomatoes may be protected by covering. If heavy frost is forecast and covering is not practical, harvest fruit before the frost event and carry indoors.

Pick ripening fruit and green tomatoes with a glossy green appearance that have reached about three-fourths of their full size. Remove stems. Wash fruit under a stream of water and allow to air dry on a clean towel. Save only blemish-free fruits for ripening indoors.

As for humidity, fruit shrivel if it is too low. If the humidity is too high, fruit mold. A gardener will have to learn by trial and error what works for their home. Some gardeners simply hang the whole plant upside down in a dark cool barn or basement to let the fruits ripen gradually. In Colorado's dry climate, fruit tend to shrivel from the low humidity.

Other options include placing tomatoes, one or two layers deep, in a covered box for ripening. Some people find better success by individually wrapping fruit in newspaper or wax paper and placing them in a covered box. Placing a few fruit together in a vegetable storage bag has been effective for others. For higher humidity, place tomatoes up to two layers deep in a blanching pan or strainer inside of a covered pan with some water in the bottom. Make sure the fruit does not touch the water.

Ethylene gas produced by ripening tomatoes is a ripening hormone. To speed the ripening process, place a ripe tomato in the container with the fruit. To slow the ripening of green tomatoes, routinely remove ripening fruit from the container.

Green fruit will ripen in about two weeks at 65ºF to 70ºF, and in about three to four weeks at 55ºF. Storage below 50ºF will give fruit a bland, off-flavor. Ripe tomatoes may be stored in the refrigerator for a few days.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Artwork by David Whiting; used by permission.

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MASTER GARDENER
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CMG GardenNotes #718

Tomato Early Blight

Outline:

Early Blight, caused by the fungus *Alternaria solani*, is common on garden tomatoes and potatoes, and occasionally infects eggplants and peppers.

Symptoms

Symptoms appear soon after fruit set- on the lower leaves- as tiny dark brown spots. The spots enlarge to over 1/2 inch in diameter and develop a grayish-white center with a darker border. As the spots enlarge, they develop concentric, target-like rings. Spots may also develop on fruit and stems.

As the disease progresses, leaves turn yellow, brown and drop off. Black *pycnidia* (fungal fruiting bodies that appear as pinhole sized black dots) form in the center of the spots as they mature.

Figure 1. Yellowing and halo target marking from Early Blight.

When the pycnidia become wet, fungal spores ooze out. The spores are spread by splashing water, insects, wind, and human contact. During rainy weather or overhead irrigation, spores quickly spread the disease through the planting.

The disease is favored by warm wet weather, overhead irrigation, and where heavy foliage delays the drying of leaves. A moist 48-hour period is required for infections to occur. It is not necessary that this be a continuous period, but may be cumulative over several days.

In the garden, the fungus can over-winter on diseased plant debris and in perennial weeds such as horse nettle and nightshade. These serve as sources for inoculum and for primary infections in the spring.

Management

Control measures center around reducing the amount of inoculum (spores) available, and promoting rapid drying of wet leaves.

Spacing and Trellising Plants

Space and trellis plants to allow for good air circulation that promotes rapid drying. Minimal spacing for trellised tomatoes is two feet apart. Crowding plants will not increase yields and increases disease problems.

Trellising also increases the distance of the upper leaves from the sources of inoculum on the soil and lower leaves.

Mulch

Use a mulch (such as black plastic) to help protect the plant from inoculum splashing from the soil onto lower leaves. Removing leaves in the lower 8 to 12 inches of the plant (as the plant grows) also helps protect lower leaves from infections splashing from the soil.

Irrigation

Avoid overhead irrigation on tomato crops. Fungal spores are easily water-splashed from one leaf to another, and they depend on standing water on the plant surface to cause infections. It may also be helpful to water in the morning in order that plants dry quickly. Plants that remain wet all night from evening watering are prime targets for disease infection.

Fertilization

A mid-summer loss of plant vigor from inadequate moisture or fertilizer will leave the plant more susceptible to the fungi. In home gardens, Early Blight frequently erupts due to low nitrogen levels in mid to late summer.

Fertilize tomatoes at planting, flowering and fruiting (as the first fruits reaches two inches in diameter). An additional application can also be made to ensure the plants are not nutrient deprived. Avoid heavy applications of nitrogen that can over- stimulate vine growth at the expense of fruiting.

Water-soluble fertilizers (such as MiracleGro, RapidGro, and Peters) applied according to label directions can be used as summer fertilizer supplements.

If using a dry granular fertilizer (such as 21-0-0, ammonium sulfate), apply one level tablespoon per plant. Sprinkle the granular fertilizer in a wide circle 12 to 20 inches out from the plant, and water in. Dry granular fertilizers can easily kill the tomatoes if over-applied

Weed Control

Keep the garden weed-free. Common weeds harbor many garden diseases. Volunteer potatoes and tomatoes can also be a source of inoculum for Early Blight.

Remove Infected Leaves

Remove infected leaves as soon as noticed. Wash hands with soap and water immediately after touching diseased leaves to prevent spreading spores to other plants. Avoid working with the plants when they are wet.

Rotation

Since fungal spores can be found on plant debris in the soil, crop rotation is a management tool. However, this may not be practical in most small, home garden situations because a rotation plan allows no tomatoes, potatoes, eggplants, vine crops, strawberries, or raspberries in the same growing area for at least four years. In a garden bed, moving the tomatoes a few rows to the left or right is not an effective rotation.

Fall Clean Up

Remove all tomatoes and potato debris in the fall. Dispose of debris in municipal trash or by burial. Do not compost unless the compost heats to at least 145º and the pile is turned occasionally. Most home compost piles do not adequately heat to kill pathogens.

Fungicides

During years with frequent rains, supplementing the above cultural practices with fungicide applications may be necessary to protect the plants. Start spraying at the first sign of spotting on lower leaves, typically in July. Once the disease begins to cause yellow leaves, fungicides lose effectiveness.

Complete coverage, including the lower leaves, is essential for control. Repeat applications at 10 to 14 day intervals as needed. Under moist conditions, reapplication may be needed at seven-day intervals.

Effective fungicides include Chlorothalonil (Daconil 2787, Ortho Multi-Purpose Fungicide) and EBDC fungicides (such as Mancozeb and Maneb).

The use of these fungicides calls for protective clothing, including rubber gloves, long sleeved shirt, and long pants.

These fungicides are toxic to fish and aquatic life. Do not apply directly to water (lakes, streams, ponds, or wetlands). Do not use on lands adjacent to water or wetlands, where drift or runoff could become hazardous to aquatic life.

Authors: David Whiting (CSU Extension, retired), with Carol O’Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Revised by Mary Small, CSU Extension

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MASTER GARDENER
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CMG GardenNotes #719

Vegetable Garden Hints

Outline:

Harvesting quality and quantity from a vegetable garden starts with the gardener's ability to provide nearly ideal growing conditions for individual crops. Central to all highly productive gardens is a rich soil, high in organic matter, created with annual additions of compost and/or other organic materials. The following home gardening hints summarize a variety of research projects focusing on quality in vegetable production. Crops are grouped by families that have similar cultural practices.

Asparagus

Soils – Asparagus tolerates a wide range of soils as long as they are well drained. It prefers soil high in organic matter, and full sun (eight hours/day minimum).

Fertilizing – Asparagus is a heavy feeder. Fertilize in spring as growth starts and again in mid-summer after the harvest period.

Mulching – Asparagus competes poorly with weeds and other crops for water, nutrients, and space. Organic mulch is recommended. Mulch also provides winter cold protection for the roots.

Harvesting – The asparagus bed can be weakened or destroyed by over harvesting. The harvest period for an established bed is only four to six weeks (May into mid-June). Harvest only larger spears. Stop harvesting if spears decrease to pencil size or smaller. Leave the ferns (foliage) to grow until fall or let stand through the winter, finally cutting before new growth begins in spring.

Planting – Extra efforts in plantings new beds pay off with increased production.

1. Thoroughly work in four inches of well-composted and aged organic matter through the soil to a 12 inch depth.
2. Before planting, soak roots in warm water for a couple of hours.
3. Dig a trench four to five inches deep and wide enough to accommodate the spread-out roots. Space roots, typically 18 inches apart, covering with only two inches of soil.
4. Add additional soil during the growing season, as plants grow. Asparagus roots are easily smothered if initially covered too deep. (Many texts talk of planting six to eight inches deep for better protection from cold winter soil temperatures. However, this deep planting will decrease yields.)

When planting from seed, start seeds indoors 12 weeks prior to transplanting outdoors. Harden off seedlings before transplanting outdoors.

Beans

Soils – Beans are tolerant of a wide range of soils, as long as they are well drained. Beans are rather sensitive to soil salt. A soil rich in organic matter (to hold water and nutrients for growth) is preferred.

Planting – Research clearly demonstrates that early growth sets potential yield.

- Avoid planting too early in the spring. Soil temperature should be above 50ºF, measured at 8 a.m., six inches deep. For example, along the Colorado Front Range, this is typically early May for well-drained sandy soils to late May for clayey soils.
- Rich soil fertility should push early growth of plants. However, heavy nitrogen fertilization will lead to excessive plant growth at the expense of fruiting and increased disease problems.

Spacing affects yields – The potential for disease explodes once the plant canopy grows to cover over the patch; avoid over-crowding! Crop research suggests the following optimum spacings:

- 24 inches between rows with two inches between plants
- 18 inches between rows with three inches between plants
- 12 inches between rows with four inches between plants – (gives 20% higher yield than 24 inches × 2 inches spacing, but may increase disease pressure.)
- Six inches between rows with six inches between plants (this block style spacing will predispose the patch to foliage diseases.)

High water demand – During flowering and fruit production, beans have the highest water use of any vegetable crop. If the water supply is optimum, most varieties will produce until frost. If the water supply is low, beans will respond by:

1. Dropping blossoms
2. Producing pinched, pollywog-shaped fruit

Depending on temperature and <u>wind, w</u>ater use during fruiting will be ¼-inch to over ½-inch of water per day. Frequent watering in the right amount is essential for bean production.

Figure 1. Beans have a high water use. With inadequate water, blossoms drop, reducing yields. When beans need water, plant color changes slightly from a dark grass green to a grayish green. Windy weather significantly increases the water demand.

Cole Crops: Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Kale, and Kohlrabi

Quality is dependent on the weather and the grower's ability to provide conditions for rapid growth.

Soils – Being shallow rooted, cole crops require a fertile, moist, well-drained soil that is rich in organic matter and nitrogen.

Fertilizer – Cole crops are heavy feeders of nitrogen, phosphorus, and potassium. Apply a plant starter fertilizer (solution of water-soluble fertilizer like MiracleGro, Peters, and Rapid Grow) at planting, three weeks and five weeks. Starter fertilizers increase yields by 20%

Mulch – Because cole crops are poor competitors, mulch to stabilize moisture and control weeds. For early spring plantings, black plastic mulch helps warm cold soils. However, plastic becomes too hot when warm weather arrives. During warm weather, a grass clipping mulch cools the soil and microenvironment.

Irrigation – Cole crops are intolerant of drying. Dry soils quickly lead to strong flavors.

Temperature – Cole crops prefer growing temperatures between 65ºF and 80ºF. Hot weather reduces sweetness. Because seeds do not like cold soils, use transplants for spring planting. For a superior quality fall crop, direct seed the main planting in early-July (Front Range area).
Both broccoli and cauliflower tolerate some frost (down to lower 20's) on maturing plants.

Using Bt – For cabbageworm and looper control, treat with *Bacillus thuringiensis, Bt,* (a biological control product). Because *Bt* is rapidly broken down by sunlight, treat in the evening. *Bt,* a living organism, has only a two-year shelf life and cannot survive storage under extreme heat or cold.

Transplants –

- Preferred growing temperature for transplants is 60ºF to 70ºF. High temperatures result in too rapid growth, and tall, weak plants that are easily broken off in transplanting.

- The ideal transplant is about four inches tall and about four weeks old. Avoid transplants older than six weeks. Quick maturing varieties should be transplanted within four weeks of seeding.

Heading – Yield is based on plant size as the head (curd) starts to develop.

- **Bolting** (rapid head formation)

  - Broccoli and cauliflower are prone to bolting when exposed to cool weather before three to four pair of true leaves develop.
  - Long days and hot weather in the summer cause broccoli to bolt and go to seed, and cause cauliflower curds to develop a red-purple discoloration.
  - Cabbage bolts if exposed to two to three weeks below 50ºF Avoid planting too early in the spring.

- **Buttoning** (development of small heads or curds [buttons] on immature plants) – Factors that restrict early plant growth (including nitrogen deficiency, cold temperatures, shock to young transplants, and drought stress) lead to buttoning. Follow practices that will result in rapid vegetative growth.

- **Blindness** (plants having lost their terminal growing points produce no head) – Damage to the terminal growing point due to low temperatures, cutworms, damage or rough handling of transplants, will result in blind plants. Handle transplants carefully, control cutworms, and avoid planting in low temperatures.

Figure 2. For quality, broccoli, cabbage, and cauliflower need cool temperatures. In warm summer climates (like the Colorado Front Range) plant mid-July for harvest in the cooler temperatures of fall. They will tolerate fall frost down to the mid-20s.

Corn

Variety types –

- Normal sugary, (su) – standard varieties
- Sugar Enhanced, (se) – Sugar Enhanced (se) genes increase the original level of sugar in the kernel and slow the conversion of sugar

into starch. Isolation is helpful, but not required

- Super Sweet, (sh) – Super Sweet (sh) genes increase sugar content two to three fold. Delay planting until soil temperatures reach 70ºF, in June. Isolation from non-super sweet types by 300 to 500 feet or 14 plus day differences in maturity is required.

Yield = water + nitrogen + space

- Water stress will reduce overall plant growth reducing yields. In particular, water stress will delay silking beyond the time when tassels shed pollen, thereby preventing kernel formation.

  ▪
- Side dress with nitrogen fertilizer frequently (every three to four weeks) through the summer to maintain a dark grass-green color. Sprinkle one cup 21-0-0 (or equivalent) per 50 feet of row, and water in.

  ▪
- Spacing affects yields. Crowding decreases sunlight to the leaves, reducing the number and size of ears. Optimum spacing is 36 inches between rows with nine inches between plants or 30 inches between rows with 12 inches between plants. Allow side shoots to develop, but do not plant in clumps.

Plant in Blocks – Corn is wind pollinated, so plant in blocks at least three rows wide, preferably four to five rows wide. Single blocks may include only a portion of the row length, with the remainder of the row being part to a block of another variety that matures at different times.

Pollination – Corn is wind pollinated, but bees collecting pollen also frequently visit it. When applying insecticides, use caution to protect pollinating insects. Do NOT spray tassels with insecticides.

Figure 3. Corn needs to be planted in blocks for wind pollination. For pollination, two side-by-side four-foot wide beds are used. Each bed has two rows going down the bed. This makes the block four rows wide. To extend the harvest season, the top of the bed could have an early planting with a later planting at the bottom.

Leafy Vegetables and Salad Crops: Lettuce, Spinach, Swiss Chard, etc.

Quality lettuce, spinach, chard, and other salad crops is the mark of a great gardener. Quality is based on the gardener's ability to match ideal conditions for rapid growth, including water, fertilizer, space, and temperature.

Soils – A rich soil, high in organic matter, is necessary for quality.

Mulch – Organic mulch (like dry grass clippings) reduces summer soil temperatures producing sweeter produce, conserves moisture, and controls weeds. Weeding by cultivation will damage surface roots.

Irrigation – Keep soil moist with 1 to 1½ inches of water per week (including rain). If the crop gets dry, it will become tough and stringy.

Spacing – Thin the crop to reduce competition for nutrients, moisture, light, and space.

Planting for fall harvest – Plant lettuce and spinach in mid to late summer to produce exceptional harvest quality during cool fall weather. It can also be planted mid-fall for extra-early spring crops. Cover the small seedlings with organic mulch for winter protection.

Figure 4. For quality, leafy vegetables need a constant supply of water, rich soils. For best quality, thin plants when crop is tiny. Here a variety of leaf vegetables are in a raised bed, going across the box. As one row is harvested, immediately replant for a continual harvest of young tasty produce.

Onion Family: Garlic, Leeks, Onions, Shallots, etc.

Soils – The onion family has a poor, inefficient root system, making the crop intolerant of poor soils and competition from weeds. The plants are heavy feeders. Quality produce arises from a well-drained, fertile soil, rich in organic matter.

Mulch – The onion family thrives with organic mulch (like dry grass clippings), which cools the soil, conserves moisture, and controls weeds.

Photoperiod sensitivity – The onion family is sensitive to the length of night, which triggers bulb development. In Colorado, plant only long day varieties that start bulbing with day lengths of 14 to 16 hours and temperatures above 65ºF. Plant size at the time conditions trigger bulb development determines the size of the bulb. Plant onions as soon as soil conditions allow in the spring.

Seed head – Keep seed heads picked. They pull plant resources away from bulb development.

Seed, Sets, or Transplants – Onions can be planted from seed, sets, or transplants. If planted from sets, sort sets larger than a dime from smaller ones. Plant small and large sets separately. Harvest from larger sets first because they do not store as well as onions grown from small sets.

Figure 5. Onions have a shallow inefficient root system. For quality they need an even moisture supply and rich soils.

Peas

Soils – Peas grow best in a rich soil, high in organic matter. They require a well-drained soil.

Types of peas –

- English Pea – standard, shelled pea
- Edible Pod Pea, Sugar Pea or Snow Pea – edible pod, pick before seeds swell
- Snap Pea – edible pod and plump sweet pea fruit

Plant as early as possible –

- Peas are sensitive to the photoperiod (length of night), influencing yields. At Colorado's latitude, an April 1st planting will have a 50% higher yield than a May 1st planting.
- Plant when soil temperatures reach 40°F. Avoid planting in wet soils.

Planting for fall harvest – Peas may be planted in mid-summer for harvest during cooler fall weather. Sweeter peas develop in cooler temperatures. However, yields of the fall crop are reduced due to photoperiodism and the vines are prone to powdery mildew in the fall.

Figure 6. *Snap peas* are edible pod types eaten with plump peas filling the pod. *Edible pod peas*, *sugar peas* or *snow peas* are edible pod types eaten before the pod fills with peas.

Potatoes

Soils – Potatoes thrive in a soil rich in organic matter that provides water and nutrient holding capacity, and improved drainage. However, avoid heavy applications of fresh manure or compost, as it will make the tuber surface rough and increase the occurrence of scab.

Certified Seed – The use of certified seed helps reduce disease problems.

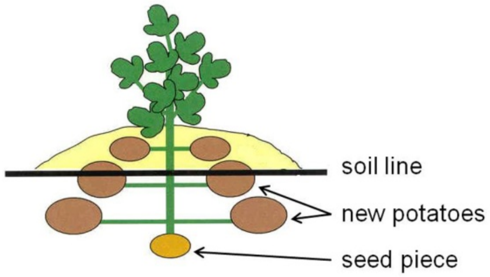
Give the plants a vigorous start –

- Plant when soil temperatures rise above 50°F, four inches deep at 8 a.m.
- Avoid using too small of a seed piece. Cutting seed pieces to 1½ to 2 inches in size provides for early plant vigor. Many gardeners prefer to use seed pieces that require no cutting to reduce decay potential.

Spacing – Plant spacing determines tuber size. Learn by experience the optimum spacing for the variety in a particular garden soil. A starting point is an equal-distant spacing of 12-15 inches between plants and between rows (or three plants across a four-foot wide raised bed). Spacing that allows the plants to close in and shade the soil yields sweeter spuds. However, thick foliage and reduced airflow can also increase the occurrence of disease.

Mulch – Transplants are hardened-off (growth rate slows so the plant is more tolerant of the move the greenhouse environment to the bright, windy outdoors) by withholding water and/or nutrients or by exposure to cooler temperature.

Figure 7. The new crop of potatoes grows above the seed piece. To shield the growing tubers from sunlight (which turns them green) soil is "hilled" (mounded) around the base of the plant. Straw mulch may be used as an alternative to hilling.



Fertilizer – Potatoes are heavy feeders of nitrogen, phosphorus, and potassium. Running out of nitrogen by August is the most common potato problem. Symptoms are a general yellowing of leaves that starts with lower interior leaves. Nitrogen stress pre-disposes the crop to Early Blight.

Moisture – If the soil is too wet or has poor drainage, tubers will rot. If the soil becomes overly dry, tubers will develop knobs.

Rhubarb

Soils -- Rhubarb thrives on any soil that is high in organic matter and well drained.

Yields – Yield is based on the plant's ability to store food reserves in the roots for the next year's crop.

- Keep seed stalk picked off.

- Stop harvest when temperatures rise above 85°F.
- Remove oldest stalks at the base when plants grow crowded, giving room for new stalks to grow. Never remove more than 1/4 of the stalks at one time.

Mulch – Rhubarb is a poor competitor for water and nutrients. Keep mulched with organic mulch.

Sun – It prefers full sun but grows poorly with reflected heat.

Coloration – Poor coloration of stalks develops from too much shade, too much heat, overly wet soils, or an inferior variety.

Re-planting – Reset when stalks become slender and the center of plant dies out, about every eight years. Rhubarb is best transplanted in the fall.

Root Crops: Beets, Carrots, Parsnips, Radish, Rutabagas, Turnips, etc.

Soils – Root crops need a rich, well-drained soil, high in aged organic matter.

Mulch – Use an organic mulch (like dry grass clippings) to cool the soil in summer, stabilize soil moisture, and control weeds.

Irrigation – Consistent soil moisture is a must!

Carrot disorders –

- Strong flavor – Many varieties have a high oil content (and the oil can turn rancid); change varieties.
- Hairy or rough root surface develop from too much fresh organic matter in the soil. Use old, well-aged compost or manure in the root crop section.
- Stubby, knobby, or cracked roots arise from uneven moisture supply, hot soil temperatures, or poor, rocky, or compacted soil conditions.
- Green shoulders result from root crowns exposed to sunlight and reduce sweetness. Mulch with dry grass clippings to shade the crown of the root.
- Failure of seedlings to emerge may arise from soil crusting, planting too deep or high soil temperatures.

Radishes –

- Hot and/or pithy radishes arise from hot weather, hot soil, and/or plants that are past maturity.
- Thin plants as soon as they pop through the ground!

Replanting of root crops for fall harvest – For tender young root crops, replant in mid-summer (Front Range area) for fall harvest.

Winter storage of roots – Some varieties of carrots store well in the garden soil or in a root cellar for year-round use. Other carrot varieties become strong-flavored as the oil becomes rancid. Two useful options for winter storage include:

- Leave undisturbed where growing in the garden and mulch the bed with straw or other organic materials. Dig as needed.
- Place harvested carrots in straw in a garbage can storage pit.

Figure 8. Burpee white radish: for quality, root crops need an even moisture supply and rich soil.

Tomato Family: Tomatoes, Peppers, and Eggplants

Mulch – Use black plastic mulch for earlier production and higher yields. The mulch also helps controls weeds, conserves water, and protects the foliage from disease spores splashing from the soil.

Trellis – Trellis or cage tomatoes to allow for easier picking and suppress Early Blight (the most common tomato disease) and psyllids. Trellising allows plants to dry quickly following rains. An ideal trellis is two feet wide and four to five feet tall. It can be easily made from a six and half-foot length of concrete reinforcing wire coiled in a circle.

Spacing – Avoid crowding plants. Crowding will not increase yields, but will promote disease problems. The minimum spacing for trellised tomatoes is two feet.

Watering – Avoid overhead irrigation, which promotes leaf diseases. A soaker hose type of drip irrigation works well under plastic mulch. Tomatoes can also be furrow irrigated with water running in furrows under the plastic mulch.

Transplanting – Except for avid gardeners who use extra protective efforts to realize a few early tomatoes, avoid early plantings. Plant the main tomato crop when the threat of frost has passed and daytime temperatures are consistently above 60°F. A week of daytime temperatures below 50°F degrees stunts growth.

Fertilizer –

- Over-fertilization causes excessive vine growth at the expense of fruiting.

- However, starter fertilizer at planting and a couple of weeks later will encourage early growth. (MiracleGro, Peters, and Rapid Grow are examples of water-soluble fertilizers that make great starter fertilizers.)
- An additional light fertilization as the first fruits color also will increase yields and resistance to Early Blight.

Blossom drop – Hot, dry summer winds can cause blossoms to drop. Inconsistent watering contributes to this condition. Mulch plants.

With night temperatures below 55°F, blossoms that open the following morning will not have pollen, and blossoms will drop. For example, there is a 50/50 probability along the Colorado Front Range that any given summer night will too cool for pollen development. For early production and in cool locations the "blossom set sprays" effectively improve yields. If daytime temperatures rise above 90°F by 10 a.m., blossom opening that morning will abort.

Blossom end rot – Irregular watering and over-watering causes development of a dark, leathery area on the blossom end of fruits. Water consistently in a deep, improved garden soil and mulch will help prevent this condition.

Figure 9. Sweet 100 Tomato - Over 2,000 cultivars allow the gardener lots of options in flavor, fruit size, and disease management.

Vine Crops: Cucumbers, Melons, Pumpkins, and Squash

Soils – Vine crops thrive in well-drained soils high in organic matter. Yearly applications of compost will likely supply needed nutrients.

Mulch – Use black plastic mulch for earlier production and higher yields. It also controls weeds and conserves water.

Planting time – Do not plant too early. Daytime temperatures should consistently be above 55°F. Protect young, tender plants from cool winds.

Seeds or Transplants – Direct seeding is reported to give higher yields. If using transplants, they should be small, never more than two to four weeks old.

Blossom Drop –

- Vine crops have male flowers and female flowers (small fruit behind the flower). Male flowers develop first, and generally predominate.

Young fruits that are not pollinated will abort.

- When bee activity is limited, increase yields by hand pollination. Pick a male flower, remove petals, and touch the center of the female flowers with the male flower.
- Any form of stress (like too much or too little water, poor soil conditions, extreme heat, and wind) can reduce flowering and lead to abortion of fruits.

Figure 10. Vine crops have female flowers (left blossom) and male flowers (right blossoms). The female blossom has a tiny fruit at the base of the petals. For production, bees or the gardener must move the pollen from the male flower to the female flower.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Photographs and line drawings by David Whiting; used by permission.

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MASTER GARDENER
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CMG GardenNotes #720

Vegetable Planting Guide

Outline: Cool season vegetables, page 1
- Hardy vegetables – Broccoli, cabbage, kohlrabi, onions, lettuce, peas, radish, spinach, turnips, page 1
- Semi-hardy vegetables – Beets, carrots, cauliflower, parsley, parsnips, potatoes, and Swiss chard, page 1

Warm season vegetables, page 2
- Tender vegetables – Beans, celery, corn, cucumbers, New Zealand spinach, and summer squash, page 2
- Very tender vegetables – Lima beans, cantaloupe, eggplant, pepper, pumpkin, winter squash and pumpkin, tomato, and watermelon, page 2

Planting Guide Table – Vegetable planting guide, page 3
Average Frost Dates, page 4

Cool Season Vegetables

These vegetables prefer cool growing temperatures (60°F to 80°F) and lose quality in hot weather. They are often replanted mid-summer for fall harvest.

Hardy Vegetable

Crops: broccoli, cabbage, kohlrabi, onions, lettuce, peas, radish, spinach, turnips

Temperatures: Hardy vegetables grow with daytime temperatures as low as 40°F and may survive a frosty nip.

When to plant:

- Based on soil temperatures, refer to Table 1.
- Plant as soon as soil adequately dries in the spring.
- These crops may be planted as early as 2-4 weeks before the date of the average last spring frost.

Semi-Hardy Vegetables

Crops: beets, carrots, cauliflower, parsley, parsnips, potatoes, and Swiss chard

Temperatures: Semi-hardy vegetables grow with minimum daytime temperatures of 40°F to 50°F, but are less tolerant of a frosty night.
When to plant:

- Based on soil temperature, refer to Table 1.
- Plant as soon as soil adequately dries in the spring.
- These crops may be planted as early as 0-2 weeks before the date of the average last spring frost.

Warm Season Vegetables

Warm season vegetables prefer summer-like weather with temperatures between 70°F and 95°F. They are intolerant of frost and may be sensitive to cool spring winds.

Tender Vegetables

Crops: beans, celery, corn, cucumbers, New Zealand spinach, summer squash

Temperatures: Tender vegetables grow with a daytime temperature above 55°F, and are intolerant of frost.

When to plant:

- Based on soil temperature, refer to Table 1.
- Soil is adequately dry to work.
- These crops may be planted (from seed) around the date of the average last spring frost. Transplants of cucumbers and summer squash without frost protection should be delayed until frost potential is over.

Very Tender Vegetables

Crop: lima beans, cantaloupe, eggplant, pepper, pumpkin, winter squash and pumpkins, tomato, and watermelon

Temperatures: Very tender vegetables are not only intolerant of frost, but also cool spring winds. They need daytime temperatures above 60°F, and prefer temperatures of 70°F to 95°F. A week of daytime temperatures below 55°F, may stunt the crop.

When to plant:

- Based on soil temperature.
- Soil is adequately dry to work.
- These crops are typically planted two plus weeks after the average last spring frost date.
- Weather is becoming summer-like, (i.e., consistently above 55°F (daytime) and breezes should have lost any cool nip).

Table 1 – Vegetable Planting Guide

Vegetable	Germination Temperature[1] Min.	Optimum	Max.	Plant Spacing[2]	Planting Depth	Days to Germination	Typical Days to Harvest	Age of Transplant (weeks)
Cool Season Crops[3]								
Beets	40°	80º	90º	4-6”	¾-1”	7-10	60	
Broccoli[4]	40°	80º	90º	18”	½”	3-10	65T[4]	5-7
Cabbage[4]	40°	80º	90º	18”	½”	3-10	85T[4]	5-7
Carrots	40°	80º	90º	2-3”	¼”	10-17	70	
Cauliflower[4]	40°	80º	90º	18”	½”	3-10	65T[4]	5-7
Kohlrabi	40°	80º	90º	7-9”	½”	3-10	50	
Leeks	40°	80º	90º	4-6”	¼”	7-12	120	
Lettuce (leaf types)	35°	70º	70º	7-9”	¼”	4-10	60	
Onion, green	35°	80º	90º	2-3”	¼”	7-12	60	
Onions, dry (seed)	35°	80º	90º	4-6”	¼”	7-12	110	
(sets)				4-6”	1-2”			
Parsnips	35°	70º	90º	5-6”	½”	15-25	70	
Peas	40°	70º	80º	4-6” or 3”×8”	1”	6-15	65	
Potatoes	45°			12-15”	4-6”		125	
Radish	40°	80º	90º	2-3”	½”	3-10	30	
Spinach	40°	70º	70º	4-6”	½”	6-14	40	
Swiss Chard	40°	85º	95º	7-9”	1”	7-10	60	
Turnips	40°	80º	100º	4-6”	½”	3-10	50	
Warm Season Crops								
Beans, snap	55°	80º	90º	6” or 4” x 12”	1-1½”	6-14	60	
Cantaloupe[5]	60°	90 º	100º	36-48”	1-1½”	3-12	85	2-3[5]
Corn	50°	80 º	100º	12” x 30” 9” x 36”	1-1½”	5-10	60-90	
Cucumbers	60°	90 º	100º	6” trellised 24-36” untrellised	1”	6-10	55	2-3[5]
Eggplant	60°	80º	90º	18-24”	¼”	7-14	60T[6]	6-9
Pepper	60º	80º	90º	15-18”	¼”	10-20	70T[6]	6-8
Tomato	50º	80º	100º	trellised: 24” between plants	¼”	6-14	65T[6]	5-7
Squash, Summer	60º	90º	100º	36-48”	1-1½”	3-12	50	2-3[5]
Squash, Winter	60º	90º	100º	36-48”	1-1½”	6-10	100	2-3[5]
Watermelons	60º	90º	110º	36-48”	1-1½”	3-12	85	2-3[5]

1 **Germination temperature –** Soil temperature is one of the best methods to determine spring planting time. Plant when soils reach minimum temperature measured at 8 a.m., 4 inches deep. Beans are an exception, being measured at 6 inches deep. Optimum temperatures listed in the table are useful for starting seeds indoors. Maximum temperatures are listed in regards to high soil temperatures that may interfere with seed germination in the summer.

2 **Plant Spacing –** Spacings given are equal-distance spacing for crops grown in block or close-row style beds. For example, beets, with a spacing of six inches are thinned to six inches between plants in all directions. In other words, beets are thinned to six inches between beets in the row and six inches between rows. The closer spacing listed should be used only on improved soils with 4-5% organic matter.

Close-row or block style planting works well for raised bed gardening, with blocks/beds 4 feet wide (any length desired) and 2-foot wide walkways between blocks/beds.

3. **Cool Season Crops** – Cool season crops prefer a cool soil. Lawn clipping and newspapers make an excellent mulch for these crops by cooling the soil, preventing weed germination, and conserving water. Apply fresh grass clippings only in thin layers (less than ½ inch) and allow it to dry between applications. Thick layers will mat and smell. Do not use clipping from lawns treated with weed killers or other pesticides. Several layers of newspapers covered with grass clippings also work well between rows. Do not use glossy print materials.

4 **Transplanted Cole Crops –** Since cole crops (cabbage, cauliflower, broccoli, and Brussels sprouts) germinate better in warmer soil, they are typically started from transplants in the spring. Days to harvest are from transplants. In the warmer areas of Colorado, these crops produce the best quality when direct seeded mid-summer (early July for the Front Range area) for harvest during cooler fall weather. Before planting out, harden off seedlings.

5 **Transplanting Vine Crops –** Vine crop (cucumbers, squash, melons) roots are extremely intolerant of being disturbed, and perform best when grown by direct seeding rather than by transplants. With the use of black plastic to warm the soil, direct seeded crops germinate rapidly. If using transplants, select small, young plants, not more than 2-3 weeks from seeding.

6 **Tomato family transplants** – The tomato family is traditionally planted from transplants. In warmer areas of Colorado, they can also be direct seeded with minimal delay. Days to harvest are from transplants.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired).

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CMG GardenNotes #721

Sample Planting Guide for Raised-Bed Garden

The following table is a guide for planting a family vegetable garden in a block-style layout. It is based on a raised bed system with boxes four feet wide and rows typically running across the bed (four feet long).

Planting times are based on May 10 and October 10 average frost dates, typical of Colorado's Front Range. In other areas, adjust the planting dates using local average frost dates.

Estimated planting for fresh use and *projected yields* are estimates on what a family of four may consume in fresh use during the harvest period. Actual plantings should be adjusted to the family's likes for various vegetables and desire for canning, freezing, and storage.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired).

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Cool Season Planting Groups	Crops	Block Style Spacing	Estimated Planting for Fresh Use amd Projected Yield	Planting Time	Harvest Period
Cole Crops	Broccoli, cabbage, and cauliflower	3 plants across a 4-foot wide block (row) with 18 inches between rows	1-2, 4-foot rows each per planting 1 head per plant = 3 heads per 4-foot row	Spring planting for summer harvest: 1. Early April – Broccoli and cabbage from transplants 2. Early May – Broccoli, cabbage, and cauliflower from transplants	Spring plantings/summer harvest in June to early July (1-3 weeks per plantings, depending on temperatures) In warm weather crops come on rapidly with reduced quality (sweetness). Check every couple of days for harvestable stage, and store crops in fridge. Crops over-mature rapidly in warm temperatures.
			2-3+ 4-foot rows each. 1 head per plant = 3 heads per 4-foot row	Summer planted for fall harvest: Broccoli, cabbage, and cauliflower by direct seed, mid-July for fall harvest	Summer planting/fall harvest – 4-8+ weeks with excellent quality due to cool fall temperatures. Harvest crops as needed. They tolerate a mild frost into the mid to low 20s and can be stored in fridge or pit for winter use.
Leafy Vegetables & Salad Crops (Kitchen garden)	Lettuce (leaf and soft head types)	Thin to 7-9 inches, with rows 7-9 inches apart	1-3, 4-foot rows, with assorted varieties per planting ~ 6 heads per 4-foot row ~ 3 lbs. per 4-foot row	1. Early April	May-June
				2. Early May	June-July (depending on temperatures)
				3. Late July	Early September+
				4. Mid August	Late September+
	Spinach	Thin to 4-6 inches, with 6 inches between rows	1-3, 4-foot rows per planting ~8 bunch per 4-foot row ~2 lbs. per 4-foot row	1. Early April	May-June
				2. Early May	June-July (depending on temperature)
				3. Late July	Early September+
				4. Mid August	Late September+
	Chard	Thin to 7-9 inches, with 7-9 inches between rows	1-2, 4-foot rows ~ 4 lbs. per 4-foot row	Late April to early May	Harvest by cutting off leaves, plants grow back, for summer long harvest
	Kohlrabi (a cole crop)	Thin to 7-9 inches, with 7-9 inches between rows	1-2, 4-foot rows per planting ~ 6 heads per 4-foot row	1. Early April	June
				2. Early May	Mid June to early July (depending on temperatures)
				3. Mid to late July	September+

Cool Season Planting Groups	Crops	Block Style Spacing	Estimated Planting for Fresh Use and Projected Yield	Planting Time	Harvest Period
Onion Family (Kitchen garden)	Dry onions	4-6 inches, with 4-6 inches between rows	2-5, 4-foot rows ~ 10 bulbs per 4-foot row ~ 3 lbs. per 4-foot row	Early April to early May Onions are sensitive to photoperiod, the early the planting the larger the bulbs.	Mid summer through fall
	Green onions	2-3inches, with 2-3inches between rows	1-2, 4-foot rows ~ 4 bunches per 4-foot row	Early April to early May	Early summer through fall
	Leeks (soup onion)	4-6 inches, with 4-6 inches between rows	1-2, 4-foot rows ~ 10 bulbs per 4-foot row	Early April to early May	Fall into winter (for winter harvest leave in garden and mulch to protect from extreme cold, dig as needed.)
Peas	Peas	Thin to 3-4 inches, with 8 inches plus between rows Note: Peas are easier to pick in a single or double row rather than in the block-style plantings	20’ double row ~ 12 lbs per 20’ double row	1. Early April to early May, as soon as soil temperature reaches 40ºF. Peas are sensitive to photoperiod, early plantings give higher yields.	June
			20’ double row ~ 6 lbs. per 20’ double row	2. Mid July	September Note: fall plantings are prone to powdery mildew and have lower yields, making them questionable.
Potatoes	Potatoes	3-4 plants across a 4-foot wide bed, with 15 inches between rows	A 16-foot by 4-foot bed of potatoes would produce around 72 pounds.	Early May	July+ Mulch with straw

Cool Season Planting Group	**Crops**	**Block Style Spacing**	**Estimated Planting for Fresh Use and Projected Yield**	**Planting Time**	**Harvest Period**
Root Crops	Carrots	Thin to 2-3 inches, with rows 3 inches between rows	6-18+, 4-foot rows ~ 4 lbs. per 4-foot row	Early May	July through fall; can be left in the garden and mulched for winter harvest.
	Beets	Thin to 4-6 inches, with 4-6 inches between rows	1-2, 4-foot rows per planting ~ 4 lbs. per 4-foot row	1. Early May	June-July – Thin for beet greens. Harvest roots while young (small) for best quality
				2. Mid July	September-October – Thin for beet greens. Harvest roots while young (small) for best quality
	Parsnips	Thin to 5-6 inches, with 5-6 inches between rows	2-6, 4-foot rows ~ 4 lbs. per 4-foot row	Early May	For late fall to winter harvest, after soils cool, mulch for harvest through the winter.
	Radish	Thin to 2-3 inches, with 2-3 inches between rows	1-2, 4-foot rows per planting ~ 4 bunches per 4-foot row	1. Early April	Early May
				2. Early May	Early June
				3. Early August	Early September
				4. Late August	Late September
	Turnips	Thin to 4-6 inches with 4-6 inches between rows	1-2, 4-foot- rows per planting ~ 4 lbs. per 4-foot row	1. Early May	June-July -- Thin for greens. Harvest roots while young (small) for best quality
				2. Mid July	September-October – Thin for greens. Harvest roots while young (small) for best quality

Warm Season Planting Group	Crops	Block Style Spacing	Estimated Planting for Fresh Use and Projected Yield	Planting Time	Harvest Period
Beans	Pole beans	Thin to 4 inches in a single row	10-20’ row ~ 10 lbs. per 10 foot row	Mid May	July till frost, with adequate water
	Bush beans	Thin to 4 inches , in double row. Beans are easier to pick in a single or double row rather than block-style planting.	10-20’ row ~ 10 lbs. per /10 foot double row	Mid May	July till frost, with adequate water
Corn		For pollination, corn must be planted in block with 4+ rows wide. In a block-style garden, plant 4 rows with 2 rows each going the length of the box, in 2 boxes side by side. Space plant 9 inches in the row.	A block of 4, 6-foot rows will give ~60 ears	1. Mid May 2. Mid June	Late July to October – Harvest period on any variety is only 10 to 20 days. For continual harvest of fresh corn plant varieties with 20+ days difference till harvest OR make second planting 20-30 after the first.
Eggplant		3 plants across a4 foot row, with rows 18-24 inches apart	1, 4-foot rows ~ 12 fruit per 4-foot row (4 fruit per plant)	Late May, temperatures consistently above 60 ºF	August till frost (A Wall-Of-Water can be used for earlier production.)
Peppers		3 plants across a 4-foot row, with rows 18 inches apart	1-4, 4-foot rows, depending on family use Yields vary with variety ~ 18 bell peppers/4-foot row (6 fruit per plant)	Late May, temperatures consistently above 60 ºF	August till frost (A Wall-Of-Water can be used for earlier production.)
Tomatoes		Trellis in single row, plants spaced 24 inches apart.	3-6 plants, depending on family use ~ 26 lbs. (½ bushel) per plant	Late May, temperatures consistently above 60 ºF	August till frost (A Wall-Of-Water can be used for earlier production.)

Warm Season Group	Crops	Block Style Spacing	Estimated Planting for Fresh Use and Projected Yield	Planting Time	Harvest Period
Vine Crops	Cucumbers	Trellis in single row, plants spaced at 6 inches.	2-4 plants, depending on family use ~ 1 lb. per plant	Mid May for direct seeding OR late May for transplants	Mid July till frost For maximum yields, do not let fruit get large on the vine.
	Zucchini and other summer squash	Single row down center of 4-foot box; two plants take 4-foot by 8-foot	2 plants	Mid May for direct seeding or late May for transplants	Mid July till frost (A Wall-Of-Water can be used for earlier production)
	Cantaloupes, Watermelon, Pumpkins, and Winter Squash	1-3 plants per type, as desired by family 2-6 fruit per plant	Single row down center of 4 inches wide box with 2-3’ between plants. Makes a great ground cover for garden areas. ~ 3-4 fruit per plant	Late May, temperatures consistently above 60°F	September-October

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CMG GardenNotes #722

Frost Protection and Extending the Growing Season

Types of Frost

Advective frosts occur when a cold front moves into the area. Temperatures may drop significantly below critical levels thereby making crop protection questionable.

Radiation frosts occur on calm clear nights that lack cloud cover to hold in heat. Radiation frosts at the beginning and end of the growing season are typically only a few degrees below critical levels, making crop protection worthwhile.

Heat Source at Night

Soil, warmed by the sun in the daytime, is the source of heat for frost protection at night. Moist, smooth soil absorbs more heat. To trap heat from the soil around young vegetables at night, place a covering that is low to the ground and spreading. To recharge the heat source for the next night, any covering must allow sunlight to shine through to the soil or must be removed in the daytime. [Figure 1]

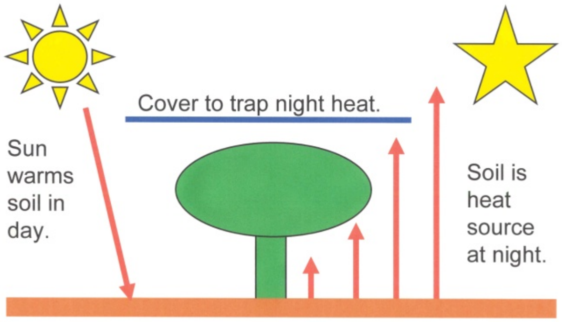

Figure 1. The sun warms the soil in the daytime. Heat from the soil keeps crops warm at night. A covering traps heat from the soil around the crops.

Coverings

Blankets and Sheets

Grandma's old method of covering the garden with blankets and sheets works well as long as the fabric remains dry. If the fabric absorbs water, evaporative cooling can lead to colder temperatures adjacent to the blanket. To recharge the heat stored in the soil, the blankets and sheets must be removed in the daytime.

Floating Row Covers

Floating row covers are lightweight fabrics that lay directly over crops. Because they transmit light, they provide crop protection over an extended period of time without being removed. They provide 2°F to 4°F of frost protection, cut wind on tender plants, and screen out some insects. On insect pollinated crops, covers must be removed for pollination to occur. [Figure 2]

Floating row covers are popular in commercial vegetable production where crops planted in large blocks are easily covered with row covers. Many brands and fabric types are commercially available.

Figure 2. Floating row cover on broccoli and cabbage, protecting crops from cabbageworms moths.

Clear Plastic Covering on Frame

When plastic is used as a covering over a growing bed, it must be held up off the plants. Plants will freeze where the plastic touches them.

Tunnel Gardening – Gardening catalogs carry wire hoops for use in "tunnel" or cloche gardening. Hoops are placed at three to five foot intervals depending on the wind exposure of the site. The wire hoops hold up a strip of plastic forming a tunnel-shape covering down the growing bed. Bury the edges of the plastic a few inches into the soil on all sides. On a raised-bed box made with lumber, staple the plastic to the sides of the box. Two-inch holes cut in the sides of the plastic tunnel at two to three foot intervals are essential to reduce overheating.

This type of covering is popular with commercial tomato, pepper, and melon growers for an early start to the growing season. It provides 2°F to 4°F of frost protection, protects tender plants from cold spring wind, and provides warmer growing temperatures inside the tunnel. Tunnels are removed when warm weather arrives and the danger of frost is past.

Plastic Covered Cold Frame Made with Concrete Reinforcing Mesh

An easy cold frame structure for a growing bed is made with 4-mil clear plastic (polyethylene film) draped over concrete reinforcing mesh. The structure is easily opened during warm days and closed for cold nights. It works well with a 4-foot wide, raised-bed garden system. [Figure 3]

Figure 3. Cold frame for a raised bed garden made from concrete reinforcing mesh covered with 4-mil plastic. Notice the belt-like plastic straps, which hold the covering in place. The covering is slid between the straps and mesh to open and close. Pictured open for ventilation on a warm day.

The frame is concrete reinforcing mesh, available at hardware and lumber stores. This stiff wire mesh typically comes five feet wide, in 50 and 100-foot rolls. A six-foot length is required to make a Quonset-type frame over a four-foot wide growing bed. In trials, the low and spreading shape was ideal for trapping heat from the soil during a frosty night.

Cover the frame with clear, 4-mil polyethylene plastic. It typically is sold in 10’ by 25’ rolls. For a four-foot wide raised bed box, place a 3½-foot wide section on each side, overlapping at the top. On a raised bed box, staple the plastic to the sides of the wood box. In soil bed applications, bury the plastic a few inches along the sides.

Hold the plastic onto the frame with small clips available at local hardware stores. Clothespins do not hold in the wind. Another method is to use a series of 6-inch wide, belt-like plastic straps arching over the frame (above the plastic cover) and stapled onto the box. Open and close the cover by sliding it between the frame and the belt-like straps. Hold the plastic closed at the ends with a rock or brick. [Figure 4]

Figure 4. Clip holds plastic on frame.

During the day, the covering MUST be opened, at least a slit, to prevent overheating. With just an hour of sun, temperatures under a closed cover can quickly rise to over 130°F! [Figure 5]

On cool days, open the top a crack to prevent excessive heat build-up. On a warm day, the plastic can be slid down the side, ventilating and providing crops exposure to the outdoors. On freezing nights, close the cover completely. On warm nights, the covers may be left open a crack. On stormy days with full cloud cover and no direct sun, the cover may remain closed. [Figure 5]

Figure 5. Left: Cover must be opened at least a slit to prevent over-heating. Right: Cold frame pictured closed for a cold night.

Not only will the covers provide frost protection, they also increase growing temperatures for early crop growth and provide protection from cold winds.

In trials in Fort Collins, Colorado, a plastic cover on a frame typically provides 3°F to over 6°F of frost protection. It works well for cool season crops that are somewhat tolerant of frosty nights, and adds two to six weeks or more on both ends of the growing season. For warm season tomatoes and summer squash crops (being intolerant of a frosty nip), adding a small light inside the cold frame provides even better frost protection.

Adding Space Blankets

On extra cold nights, placing an aluminum space blanket over the plastic on the frame significantly adds to the frost protection. With the aluminized side placed down (towards the plants), a space blanket reflects 99% of the heat. They are readily available where camping gear is sold. [Figure 6]

In trials in Fort Collins, topping a plastic-covered, concrete mesh cold frame with a space blanket prevented freezing when outside temperatures dipped to 0°F following a sunny spring day. The space blanket must be removed each day to recharge the soil’s stored heat

Figure 6. Aluminum space blanket covering a cold frame for extra protection on cold nights.

Lights for Additional Heat

Christmas tree lights – For additional protection, add Christmas tree lights inside the cold frame. In Fort Collins trials, one 25 light string of C-7 (mid-size) Christmas lights per frame unit (four feet wide by five feet long) gave 6°F to over 18°F frost protection. Lights were hung on the frame under the plastic and turned on at dusk and off at dawn. Christmas lights work better than a single, large light bulb in the center by eliminating cold corners and edges. [Figure 7]

Figure 7. Cold frame with Christmas tree lights for additional warmth.

Space blanket with Christmas tree lights – For the gardener really wanting to extend the growing season, try Christmas lights plus a space blanket. One 25 light string of C-7 (mid-size) Christmas lights per frame unit (four feet wide by five feet long) with a space blanket on top gave 18°F to over 30°F frost protection in Fort Collins trials.

Wall of Water®

The Wall-of-Water® is a cone-shaped ring of connected plastic tubes filled with water that surrounds a single plant, like a tomato, pepper, or summer squash. [Figure 8]

This device works on the chemistry principle of heat release in a phase change; there is a significant amount of heat released as water freezes (changes from the liquid phase to the solid or ice phase). A Wall-of-Water provides frost protection typically down to temperatures in the mid-teens. It also provides wind protection for tender plants and growing temperatures may be slightly warmer inside a Wall-of-Water.

They are helpful to get a few extra weeks head start on vine ripe tomatoes. However, an extra early tomato may out-grow the protection and the tops may be nipped back by frost.

Both cold air temperatures and cold soil temperatures are limiting factors in early crop production. When using a Wall-of-Water to start early crops, warm the soil with black plastic mulch.

In filling the Wall-of-Water, be careful not to splash excessive water onto the soil. A wet soil will be both slow to warm and dry in the spring. Moderately moist soils are best.

Figure 8. Tomato in Wall-of-Water. Notice use of black plastic mulch to warm the soil, another limiting factor of early production. Also, note the plant has grown beyond the device and is now less protected from frost.

Authors: David Whiting (CSU Extension, retired), with Carol O'Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Photographs by David Whiting; used by permission.

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #723

Growing Vegetables in a Hobby Greenhouse

Extending the Growing Season

Off-season vegetable production in the hobby solar greenhouse is an enjoyable way for year-round gardeners to extend the harvest season of fresh vegetables. However, without the expense of a greenhouse, gardener can extend the growing season weeks to even months with cold frames and plastic tunnel gardening

Winter vegetable production in a greenhouse is only cost effective with an energy efficient greenhouse structure, a well-designed solar collector, and optimum management. Winter vegetables have a slow growth rate due to low light intensity. Crops should be planted to obtain a near harvestable size by mid-October. The use of artificial light for vegetable production (except for starting transplants) is generally not cost effective.

A gardener's success is dependent on the greenhouse design and construction to conserve energy and on the management care given the greenhouse crops.

Before investing in a greenhouse, carefully consider your real interests in extending the gardening season. Are you only interested in adding a few weeks to the harvest season? Are you interested in year-round gardening in a solar greenhouse OR do you need a winter break?

Passive Solar Greenhouse

For the gardener considering a passive solar hobby greenhouse, here are a few key points to consider. Refer to other greenhouse references for additional details.

For solar collectors, any area with direct sun, but not blocking solar illumination of plants, is a potential location. For a hobby greenhouse, solar collectors are typically built into an insulated north wall.

A solid brick wall on the north makes a good solar collector. Brick absorbs 30 to 35% of the solar radiation. With a brick storage wall, the greenhouse quickly heats on a sunny winter day and ventilation will be needed by mid morning. [Figure 1]

Figure 1. Brick storage wall in passive solar hobby greenhouse – Thermal storage mass is a wall made with two layers of brick filled with concrete. In this well-built structure, nighttime temperatures dropped to 35°F with no supplemental heat when outside temperatures dropped to -17°F. Note young crops in raised-bed style garden with drip irrigation.

Water storage using plastic milk jugs makes a great storage system. Water jugs absorb 90% of the solar radiation, holding three times more heat than brick or rock. This increased heat storage holds night temperature higher longer into the night, resulting in slightly improved crop growth compared to brick storage. [Figure 2]

Figure 2. Milk jug water storage wall in a passive solar hobby greenhouse. Disposable milk jugs on left and returnable milk jugs on right are spray painted flat black. In this well-built structure, nighttime temperatures dropped to 39°F with no supplemental heat when outside temperatures dropped to -17°F.

With milk jug storage, spray the milk jugs with flat black paint, and add one tablespoon of liquid bleach per jug (to prevent algae growth in the warm water). Secure the cap back on the jug with a ring of caulk. Place the milk jug on a bookcase type frame not more than two jugs high.

Disposable milk jugs develop leaks over time and require routine replacement. Heavier weight jugs (like returnable plastic milk jugs) last longer. Other types of containers may be used. Keep the size two gallons or smaller or water will stratify with hot water on the top and cooler water on the bottom, reducing efficiency.
A passive solar hobby greenhouse is only effective when built to optimum energy specifications. Because the major heat loss is through the glazing, double-glazing (which reduces heat loss by 25 to 35%) is required. Double glazed patio door glass is great for glazing a hobby greenhouse. Glass suppliers sometimes have recycled

(used) patio door glass available at minimal prices. Night curtains may add an additional 30 to 50% energy conservation. On a passive solar hobby greenhouse, the north, east, and west walls are typically insulated to an R-value of R38. The foundation and floor are insulated from heat loss to the ground. [Figure 3]

Figure 3. Hobby greenhouse being constructed with double glazed patio door glass.

Cold air infiltration is the second major source of heat loss. For passive solar to be effective, minimize cold air infiltration with good design and construction techniques. Insulative vent covers help reduce cold air infiltration at night, but must be removed daily to allow thermostats to maintain proper temperature.

A passive solar hobby greenhouse requires an east to west orientation. In northern Colorado latitudes, an east to west orientation receives 25% more solar energy than a north to south orientation. Sometimes the hobby greenhouse may be oriented slightly to the east for faster morning warming. An orientation 20º off east to west will cut 4 to 5% of the solar potential, while an orientation 45º off east to west will cut 18 to 20% of the solar potential. At northern Colorado latitudes in January, a north to south orientation cuts 25% of the solar potential.

A poorly constructed greenhouse cannot be retrofitted into an efficient passive solar unit.

Cool Season Vegetables

Cool season vegetables do well in the greenhouse or cold frame. High temperatures are not desirable, and an occasional near freezing dip will not harm crops. High light intensity is not as critical for cool season crops as for warm season crops. [Figure 3]

Figure 4. Lettuce in solar greenhouse raised bed.

General temperatures for cool season crops

Daytime: 50ºF to 70ºF Short-term temperature extremes: 35ºF to 90ºF
Nighttime: 45 ºF to 55 ºF Germination: 40ºF to 75ºF

Vegetable	**Minimum Container Size***	**Minimum Equal-Distance Spacing**	**Remarks**
Beets	8" deep	6"	• Grow in fall and hold in cool greenhouse for winter use. • Properly thin.
Broccoli Cabbage Cauliflower	10" deep 5 gallons/plant	18"	• High yield for space used. • Avoid long-term temperature extremes. • Heads split with warm humid conditions.
Carrots	12" deep	3"	• Extremely sweet with adequate water and cool temperatures. • Use short varieties, like Short & Sweet or Scarlet Nantes • Questionable use of greenhouse space.
Chard	8" deep	9-12"	• Does exceptionally well.
Kohlrabi	8" deep	9"	• Does exceptionally well.
Leaf lettuce	4" deep	9"	• Easy to grow in fall, winter and spring in solar greenhouse. • Use softhead or leaf types. • Keep temperatures under 70 ºF.
Green onions	6" deep	3"	• Never let onions get dry. • Sensitive to photoperiod (length of night). With short days (long nights), growth goes into leaf production. With long days (12-16 hours) energy goes into bulb production.
Peas	8" deep	6"	• Use dwarf, edible-pod or snap types for salads and stir-fry. • Avoid temperature extremes. • Questionable use of space. • Do not transplant well, not well suited to container gardening.
Radish	5" deep	2-3"	• Avoid water and heat stress. • Must have 12 hours of light to root. • For fall and spring crops in greenhouse.
Spinach	8" deep	6"	• Needs cool greenhouse (45ºF to 50ºF) for best quality. • Avoid temperature fluctuations.
Turnips	8" deep	6"	• Good for fall and spring crops.

Many oriental vegetables are also suited for greenhouse production.
*A larger container size will make crop easier to care for, providing a larger supply of water and nutrients.

Warm Season Vegetables

Warm season vegetables require high light intensity and moderate night temperatures. They cannot be cost effectively grown during the winter in a hobby greenhouse without solar heat collectors. Greenhouse climates control is critical for these fruiting crops to produce. Warm season crops are not compatible with cool season crops due to differing temperature needs.

General temperatures for warm season crops

Daytime – 60ºF to 85ºF　Short-term temperature extremes – 50ºF to 95ºF
Nighttime – 55ºF to 65ºF　Germination – 60ºF to 85ºF

Vegetable	**Minimum Container Size**	**Minimum Equal-Distance Spacing**	**Remarks**
Beans	8" deep	6"	• Not a common greenhouse crop. • Good production with adequate light and spacing in spring and fall. Poor winter production. • May be questionable use of greenhouse space.
Cucumbers	8" deep 3-4 gallons/plant	18"	• Requires high humidity, high light intensity, and good moisture. • Needs 75ºF to 80ºF day temperatures and 50ºF minimum nights. • Avoid temperature fluctuations greater than 20ºF. • Poor mid-winter production. • Plant gynecious greenhouse types. • Needs good air circulation to minimize powdery mildew.
Eggplant	8" deep 4-5 gallons/plant	24"	• Hand pollination required.
Muskmelon	8" deep 5 gallons/plant	24"	• Uses lots of space for yield, try trellising. • Needs 80ºF day temperatures. • Requires hand pollination. • Needs good air circulation to minimize powdery mildew.
Peppers	8" deep 2-5 gallons/plants	15"	• Minimum night temperatures of 55ºF. • Hand pollination required.
Summer Squash	8" deep 5 gallons/plant	24"	• Hand pollination required. • Needs good air circulation to minimize powdery mildew. • Productive with good sunshine.
Tomatoes	12" deep 2-5 gallons/plant (depending on cultivar/plant size)	24"	• Minimum night temperature of 55 F. • Hand pollination required. • Productive with good sunshine.

*A larger container size will make crop easier to care for, providing a larger supply of water and nutrients.

Figure 5. Beans in solar greenhouse raised bed

Figure 6. Raised bed in solar greenhouse.

Authors: David Whiting (CSU Extension, retired), with Carol O’Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired). Photographs by David Whiting; used by permission.

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MASTER GARDENER
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CMG GardenNotes #724

Vegetable Gardening in Containers

Container vegetable production is somewhat more demanding than growing flowers and other ornamentals in containers. Quality of most vegetables is based on the soil's ability to provide a constant supply of water and nutrients. Vegetables become strong flavored, stringy, and tough under dry or low fertility conditions. With the limited root spread in a container, the gardener must frequently and regularly supply water and fertilizer. In growing container flowers, minor lapses in daily care may interrupt flower production, but flowering eventually resumes with returned quality care. With container vegetables, minor lapses in daily care may significantly reduce produce quality.

Warm Season Vegetables

Warm season vegetables prefer warmer summer temperatures (70ºF to 95ºF) and are intolerant of frost. They are typically planted after the average spring frost date as summery weather moves into the area. Along the Colorado Front Range, planting time would be mid-May to early June. Warm season crops need full sun.

Cool Season Vegetables

Cool season vegetables prefer the cool growing temperatures (60ºF to 80ºF) of spring and fall. Most are intolerant of summer heat. They do tolerate light frosts. Leafy and root vegetables prefer full sun, but are tolerant of partial shade. They are intolerant of reflected heat during the summer season.

Spring crops are typically planted two to four weeks before the average spring frost date. Along the Colorado Front Range, spring planting times are mid-April to early-May. Most are replanted in mid-July to mid-August for a fall harvest.

The quality of these vegetables is directly related to their ability to grow rapidly in a good soil mix under frequent light fertilization and a constant supply of water. Crops become strong flavored if they become dry.

Warm Season Vegetables

Vegetable	Minimum Container Size*	Minimum Direct Sunlight Per Day	Remarks
Beans	8” deep	full sun	• In a long box 12 inches wide, plant bush beans or trellis pole beans. • Beans have a high water requirement during blossoming. • Beans drop blossoms with dry soil or excessive wind.
Cantaloupes Muskmelons	5+ gallons/plant	full sun	• May be trellised to conserve space. • Compact varieties preferred for container gardening. • With male and female blossoms, may need hand pollination. • Needs good air circulation to minimize powdery mildew.
Cucumbers	8” deep 3+ gallons/plant	full sun	• Grow bush-types in hanging baskets or on a trellis (vines grow 18-24 inches long). • Grow strong vining-types on trellis. • Needs good air circulation to minimize powdery mildew. • Young plants are very sensitive to wind burn.
Eggplant	8” deep 4-5 gallons/plant	full sun	• One plant per container. • Needs night temperatures above 55ºF for pollen development.
Peppers	8” deep 2-5 gallons/plants	full sun	• One plant per container or space to 14 to 18 inches in row. • Needs night temperatures above 55ºF for pollen development. • Decorative, attractive plant with fruit.
Summer Squash (Zucchini)	36” by 36” space 8” deep 5 gallons/plant	full sun	• Compact varieties more suited to container gardening. • Great in a whiskey barrel size container. • One plant will produce six or more fruit per week. • Has male and female blossoms. May need hand pollination. • Needs good air circulation to minimize powdery mildew. • Keep fruit picked for continued production.
Tomatoes	12” deep 2-5 gallons/plant depending on variety (plant size)	full sun	• Varieties vary in mature plant size from determinate (bush) types to large, indeterminate vines over 6 feet tall. • Patio types (small vines) are great for container gardening and may be grown as hanging baskets or trellised. • Standard garden types require a larger container (like a whiskey barrel) and trellising. • Needs night temperatures above 55ºF for pollen development. • Crowding cuts yields and increases disease potential. • Blossom end rot (black sunken area on bottom of fruit) is a symptom of inconsistent watering or a soil that does not have enough water storage.

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* Larger container sizes will make crop easier to care for, providing a bigger supply of water and nutrients.

Cool Season Vegetables

Vegetable	Minimum Container Size*	Minimum Direct Sunlight Per Day	Remarks
Beets	8” deep	8 hours	• Best in cool temperatures, grow a spring and fall crop. • To give space for root development, thin greens to 3”. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce.
Broccoli Cabbage Cauliflower Kale Collards	10” deep 5 gallons/plant	8 hours	• Best in fall production (e.g., plant mid July for fall harvest along the Colorado Front Range). • Minimum spacing per plant is 18 by 18 inches. • A consistent supply of water and nutrients promotes rapid growth and is essential for quality produce. • Heavy feeder, requiring frequent light fertilization. • Crops develop a strong flavor if the soil gets dry.
Carrots	12” deep	8 hours	• Best in cool temperatures, grow a spring and fall crop. • Use short root varieties. • Roots will crack and be strong flavored if the soil gets dry. • Thin early to two to three inches apart. • Foliage is rather decorative.
Chard	8” deep	6 hours	• Space to six plus inches between plants in a row. • Harvest outer leaves allowing plants to continue to grow. Makes an excellent “cut and grow again” crop. • Colored varieties are very decorative. • Responds to frequent light fertilization. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce.
Kohlrabi	8” deep	8 hours	• Best in cool temperatures, grow a spring and fall crop. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce. • Never allow soil to become dry. • Kohlrabi is a heavy feeder, requiring frequent, light fertilization.
Lettuce (leaf)	8” deep	6 hours	• Grow as a spring or fall crop; avoid hot summer temperatures. • Use softhead or leaf types. • As the young crop grows, thin to 9” spacing; crowding (competition for space, water and nutrients) reduces quality. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce. • Responds to frequent light fertilization. • Lettuce become strong flavored if the soil become dry, during hot weather, and with crowded plants

Vegetable	Minimum Container Size*	Minimum Direct Sunlight Per Day	Remarks
Onions (green)	6” deep	8 hours	• Onions require a consistent supply of water. Never allow soil to become dry. • Thin the crop by harvesting young plants. • Plant in early spring. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce.
Peas	8” deep	Full sun	• Not well suited to container gardening. • Best in cool temperatures, grow a spring and fall crop. • Use dwarf, edible-pod or snap types for salads and stir-fry. • May be grown in hanging baskets or trellised. • Needs good air circulation to avoid powdery mildew.
Radish	8” deep	8 hours	• Best in cool temperatures, grow a spring and fall crop. • A consistent supply of water and nutrients to promote rapid growth is essential for quality produce.
Spinach	8” deep	6 hours	• Best in cool temperatures, grow a spring and fall crop. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce.
Turnips	8” deep	8 hours	• Best in cool temperatures, grow a spring and fall crop. • When large enough to make greens, thin to four inches allowing roots to develop. • A consistent supply of water and nutrients promotes the rapid growth essential for quality produce.

* Larger container sizes will make crop easier to care for, providing a bigger supply of water and nutrients.

Authors: David Whiting (CSU Extension, retired), with Carol O’Meara (CSU Extension, Boulder County), and Carl Wilson (CSU Extension, retired).

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MASTER GARDENER
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CMG GardenNotes #731

Herb Gardening

Outline:

From every walk of life and corner of the globe, humans and herbs have shared history. Throughout ancient Egypt, Mesopotamia, Africa, India, and China, some of the earliest herb gardens have served us with medicinal, religious, and culinary staples; they've perfumed bodies, disinfected houses, and repelled insects. Monasteries and some in the Islamic culture began what is considered modern herb gardens: growing similar plants together in mostly symmetrical blocks.

Herbs are defined as any plants or plant parts valued for "medicinal, savory, or aromatic qualities." By this definition, herbs can be trees, shrubs, herbaceous perennials, annuals, vines or lower plants. Classified in many ways, though method of use is one of the most common: culinary, ornamental, medicinal, aromatic, and economic/industrial (dyes, cosmetics, pesticides, etc). Length of growing period, and whether they're annuals or perennials can also be classifiers.

Herbs are grown directly in the ground or in container production. Containers can be placed outdoors, indoors, or moved back and forth based on the season and plant needs.

Herb Garden at Government House, Victoria, BC

Ground Production

Light

Light is the most important consideration when choosing placement of herbs in a garden. In general, herbs need a minimum of 6 hours of full/direct sunlight daily. In Colorado, west and south exposures are ideal for growing herbs.

Soil

Most herbs prefer well-draining soil. Colorado soils tend to be low in organic matter and therefore need amending with plant-based compost. Mix the organic matter in with the soil as deep as the expected root depth, usually 24 inches or more. All soil amendments need to take place before planting.

Soil pH level is also important. The majority of herbs thrive in a pH of 6-6.5, just below neutral. However, the pH of most soils in Colorado tends to be high or alkaline, which is difficult to correct.
Before the first frost, plants should be covered with a layer of straw for extra protection from winter damage and winter kill. Periodic watering throughout the winter season will aid in plant root health.

Water

Many herbs originate from around the Mediterranean. Most herbs, like fennel, prefer warm and dry locations. Some exceptions, such as mints, parsley, cress, or chervil, thrive in higher moisture levels. Most plant tags provide watering information or can be investigated online.

Diseases are common on many herbs and spread by splashing water, especially onto plant leaves. Therefore, drip irrigation is recommended, as it prevents disease and conserves water. Water container plants at the base, not the top of the plant.

Pruning

Most herbs need to be pruned in early spring to control growth, especially woody herbs. Make sure to remove all dead and damaged branches and stems. A mid-summer pruning can also be beneficial. However, at that time, only shorten the branches by one-third to one-half their length, making sure to leave some greenery and growth nodules (look like bumps or scars) on the stems. Some herbs have more detailed or special pruning needs.

Harvesting

The best time to harvest is in the morning, after the dew has dried, on a day with no rain. Harvest no more than one-third of perennial plants at a time. Harvest annuals to about four inches tall, allowing for a second growth that can be harvested later that season.

Container Production

Container Type

Take into consideration what material the container is made of: ceramic, clay, plastic or wood. There are good and bad aspects to all types. Plastic containers work well during the summer in hot environments, but need a heavier media to provide support for the plants. Plastic holds water in, is lightweight, and restricts air movement. Clay pots are good for support and air movement, but can be heavy, hard to move, and require more frequent watering. Wood containers have better air movement, but also need more frequent watering. Ceramic pots typically have glazing on the outside, so they restrict air movement but hold water well. For more information see “Container Gardens” fact sheet on the CSU Extension.

Light

Herbs need the same amount of direct sunlight in containers as when planted in the ground. Place containers appropriately for this consideration. Inside the house, they should be placed by west and/or south facing windows. If they still cannot get the correct amount of light indoors, supplemental lighting can be used. Growing lights can be purchased at garden centers and most major hardware stores. If this is not financially an option, two 40 watt white florescent bulbs can be placed six to twelve inches away from the plants and left on for 14-16 hours per day.
Rotate containers periodically in order for the light to reach all sides of the plants equally. This will enable healthy and balanced growth.

Soil

Soilless media is very common for container use; it looks like soil but is lighter weight and holds water and nutrients well. Soil mixes are also available but need to be free of weed seeds, insects, and diseases. Putting soil directly from the ground into a container does not work well because it will not provide adequate drainage and air movement.

Mix controlled-release fertilizer into the media at planting time, then fertilize every week or two with a water soluble fertilizer to maintain fertility.

Water

Containers tend to dry out more quickly than ground soil. Therefore, containers require more frequent watering. Frequency of watering is dependent on whether the pot is porous, like wood and clay, or not. Herbs that have similar water requirements can be placed together. Dill, cilantro and parsley like similar amounts of water, so can be planted together.

Outdoors, containers need more water more frequently. Containers indoors should be monitored to make sure they aren't over watered and that they don't attract pests or develop diseases like powdery or downy mildew.

Common Herbs

Chervil – *Anthriscus cerefolium*

Part of the Carrot family, chervil is a short-lived, cold hardy annual. The foliage is aromatic and the leaves have culinary uses. Chervil grows between 12-28" tall and 9-12" wide. Moist, cool, and well-draining soil is best; seed germination won't take place if the soil is too warm and dry.

Chervil likes part shade in the spring and fall, full sun in the winter and full shade in the summer, so a partially shaded spot is best. Chervil doesn't do well indoors.

Chervil is propagated through seed in the spring. Wait until the plants are four inches tall before harvesting leaves. Harvest the outermost stems first, but only until summer flowering. Common chervil pests are slugs, caterpillars, and, rarely, powdery mildew.

Chives – *Allium schoenoprasum*

Chives are hardy perennials belonging to the onion family. The main use is culinary (using the foliage) but they are also aromatic and occasionally ornamental. They grow 12-24" tall and 12-18" wide in full sun and a moist soil, but not constantly wet. Chives grow in hardiness zones 3-9. Flowering comes during late spring and early summer. Cut back the stalks after blooming.

Plant bulbs or through division in the fall and the first growth might be as early as March. Divide clumps every three years. Harvest the outside leaves first. Every 4-6 weeks during the growing season, the plants can be harvested. Harvest fairly frequently, even if not needed, for best plant growth.

Chives grow well both in the ground and in containers, indoors and outside. However, they are susceptible to powdery mildew, downy mildew, rusts and onion smut. So, when growing Chives indoors, carefully monitor the amount of water applied as to not increase the chances of disease.

Cilantro / Coriander – *Coriandrum sativum*

The leaves of Coriandrums are called “cilantro” while the seeds are coriander. As part of the Carrot family, Coriandrum is an annual that grows between one to three feet tall and 4-12” wide. Growth is best in full sun with moist but not constantly wet soil. The foliage is aromatic and the plants have economic and culinary uses. Flowering takes place in summer.

Coriandrum should not be planted near fennel because it inhibits fennel seed production. Propagate by seed in the spring and fall, but germination is unpredictable. Stems need staking once seeds set and begin to ripen.

Cilantro should be harvested when the leaves are young, starting with the outermost leaves. Harvesting leaves should not take place after flowering. Coriander should be harvested when half of the seeds are still green and the other half have ripened to gray.

Fusarium wilt, leaf and flower spot, and powdery mildew are problems for Coriandrum. Outdoors, caterpillars feeding on the foliage can also be pests.

Dill – *Anethum graveolens*

An annual that grows about 20-48” tall belonging to the Carrot family, dill has ornamental flowers, aromatic value and culinary uses for the foliage. They like full sun and moist, medium-heavy soil that drains well. Plant dill in a sheltered location to protect it from the wind, staking if necessary once the plant reaches 18” or taller. It will cross pollinate with Fennel planted nearby.

Start dill from seed; it does not tolerate transplanting well. Avoid overcrowding by thinning seedlings when they reach 12” tall. Pruning in the summer can promote new growth.

Dill is susceptible to Fusarium root rot, especially in containers. Slugs and Parsley worm, which is the larvae of the tiger swallowtail butterfly, can damage plant foliage and roots.

Fennel – *Foeniculum vulgare*

Another member of the Carrot family, fennel is an herbaceous annual. The foliage is aromatic, the seeds and bulbs have culinary uses, and the plant is used economically to make products like perfumes and cosmetics. Butterflies are attracted to fennel.

Full sun and moist but well-draining soil are best, yet fennel is drought tolerant and does well in hardiness zones 4-10. Fennel grows about 6” tall and 18” wide. Don’t plant near bush beans, kohlrabi, or tomatoes because it inhibits their growth. Fennel doesn’t grow well indoors.

Propagate by seed in the spring, or divide bulbs in early spring. Due to heavy self-sowing, cut back flower heads before seed set unless seeds are desired.

Harvest the leaves any time during the growing season. Harvest seeds for fresh use in the summer and for drying in the fall.

Fennel is susceptible to Cercospora leaf spot and mycoplasm. Slugs and aphids are also problematic.

Horseradish – *Armoracia rusticana*

Belonging to the Mustard family, horseradish is a hardy herbaceous perennial that grows 1-4 ft tall. It likes full sun and moist soil, but can be slightly drought tolerant. Hardiness zones 3-10 are optimum. Contact with the sap can cause skin irritation. Both roots and leaves have culinary uses.

This plant is very invasive; once planted horseradish is difficult to remove. Planting in containers can prevent this, but division and repotting are necessary. Division is the best form of propagation and should be done in early spring. Horseradish needs frequent watering so the roots don’t become woody.

Only the larger roots should be harvested. Harvest in the spring and/or fall. Leaves are harvested when young, especially in the spring.

Horseradish is susceptible to white rust and bacterial leaf spot. The cabbage caterpillar is also a common pest.

Mint – *Mentha* spp.

As herbaceous perennials, mints grow in hardiness zones 4-9. They are aromatic and can be used for culinary purposes. Mints grow well in full sun to partial shade with well-draining, moist soils. Different species of mint should be grown separately to prevent cross breeding.

Mints are vigorous growers and can take over a garden, so border the plants with deep edging or put in containers that are then planted into the ground to prevent spreading. Division is necessary every three years, replanting the young growth for reestablishment.

Traditional container production works well. However, pot soil should never be allowed to dry out and, due to the fast growth rate, frequent division and repotting is necessary. Divide during spring or fall.

Harvest for fresh crops any time during the growing season. Mint harvested for drying should be taken before flowering.

Rust is a major disease of mint, but has no form of management, so any plants showing rust should be thrown out. Verticillium wilt, a fungal disease, is also of concern. No treatment is available; remove and destroy infected plants.

Oregano – *Origanum vulgare*

Oregano is a hardy perennial belonging to the Mint family. Height and width reach 12-36” with summer blooming flowers. Oregano likes full sun and well-draining, slightly alkaline soil. The leaves are used for culinary purposes and the foliage is aromatic. Hardiness zones 4-9 are optimum.

Propagate by seed in the spring or fall. Cutting and division propagation takes place in the spring. Division can also be done after flowering. Cut back after flowering.

Container growth is successful in Colorado if plants are brought indoors during winter. Indoors, nighttime temperatures should be between 40-50˚F; during the day, temperatures should be raised a few degrees. Be careful not to overwater during winter, opening up the plants to stem and root rots as well as Fusarium wilt. Harvesting can take place any time.

Parsley – *Petroselinum crispum*

A biennial grown like an annual, parsley belongs to the Carrot family. The height is 12-32” and width 12-24.” Hardiness zones 5-9 are the most suitable. Parsley likes full sun to partial shade and neutral to slightly alkaline, moist, well-draining soil. Parsley is allelopathic, suppressing growth of nearby plants by chemicals released from leaves and roots.

Parsley is propagated by seed from spring to late summer, growing well both outdoors and in containers. Cut flower stalks back when they first begin to grow to prolong leaf harvest; leaves are no longer good for harvesting after bloom. Harvesting only a small amount at a time can also prolong growth. Parsley can be taken any time during the season.

Many pests attack parsley. Carrot fly, celery fly, cabbage loopers, beet armyworms, carrot weevils, corn earworms, flea beetles, leaf hoppers, and slugs are problematic. Parsley is susceptible to a few diseases as well: Pythium (damping off,) Septoria leaf spot, and aster yellows.

Rosemary – *Rosmarinus officinalis*

As a member of the Mint family, Rosemary is a shrubby, tender perennial grown as an annual in Colorado, which grows 3-6 ft tall and wide. Hardiness zones 7-11 are best. Grow in full sun with moist, well-draining soil. Container production is best in Colorado because they don’t thrive in cold. Rosemary is aromatic and the leaves, stems and flowers have culinary uses.

Most often propagation is done by cuttings. Rosemary should be repotted and/or divided fairly frequently to prevent from becoming root bound.
Avoid overwatering to prevent root rots or bacterial leaf spots. Light pruning after flowering is beneficial. Don’t apply fertilizers until after flowering. Leaves and flower tops are harvested in the spring and early summer.

Sage – *Salvia officinalis*

Sage is a perennial in the Mint family growing 2-3 ft tall and wide in hardiness zones 5-8. Along with the leaves being used for culinary purposes, sage is aromatic and ornamental. Full sun in a moist, well-draining soil is best. Flowers bloom in the summer.

Sage is propagated by seed and cuttings in the spring. Pinch branch tips often throughout the first summer. Prune in the spring and after the flowers bloom in the late summer. Replace sage every 4-5 years to avoid having plants become too woody.

If planted in the ground, apply fertilizer when growth first begins in the spring and in the first week of June. Sage grows well in containers if fertilized monthly. However, take care that container sage is not over watered, allowing the media to slightly dry between irrigation.

In the first year only harvest the leaves once in the fall from the top 3-5" of the plant. In following years 2-3 leaf harvests can be taken at any time.

Sage is susceptible to rust, powdery mildew, stem rot and fungal leaf spots. These can, for the most part be prevented by not over watering.

Sweet Basil – *Ocimum basilicum*

Basil is a tender annual that grows 12-24" tall and 6-15" wide that is part of the Mint family. Besides culinary uses, basil is also aromatic and ornamental. Moist, but well-draining, medium-textured soil, full sun and wind protection are the proper growing environment.

Propagate by seed in the spring and cuttings in the summer. Pinch to prevent flowering if leaves will be harvested for culinary purposes.

The first leaf harvest is done when the plant is 1 foot tall or has 6 leaves (all should be taken.) Plants can also be cut back to 6" when flowering takes place. Main harvesting is during the summer picking the leaves from top to bottom. When growing in high temperature areas, like Colorado, harvesting can take place as often as every 3 weeks.

Inspect plants for Fusarium and Rhizoctonia, which can cause damping off. A good preventative measure is not overwatering.

Sweet Bay – *Laurus nobilis*

Bay is part of the Laurel family. It is a perennial tree that can grow 10-60 feet tall and 12-30 feet wide. Along with culinary use of the leaves, bay is aromatic and ornamental. It grows in full sun with moist, well-draining soil and is slightly drought tolerant. Bay is not suited to landscapes in Colorado; it's hardy in zone 8.

Propagate by layering in the spring or fall. Bay is very difficult to propagate any other way. However, division is possible and should be done if any offshoots come up.

Despite its size, bay does very well when grown in pots. In Colorado it is best to grow bay in containers that are placed in a sheltered spot to protect the plants from wind damage in the summertime. During winter, bay needs to be brought indoors with night temperatures going no higher than 50˚F and the day temps only a few degrees above that. Media should be allowed to dry between irrigation during the winter.

Apply fertilizer every other week during spring and summer. Prune to shape bay trees in the summer. Cut back plants to the base every winter to encourage new growth for the next year.

Because bay is an evergreen, the leaves can be harvested any time. Scale insects are the only pests that harm bay plants.

Sweet Marjoram – *Origanum majorana*

As part of the Mint family, sweet marjoram is an herbaceous perennial that is tender and treated like an annual in Colorado. Marjoram is aromatic, ornamental and the leaves are used in cooking. The height ranges 12-40” and the width 12-18”. Full sun and a slightly alkaline, well-draining soil are ideal. Flowering occurs in the summer.

Because of tenderness marjoram belongs in hardiness zones 9-10. Due to Colorado’s lower hardiness zones, sweet marjoram does best when grown in containers indoors. However, be careful not to overwater, especially in winter.

Propagate by seed in spring and/or fall. Cuttings are taken from spring to early summer. Cut back plants after flowering is over. Harvest any time during the season for both fresh and dry leaves, but some prefer to harvest before flowering if it is to be dried.

Tarragon – *Artemisia dracunculus*

Tarragon belongs to the Daisy family. A hardy herbaceous perennial used for aromatic, culinary, and economic purposes (products like perfumes and detergents.) Height ranges 18” to 48” tall 12-15” wide Full sun and well-draining soil are important. Drought tolerance helps them to thrive in warm and dry environments and in hardiness zones 3-7.

Propagate by seed in the spring, but tarragon in the garden rarely, if ever, produces seed. Cuttings can be taken in the summer. They should be divided every 3-5 years in spring or fall. Summer flowers should be removed. Cut back to the base in the fall.

Harvest for fresh leaves any time during the growing season. When harvesting for freezing, leaves should be taken during the summer.

The only disease tarragon is susceptible to is rust. Any plants showing rust should be discarded.

Thyme – *Thymus vulgaris*

Belonging to the Mint family, thyme is a perennial. They grow 6-14" tall and 8-16" wide in full sun with moist, well-draining, slightly alkaline soil. Thyme can handle drought conditions in hardiness zones 4-9. Flower tops and leaves have culinary uses and the foliage is aromatic.

Seed propagation takes place in the spring. The preferred methods of propagation are division in the spring and cuttings in the summer. Thyme grows really well in containers, especially indoors. Don't overwater due to root rot susceptibility.

A heavy early spring pruning of one-half to one-third of the stem length is healthy for the plant. Light pruning should be done after flowering in the summer. Harvest the plant to 4" tall in the middle of summer and again at the end of the growing season.

Authors: Carol O'Meara (CSU Extension, Boulder County), Alison O'Connor (CSU Extension, Larimer County), and Chelsea Bragg (former student, Department of Horticulture and L.A., Colorado State University).
Photographs by David Whiting and Carol O'Meara (CSU Extension); used by permission.

October 2013

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #741

Climate Summary: Boulder and Longmont, Colorado

		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Annual**
Monthly Temperatures														
Boulder	average extreme high	64	67	72	80	86	94	97	94	90	81	71	67	
	normal high	45	48	55	62	71	82	87	85	77	66	52	46	65
	normal low	**19**	**23**	**28**	**35**	**43**	**52**	**57**	**56**	**48**	**38**	**28**	**22**	**38**
	average extreme low	-4	0	9	18	31	41	49	48	32	21	6	0	
Longmont	average extreme high	63	67	75	82	89	97	100	98	94	84	73	64	
	normal daily high	**42**	**47**	**54**	**62**	**72**	**83**	**89**	**87**	**78**	**66**	**52**	**44**	**65**
	normal daily low	**12**	**17**	**24**	**32**	**42**	**51**	**55**	**53**	**44**	**33**	**22**	**14**	**33**
	average extreme low	-9	-5	6	17	30	40	48	46	31	19	4	-8	

Note: Climate averages/norms are based on a 30 year period.

Site Information	Station	Number	Elevation	Latitude	Longitude
	Boulder	50848	5400	40º 01’	105º 16’
	Longmont	55116	4950	40º 10’	105º 04’

		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Total Monthly Precipitation (inches)														
Boulder	normal	0.7	0.7	1.8	2.7	2.9	2.0	1.9	1.7	1.9	1.3	1.5	0.8	19.71
	maximum*	2.2	2.4	5.2	6.0	9.6	6.0	4.8	5.5	4.3	4.3	3.5	2.2	29.4
Longmont	normal	0.4	0.4	1.2	2.0	2.4	1.7	1.1	1.4	1.5	0.8	0.8	0.6	14.4
	maximum*	1.4	1.5	4.7	4.8	7.0	5.1	3.5	4.8	3.8	4.8	2.5	1.7	20.9
Total Monthly Snowfall (inches)														
Boulder	normal	10.9	9.9	16.9	12.0	1.1	0	0	0	2.1	4.7	16.0	11.8	83.6
	maximum*	29.1	28.8	56.7	38.6	23.0	0	0	0	21.0	30.1	44.6	31.5	125.3
Longmont	normal	5.2	3.4	5.5	4.7	0.5	0	0	0	0.5	1.2	5.5	7.1	32.3
	maximum*	13.8	13.8	26.0	19.0	8.0	0	0	0	10.0	12.0	22.0	32.0	72.0

Frost Probability and Growing Season Length Summary

		Spring Frost Probability			Fall Frost Probability			Length of Growing Season (days)		
		90%	50%	10%	10%	50%	90%	10%	50%	90%
Boulder	32^{o} threshold	Apr 22	May 3	May 13	Sept 18	Oct 1	Oct 15	133	152	171
	28^{o} threshold	Apr 8	Apr 21	May 5	Sept 23	Oct 11	Oct 28	154	172	191
	24^{o} threshold	Mar 31	Apr 11	Apr 22	Sept 27	Oct 19	Nov 11	169	191	213
Longmont	32^{o} threshold	Apr 22	May 05	May 17	Sept 15	Sept 27	Oct 9	127	145	163
	28^{o} threshold	Apr 10	Apr 24	May 8	Sept 22	Oct 9	Oct 25	146	168	190
	24^{o} threshold	Mar 31	Apr 15	Apr 29	Sept 29	Oct 17	Nov 4	165	185	206

Typical planting and harvest period based on average frost dates and normal temperatures

<table>
<tr><th>Mid
April</th><th>Late
April</th><th>Early
May
FROST</th><th>Mid
May</th><th>Late
May</th><th>Early
June</th><th>Mid
June</th><th>Late
June</th><th>Early
July</th><th>Mid
July</th><th>Late
July</th><th>Early
Aug.</th><th>Mid
Aug.</th><th>Late
Aug.</th><th>Early
Sept.</th><th>Mid
Sept.</th><th>Early
Oct.
FROST</th></tr>
<tr><td colspan="7">40-45 day, cool season crops (spinach, lettuce)</td><td></td><td colspan="8">75 day, cool season crops</td><td></td></tr>
<tr><td colspan="8">50-55 day, cool season crops (kohlrabi)</td><td></td><td colspan="7">65-70 day, cool season crops (peas)</td><td></td></tr>
<tr><td colspan="9">60-70 day, cool season crops (beets, broccoli, cabbage, carrots, cauliflower, chard, peas)</td><td></td><td colspan="6">50-60 day, cool season crops (kohlrabi, beets, broccoli, cabbage, carrots, cauliflower, chard,)</td><td></td></tr>
<tr><td colspan="10">75 day, cool season crops</td><td></td><td colspan="5">40-45 day, cool season crops (spinach, lettuce)</td><td></td></tr>
<tr><td></td><td></td><td colspan="8">50-55 day, semi-tender, warm season crops (summer squash)</td><td></td><td colspan="5"></td><td></td></tr>
<tr><td></td><td></td><td colspan="9">60-65 day, semi-tender, warm season crops (cucumbers)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="10">70-75 day, semi-tender, warm season crops (beans, corn)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="11">80-85 day, semi-tender, warm season crops (corn)</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="9">70 day, tender, warm season crops (tomatoes, peppers, eggplant)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="10">75-80 day, tender, warm season crops (cantaloupe, watermelon)</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="11">85-90 day, tender, warm season crops (cantaloupe, watermelon, winter squash)</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="12">95-100 day, tender, warm season crops (winter squash)</td><td></td><td></td></tr>
</table>

Prepared by David Whiting, Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University
Source: Colorado Climate Center at http://ccc.atmos.colostate.edu

o CMG GardenNotes are available online at www.cmg.colostate.edu.
o Colorado Master Gardener training is made possible, in part, by a grant from the Colorado Garden Show, Inc.
o Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

Revised December 2006

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #742

Climate Summary: Castle Rock, Littleton, and Parker, Colorado

Monthly Temperatures

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Castle Rock	average extreme high	63	65	71	77	84	92	95	92	87	81	72	65	
	normal daily high	**45**	**48**	**53**	**59**	**69**	**80**	**86**	**84**	**76**	**66**	**53**	**46**	**63**
	normal daily low	**13**	**17**	**23**	**30**	**39**	**48**	**53**	**51**	**43**	**31**	**21**	**14**	**32**
	average extreme low	-12	-6	1	12	26	35	45	44	27	15	0	-8	
Littleton	average extreme high	65	71	74	82	85	94	96	94	89	81	73	65	
	normal daily high	**43**	**48**	**54**	**63**	**69**	**80**	**86**	**83**	**75**	**64**	**51**	**44**	**63**
	normal daily low	**16**	**19**	**28**	**35**	**43**	**53**	**58**	**56**	**46**	**34**	**23**	**15**	**36**
	average extreme low	-6	-5	9	19	30	41	50	49	32	19	7	-6	
Parker	average extreme high	62	64	71	77	83	92	95	93	88	80	71	64	
	normal daily high	**42**	**46**	**52**	**60**	**69**	**80**	**85**	**84**	**76**	**65**	**50**	**44**	**63**
	normal daily low	**17**	**20**	**25**	**32**	**41**	**50**	**57**	**55**	**47**	**36**	**25**	**18**	**35**
	average extreme low	-8	-3	4	13	27	37	47	46	31	17	4	-5	

Note: Weather averages/norms are based on a 30 period.

Total Monthly Precipitation (inches)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Castle Rock	**normal**	**0.5**	**0.5**	**1.5**	**1.8**	**2.4**	**2.0**	**2.3**	**2.1**	**1.2**	**1.1**	**1.0**	**0.7**	**17.8**
	maximum	1.3	2.0	4.4	6.7	7.3	4.6	4.9	5.5	2.9	2.9	2.6	2.3	24.7
Littleton	**normal**	**0.3**	**0.5**	**1.4**	**1.5**	**2.8**	**1.8**	**1.9**	**2.0**	**1.1**	**1.2**	**1.2**	**0.6**	**16.4**
	maximum	0.7	1.2	4.2	3.0	4.3	4.6	3.9	4.2	2.2	4.5	3.8	1.5	24.2
Parker	**normal**	**0.3**	**0.3**	**1.0**	**1.4**	**2.7**	**2.1**	**2.3**	**2.2**	**1.2**	**0.9**	**0.8**	**0.3**	**15.2**
	maximum	1.4	1.1	4.0	2.5	6.6	4.0	5.7	6.0	4.4	4.2	2.7	1.7	21.6

Total Monthly Snowfall (inches)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Castle Rock	**normal**	**6.0**	**6.0**	**11.2**	**9.1**	**1.1**	**0**	**0**	**0**	**0.8**	**3.3**	**9.6**	**10.4**	**56.9**
	maximum	18.0	21.0	50.0	25.5	12.0	0	0	0	11.5	11.9	38.5	43.0	117.3
Littleton	**normal**	**8.8**	**7.8**	**11.9**	**7.8**	**0.6**	**0**	**0**	**0**	**0.9**	**3.0**	**13.0**	**12.7**	**66.4**
	maximum	21.5	18.0	32.0	15.0	4.0	0	0	0	10.0	12.0	40.8	36.0	101.1
Parker	**normal**	**4.7**	**4.2**	**9.0**	**9.6**	**2.1**	**0.2**	**0**	**0**	**1.4**	**5.1**	**9.1**	**5.7**	**56.2**
	maximum	18.0	13.0	43.0	20.0	14.0	6.0	0	0	17.0	43.0	35.0	21.0	113.0

Prepared by David E Whiting, Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University
Source: Colorado Climate Center at http://ccc.atmos.colostate.edu

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Revised December 2006

Frost Probability and Growing Season Length Summary

		Spring Frost Probability			Fall Frost Probability			Length of Growing Season (days)		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**10%**	**50%**	**90%**
Byers	32º threshold	Apr 27	**May 10**	May 23	Sept 13	**Sept 26**	Oct 10	118	139	160
	28º threshold	Apr 21	May 2	May 12	Sept 19	Oct 3	Oct 16	136	154	172
	24º threshold	Apr 6	Apr 22	May 9	Sept 28	Oct 15	Nov 1	152	176	200
Castle Rock	32º threshold	May 5	**May 25**	June 14	Sept 10	**Sept 23**	Oct 6	94	121	148
	28º threshold	Apr 21	May 7	May 24	Sept 16	Sept 29	Oct 12	120	145	169
	24º threshold	Apr 19	Apr 29	May 10	Sept 16	Oct 7	Oct 28	135	161	186
Kassler	32º threshold	Apr 28	**May 14**	May 29	Sept 13	**Sept 27**	Oct 12	115	137	159
	28º threshold	Apr 16	Apr 26	May 5	Sept 23	Oct 12	Oct 31	149	169	190
	24º threshold	Apr 3	Apr 18	May 2	Sept 30	Oct 18	Nov 4	160	183	206
Littleton	32º threshold	Apr 19	**Apr 30**	May 11	Sept 18	**Oct 1**	Oct 14	137	154	172
	28º threshold	Apr 6	Apr 20	May 4	Sept 30	Oct 11	Oct 22	158	174	189
	24º threshold	Mar 25	Apr 8	Apr 23	Oct 5	Oct 19	Nov 3	176	194	212
Parker	32º threshold	Apr 29	**May 17**	June 4	Sept 11	**Sept 26**	Oct 10	104	132	160
	28º threshold	Apr 19	May 2	May 15	Sept 20	Oct 6	Oct 23	135	158	181
	24º threshold	Apr 11	Apr 25	May 9	Sept 29	Oct 15	Oct 31	152	173	194

Site Information	Station	Number	Elevation	Latitude	Longitude
	Byers	#51179	5200	39º 42’	104 º 13’
	Castle Rock	#51401	6250	39 º 22’	104 º 52’
	Kassler	#54452	5500	39 º 30’	105 º 6’
	Littleton	#55056	5360	39 º 37’	105º 1’
	Parker	#56326	6300	39 º 31’	104 º 39’

Typical planting and harvest period based on average frost dates and normal temperatures

Castle Rock

<table>
<tr><th>Mid April</th><th>Late April</th><th>Early May</th><th>Mid May</th><th>Late May</th><th>Early June</th><th>Mid June</th><th>Late June</th><th>Early July</th><th>Mid July</th><th>Late July</th><th>Early Aug.</th><th>Mid Aug.</th><th>Late Aug.</th><th>Early Sept.</th><th>Mid Sept.</th><th>Late Sept.</th><th>Early Oct.</th></tr>
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Littleton

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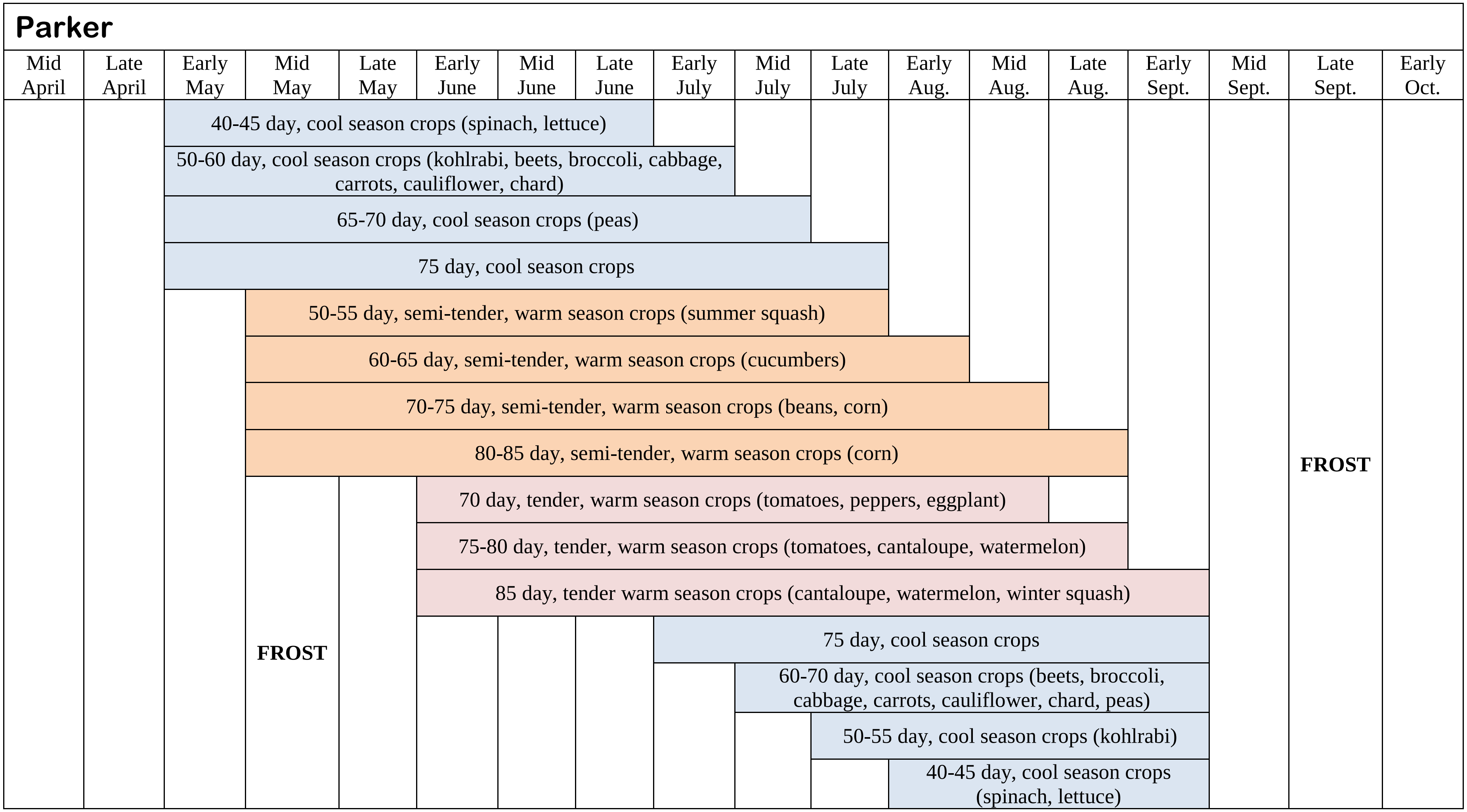

Parker

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #743

Climate Summary: Colorado Springs, Colorado

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Monthly Temperature [1] (degrees F)													
average high	42	46	52	59	69	79	84	82	74	63	49	42	62
average low	17	20	26	33	43	51	57	55	47	36	24	18	36
Monthly Precipitation [1] (inches)	0.3	0.4	1.0	1.6	2.6	2.3	2.9	3.2	1.4	0.8	0.6	0.4	17.5
Monthly Snowfall [2] (inches)	5.1	5.3	9.8	6.8	1.3	0	0	0	0.5	3.9	6.1	6.5	46.2

		Spring Frost Probability			**Fall Frost Probability**			**Length of "Frost Free" Season** (days)		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**10%**	**50%**	**90%**
Colorado Springs	**32° threshold**	Apr 23	**May 6**	May 18	Sept 18	**Oct 6**	Oct 18	126	**152**	170
	28° threshold	Apr 9	Apr 27	May 12	Sept 27	Oct 13	Oct 29	152	171	189
	24° threshold	Apr 1	Apr 15	May 1	Oct 8	Oct 23	Nov 8	170	190	210

Typical planting and harvest period based on average frost dates and normal temperatures

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Prepared by David Whiting Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University
Source: Colorado Climate Center at www.wrcc.dri.edu/summary/climsmco.html

Revised April 2008

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #744

Climate Summary: Dillon, Colorado

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Monthly Temperatures[1] (degrees)													
Average high	32	35	40	47	57	67	73	71	65	54	39	32	51
Average low	2	5	12	19	27	34	38	38	31	22	12	4	20
Average Monthly Precipitation[1] (inches)	0.8	1.0	1.1	1.2	1.5	1.3	1.7	1.7	1.3	0.9	0.8	0.8	14.1
Average Monthly Snowfall[2] (inches)	18.5	18.7	22.1	18.1	7.3	0.8			1.7	7.6	15.2	17.5	127.5

		Spring Frost Probability			**Fall Frost Probability**			**Length of "Frost Free" Season (days)**		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**90%**	**50%**	**10%**
Dillon	32º threshold	June 25	**July 18**	July 30	July 31	**Aug 10**	Sept 3	1	**25**	59
	28º threshold	June 10	June 25	July 14	Aug 5	Aug 27	Sept 16	28	61	93
	24º threshold	May 18	June 9	June 26	Aug 20	Sept 12	Sept 26	69	93	124

Prepared by David Whiting Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University. Source: Colorado Climate Center at www.wrcc.dri.edu/summary/climsmco.html

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- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.
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Revised April 2008

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #745

Climate Summary: Eagle and Glenwood Springs, Colorado

Average Monthly Temperatures (degrees F)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Vail	average daily high	30	35	43	51	62	72	77	76	68	56	38	29	53
	average daily low	5	8	16	23	31	35	40	40	33	24	13	6	23
Eagle FAA	average daily high	35	41	50	59	69	80	85	83	75	63	45	35	60
	average daily low	5	12	21	27	34	41	47	45	37	27	17	6	27
Glenwood	average daily high	37	44	53	62	71	82	88	86	78	65	47	37	63
Springs	average daily low	13	19	26	31	39	45	52	51	43	33	23	15	33
Rifle	average daily high	38	46	56	64	73	84	90	88	79	67	49	39	65
	average daily low	10	18	25	31	39	46	52	51	42	31	22	12	31

Average Total Monthly Precipitation (inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Vail	1.8	2.2	1.8	2.1	2.0	1.6	2.0	1.8	1.8	1.6	1.7	1.6	22.0
Eagle FAA	0.8	0.7	0.8	0.8	1.0	0.8	1.3	1.1	1.1	1.0	0.8	0.9	10.9
Glenwood Springs1.5	1.3	1.4	1.7	1.9	1.3	1.2	1.4	1.8	1.8	1.4	1.5	18.2	
Rifle	0.9	0.9	1.0	1.1	1.2	0.8	1.1	1.1	1.2	1.3	1.1	1.1	12.8

Average Total Monthly Snowfall (inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Vail	33.6	34.1	24.7	21.2	4.1	0.3	0.0	0.0	1.1	7.5	31.1	26.6	184.3
Eagle FFA	10.5	6.2	6.8	3.7	1.2	0.1	0.0	0.0	0.5	2.2	6.2	10.3	47.7
Glenwood Springs 18.1	11.3	6.7	1.9	0.3	0.0	0.0	0.0	0.0	1.1	5.3	15.3	60.2	
Rifle	11.1	7.7	3.7	0.8	0.0	0.0	0.0	0.0	0.0	0.5	3.8	11.1	38.6

Frost Probability and Length of Growing Season

		Spring Frost Probability			Fall Frost Probability			Length of "Frost Free" Season (days)		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**90%**	**50%**	**10%**
Vail	32° threshold	June 11	**June 26**	July 23	Aug 27	**Sept 10**	Sept 22	57	79	93
	28° threshold	May 14	June 7	June 29	Sept 2	Sept 20	Sept 28	76	108	136
	24° threshold	Apr 29	May 14	June 2	Sept 14	Sept 23	Oct 7	121	134	153
Eagle	32° threshold	May 31	**June 12**	June 30	Aug 21	**Sept 8**	Sept 20	53	86	111
	28° threshold	May 13	May 27	June 10	Sept 1	Sept 16	Sept 30	94	112	131
	24° threshold	Apr 26	May 15	May 28	Sept 18	Sept 29	Oct 13	115	139	163
Glenwood Springs	32° threshold	May 1	**May 19**	June 10	Sept 13	**Sept 26**	Oct 14	104	130	153
	28° threshold	Apr 16	May 1	May 28	Sept 19	Oct 7	Oct 24	127	158	182
	24° threshold	March 30	Apr 16	May 7	Oct 6	Oct 23	Nov 5	157	191	212
Rifle	32° threshold	May 5	**May19**	June 14	Sept 12	**Sept 23**	Oct 8	92	126	150
	28° threshold	Apr 20	May 8	May 19	Sept 19	Oct 5	Oct 19	128	152	173
	24° threshold	Apr 1	April 21	May 12	Sept 30	Oct 19	Nov 1	156	181	206

Typical planting and harvest period based on average frost dates and normal temperatures

	Late April	Early May	Mid May	Late May	Early June	Mid June	Late June	Early July	Mid July	Late July	Early Aug.	Mid Aug.	Late Aug.	Early Sept.	Mid Sept.	Late Sept.
Vail								**FROST**				**FROST**				
						40-50 day, cool season crops (spinach, lettuce, kohlrabi)										

	Late April	Early May	Mid May	Late May	Early June	Mid June	Late June	Early July	Mid July	Late July	Early Aug.	Mid Aug.	Late Aug.	Early Sept.	Mid Sept.	Late Sept.
Eagle				40-45 day, cool season crops (spinach, lettuce)											**FROST**	
				50-60 day, cool season crops (kohlrabi, beets, broccoli, cabbage, carrots, cauliflower, chard)												
				65-70 day, cool season crops (peas)												
				75 day, cool season crops												
						50 day, semi-tender, warm season crops (summer squash)										
						55 day, semi-tender, warm season crops										
						60 day, semi-tender, warm season crops (cucumbers)										
						FROST	60-65 day, cool season crops (beets, broccoli, cabbage, carrots, cauliflower, chard, peas)									
								50-55 day, cool season crops (kohlrabi)								
									40-45 day, cool season crops (spinach, lettuce)							

Prepared by David Whiting Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University
Source: Colorado Climate Center at www.wrcc.dri.edu/summary/climsmco.html

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</table>

<table>
<tr><th></th><th>Late April</th><th>Early May</th><th>Mid May</th><th>Late May</th><th>Early June</th><th>Mid June</th><th>Late June</th><th>Early July</th><th>Mid July</th><th>Late July</th><th>Early Aug.</th><th>Mid Aug.</th><th>Late Aug.</th><th>Early Sept.</th><th>Mid Sept.</th><th>Late Sept.</th></tr>
<tr><td rowspan="15">Rifle</td><td rowspan="15"></td><td colspan="6">40-45 day, cool season crops (spinach, lettuce)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="15">FROST</td></tr>
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</table>

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #746

Climate Summary: Fort Collins, Greeley, and Estes Park, Colorado

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Monthly Temperatures														
Estes Park	average extreme high	53	55	60	69	75	84	88	85	80	72	62	55	
	normal daily high	**38**	**41**	**46**	**54**	**62**	**73**	**78**	**77**	**70**	**59**	**45**	**39**	**57**
	normal daily low	**16**	**18**	**22**	**27**	**35**	**41**	**47**	**45**	**38**	**30**	**23**	**16**	**30**
	average extreme low	-12	-10	-1	5	22	30	38	37	23	12	-3	-8	
Fort Collins	average extreme high	62	65	72	79	85	93	96	94	89	81	70	62	
	normal daily high	**42**	**46**	**53**	**61**	**70**	**80**	**85**	**83**	**75**	**64**	**50**	**43**	**63**
	normal daily low	**15**	**20**	**27**	**34**	**43**	**52**	**57**	**56**	**47**	**36**	**25**	**17**	**36**
	average extreme low	-6	0	10	18	32	41	49	48	32	20	7	-3	
Greeley	average extreme high	62	65	75	82	88	97	100	97	93	83	71	61	
	normal daily high	**40**	**47**	**55**	**63**	**73**	**83**	**89**	**87**	**78**	**66**	**50**	**42**	**64**
	normal daily low	**14**	**20**	**27**	**35**	**44**	**53**	**58**	**56**	**47**	**35**	**24**	**16**	**36**
	average extreme low	-7	-1	9	20	32	43	50	49	32	21	6	-4	

		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Total Monthly Precipitation (inches)														
Estes Park	**normal**	**0.3**	**0.5**	**1.0**	**1.3**	**1.9**	**1.5**	**2.3**	**1.9**	**1.2**	**1.0**	**0.7**	**0.4**	**14.3**
	maximum	1.8	2.1	3.3	4.0	5.4	3.8	5.3	5.8	2.7	2.9	2.1	1.2	17.4
Fort Collins	**normal**	**0.4**	**0.4**	**1.5**	**2.1**	**2.6**	**2.1**	**1.9**	**1.4**	**1.3**	**1.0**	**0.8**	**0.5**	**15.9**
	maximum	1.1	1.3	5.6	8.3	7.5	5.8	6.7	5.1	4.1	2.9	2.3	1.5	25.2
Greeley	**normal**	**0.5**	**0.4**	**1.2**	**1.8**	**2.5**	**1.9**	**1.5**	**1.2**	**1.2**	**0.9**	**0.8**	**0.5**	**14.4**
	maximum	1.4	1.5	4.1	7.4	5.4	4.0	3.4	3.9	3.4	2.9	2.3	1.1	22.2
Total Monthly Snowfall (inches)														
Estes Park	**normal**	**1.9**	**5.9**	**7.6**	**3.3**	**0.5**	**0.1**	**0**	**0**	**0.6**	**1.2**	**4.4**	**2.7**	**25.2**
	maximum	12.0	30.0	31.5	14.0	6.0	3.0	0	0	4.0	9.0	18.0	12.5	64.5
Fort Collins	**normal**	**8.4**	**6.2**	**12.3**	**7.28**	**1.4**	**0.1**	**0**	**0**	**1.2**	**3.9**	**9.9**	**8.4**	**59.1**
	maximum	19.2	16.7	39.6	24.4	27.8	2.2	0	1.4	15.0	17.5	29.1	20.7	107.1
Greeley	**normal**	**6.2**	**4.2**	**7.5**	**5.9**	**0.8**	**0**	**0**	**0**	**0.9**	**2.5**	**8.0**	**5.4**	**41.9**
	maximum	16.3	13.2	17.0	16.5	6.0	0.2	0	0	9.0	20.2	23.5	13.8	69.9

Frost Probability and Growing Season Length Summary*

		Spring Frost Probability			Fall Frost Probability			Length of Growing Season		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**10%**	**50%**	**90%**
Estes Park	32° threshold	May 27	June 9	June 21	Sept 3	Sept 14	Sept 25	83	97	111
	28° threshold	May 5	May 21	June 6	Sept 10	Sept 21	Oct 1	106	123	140
	24° threshold	Apr 18	May 8	May 27	Sept 18	Oct 4	Oct 19	125	149	173
Fort Collins	32° threshold	Apr 23	May 4	May 16	Sept 18	Oct 2	Oct 17	130	151	172
	28° threshold	Apr 5	Apr 19	May 2	Sept 25	Oct 11	Oct 26	155	175	196
	24° threshold	Mar 26	Apr 7	Apr 20	Oct 3	Oct 20	Nov 6	174	196	218
Greeley	32° threshold	Apr 21	May 2	May 12	Sept 17	Oct 1	Oct 14	134	152	170
	28° threshold	Apr 4	Apr 18	May 2	Sept 26	Oct 11	Oct 25	155	175	196
	24° threshold	Mar 25	Apr 7	Apr 20	Oct 6	Oct 22	Nov 6	175	198	220

Site Information	Station	Number	Elevation	Latitude	Longitude
	Estes Park	52759	7750	40° 23’	105° 31’
	Fort Collins	51179	5200	39° 42’	104° 13’
	Greeley	53553	4650	40° 25’	104° 42’

Prepared by David Whiting Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University
Source: Colorado Climate Center at www.wrcc.dri.edu/summary/climsmco.html

o CMG GardenNotes are available online at www.cmg.colostate.edu.
o Colorado Master Gardener training is made possible, in part, by a grant from the Colorado Garden Show, Inc.
o Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

Revised December 2006

Typical planting and harvest period based on average frost dates and normal temperatures

Estes Park

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</table>

Fort Collins

<table>
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Greeley

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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #747

Climate Summary: Gunnison and Crested Butte, Colorado

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Monthly Temperatures (degrees F)														
Gunnison	Average high	27	32	44	55	66	76	80	78	72	61	42	30	55
	Average low	-5	1	14	22	30	36	42	41	33	22	11	-2	20
Crested Butte	Average high	27	32	39	46	58	69	74	73	65	54	38	28	50
	Average low	-4	-1	7	18	28	33	38	38	30	21	9	-2	18
Average Monthly Precipitation (inches)														
Gunnison		0.8	0.7	0.5	0.7	0.8	0.6	1.3	1.6	1.1	0.7	0.6	0.8	10.1
Crested Butte		2.6	2.7	2.2	1.9	1.6	1.3	1.9	2.1	2.0	1.8	2.0	2.3	24.2
Average Monthly Snowfall (inches)														
Gunnison[2]		12.0	10.2	6.9	3.5	0.8	0.1			0.2	1.3	5.3	10.3	50.5
Created Butte[3]		40.0	34.3	32.0	17.4	6.5	0.7			1.3	7.8	24.3	33.6	197.9

Frost Probability and Growing Season Summary*

		Spring Frost Probability			Fall Frost Probability			Length of "Frost Free" Season (days)		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**90%**	**50%**	**10%**
Gunnison	**32º threshold**	June 14	**June 27**	July 11	Aug 8	**Aug 29**	Sept 9	37	**62**	86
	28º threshold	May 24	June 10	June 23	Aug 25	Sept 12	Sept 19	70	94	115
	24º threshold	May 8	May 22	June 8	Sept 10	Sept 21	Sept 28	99	121	140
Crested Butte	**32º threshold**	June 19	**July 9**	July 29	Aug 1	**Aug 17**	Sept 2	4	**37**	68
	28º threshold	May 31	June 17	July 3	Aug 15	Sept 4	Sept 14	48	79	97
	24º threshold	May 9	May 27	May 18	Sept 1	Sept 17	Sept 30	78	113	141

Prepared by David Whiting Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University
Source: Colorado Climate Center at www.wrcc.dri.edu/summary/climsmco.html

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- CSU Extension programs are available to all without discrimination.
-

Revised April 2008

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #748

Climate Summary: Northeast Colorado

Frost Probability and Growing Season Length Summary

		Spring Frost Probability			Fall Frost Probability			Length of “Frost Free” Season (days)		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**10%**	**50%**	**90%**
Akron	32° threshold	Apr 29	**May10**	May 20	Sept 17	**Sept 30**	Oct 13	126	**143**	160
	28° threshold	Apr 13	Apr 24	May6	Sept 28	Oct 12	Oct 26	123	171	189
	24° threshold	Apr 2	Apr 17	May 2	Oct 5	Oct 20	Nov 4	163	186	209
Burlington	32° threshold	Apr 25	**May 7**	May 19	Sept 14	**Oct 4**	Oct 25	122	**150**	179
	28° threshold	Apr 8	Apr 20	May 2	Sept 29	Oct 15	Nov 1	159	178	198
	24° threshold	Apr 1	Apr 14	Apr 27	Oct 3	Oct 23	Nov 11	168	192	216
Cheyenne Wells	32° threshold	Apr 21	**May 5**	May 20	Sept 12	**Sept 28**	Oct 14	125	**145**	166
	28° threshold	Apr 13	Apr 24	May 6	Oct 1	Oct 17	Nov 1	157	175	193
	24° threshold	Mar30	Apr 13	Apr 26	Oct 03	Oct 21	Nov 9	170	192	213
Fort Morgan	32° threshold	Apr 22	**May 2**	May 13	Sept 20	**Oct 3**	Oct 17	137	**154**	171
	28° threshold	Apr 5	Apr 20	May 5	Sept 29	Oct 13	Oct 27	156	176	197
	24° threshold	Mar 27	Apr 9	Apr 23	Oct 2	Oct 20	Nov 6	169	193	218

		Spring Frost Probability			Fall Frost Probability			Length of “Frost Free” Season (days)		
		90%	50%	10%	10%	50%	90%	10%	50%	90%
Holyoke	32º threshold	Apr 26	**May 5**	May 15	Sept 20	**Oct 2**	Oct 15	132	**150**	168
	28º threshold	Apr 15	Apr 26	May 7	Sept 29	Oct 13	Oct 27	156	170	185
	24º threshold	Mar 29	Apr 13	Apr 27	Oct 4	Oct 18	Nov 2	171	189	207
Kit Carson	32º threshold	Apr 27	**May 7**	May 18	Sept 17	**Sept 29**	Oct 12	126	**145**	164
	28º threshold	Apr 12	Apr 24	May 6	Sept 24	Oct 9	Oct 24	151	168	185
	24º threshold	Apr 4	Apr 16	Apr 29	Oct 1	Oct 17	Nov 3	162	184	205
Sterling	32º threshold	Apr 23	**May 4**	May 15	Sept 17	**Oct 1**	Oct 15	131	**150**	169
	28º threshold	Apr 8	Apr 22	May 5	Sept 27	Oct 11	Oct 25	152	172	192
	24º threshold	Mar 30	Apr 13	Apr 27	Oct 6	Oct 21	Nov 6	170	191	213
Wray	32º threshold	Apr 25	**May 7**	May 18	Sept 18	**Oct 2**	Oct 16	134	**148**	163
	28º threshold	Apr 12	Apr 25	May 9	Sept 28	Oct 11	Oct 24	151	169	186
	24º threshold	Apr 2	Apr 18	May 5	Oct 12	Oct 23	Nov 3	169	187	206
Yuma	32º threshold	Apr 24	**May 5**	May 17	Sept 20	**Oct 2**	Oct 14	133	**150**	166
	28º threshold	Apr 12	Apr 24	May 6	Sept 27	Oct 12	Oct 26	153	171	188
	24º threshold	Apr 3	Apr 15	Apr 27	Sept 30	Oct 17	Nov 2	168	185	202

Site Information	Station	Number	Elevation	Latitude	Longitude
	Akron	50114	4580	40º 7’’	103º 10’
	Burlington	51121	4170	39º 18’	102º 16’
	Cheyenne Wells	51564	4250	38º 49’	102º 21’
	Fort Morgan	53038	4320	40º 15’	103º 48’
	Holyoke	54082	3730	40º 35’	102º 18’
	Kit Carson	54603	4280	38º 46’	102º 47’
	Sterling	57950	3940	40º 37’	103º 12’
	Wray	59243	3510	40º 4’	102º 13’
	Yuma	59295	4130	40º 7’	102º 44’

Prepared by David Whiting Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University. Source: Colorado Climate Center at www.wrcc.dri.edu/summary/climsmco.html

- CMG GardenNotes are available online at www.cmg.colostate.edu.
- Colorado Master Gardener training is made possible, in part, by a grant from the Colorado Garden Show, Inc.
- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.
- CSU Extension programs are available to all without discrimination.
-

Revised December 2006

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #749

Climate Summary: Northwest Colorado

Monthly Temperatures

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Craig	average extreme high	44	50	60	74	79	89	92	91	87	77	63	49	
	normal daily high	**30**	**34**	**46**	**56**	**66**	**74**	**84**	**83**	**74**	**61**	**43**	**32**	**57**
	normal daily low	**6**	**10**	**22**	**29**	**37**	**44**	**50**	**49**	**40**	**30**	**19**	**8**	**28**
	average extreme low	-14	-13	6	16	26	33	41	41	27	15	1	-11	
Hayden	average extreme high	44	48	60	73	82	90	93	91	86	77	63	48	
	normal daily high	**30**	**34**	**45**	**57**	**68**	**79**	**85**	**83**	**74**	**61**	**44**	**32**	**58**
	normal daily low	**7**	**10**	**20**	**28**	**36**	**43**	**49**	**48**	**40**	**29**	**20**	**9**	**29**
	average extreme low	-16	-13	2	15	25	32	40	39	25	15	0	-12	
Steamboat	average extreme high	44	47	57	70	78	87	90	89	84	75	60	45	
	normal daily high	**29**	**34**	**43**	**53**	**64**	**76**	**82**	**81**	**72**	**60**	**42**	**29**	**55**
	normal daily low	**3**	**5**	**17**	**24**	**32**	**36**	**42**	**41**	**34**	**24**	**16**	**4**	**23**
	average extreme low	-25	-21	-4	9	21	28	33	33	19	10	-5	-21	
Yampa	average extreme high	47	49	56	66	75	82	84	84	79	71	58	48	
	normal daily high	**31**	**35**	**41**	**51**	**62**	**72**	**76**	**76**	**68**	**56**	**41**	**32**	**54**
	normal daily low	**6**	**9**	**16**	**23**	**32**	**39**	**45**	**44**	**36**	**27**	**16**	**8**	**25**
	average extreme low	-17	-14	-5	5	19	27	35	35	21	10	-6	-14	

Total Monthly Precipitation (inches)

		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Craig	normal	1.1	1.1	1.5	1.7	1.6	1.2	1.4	1.2	1.5	1.8	1.5	1.0	16.7
	maximum	2.4	2.3	2.7	3.4	4.0	3.0	3.0	2.4	5.2	4.5	2.9	3.4	25.0
Hayden	normal	1.6	1.2	1.2	1.6	1.6	1.2	1.4	1.3	1.4	1.7	1.5	1.5	17.3
	maximum	3.5	2.6	2.5	3.3	4.1	3.4	3.5	3.1	6.2	3.8	3.7	5.1	26.4
Steamboat Springs	normal	2.6	2.1	2.0	2.4	2.3	2.3	1.5	1.5	1.5	1.7	1.9	2.3	23.8
	maximum	5.9	4.7	3.5	4.2	5.7	3.9	3.3	3.5	6.5	4.3	5.6	6.8	34.5
Yampa	normal	1.3	3.4	1.3	1.4	1.6	1.4	2.1	1.6	1.4	1.3	1.3	1.1	19.3
	maximum	2.9	7.3	3.1	2.9	3.5	2.6	4.0	3.8	3.9	3.6	3.0	3.2	

Total Monthly Snowfall (inches)

		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Craig	normal	17.2	14.2	11.6	6.4	1.1	0.1	0	0	0.4	4.0	12.1	12.6	81.2
	maximum	45.5	37.5	27.0	16.0	7.0	2.0	0	0	5.0	20.0	25.0	42.0	121.8
Hayden	normal	29.2	18.5	14.1	8.8	1.2	0.3	0	0	0.2	6.3	17.4	24.3	119.3
	maximum	71.3	49.0	30.5	21.5	9.5	8.0	0	0	4.0	24.0	50.9	74.5	178.4
Steamboat Springs	normal	40.5	27.8	20.6	12.9	2.4	0.3	0	0	0.3	8.0	25.0	35.2	179.4
	maximum	111.6	51.0	35.1	31.4	10.2	5.6	0	0	3.2	32.3	57.0	92.6	301.4
Yampa	normal	21.8	15.2	17.7	12.6	2.9	0.2	0	0.1	0.6	7.9	19.2	19.6	118.8
	maximum	68.6	40.5	34.5	28.0	15.0	4.0	0	1.5	5.0	23.0	44.0	59.7	190.2

Frost Probability and Growing Season Length Summary

		Spring Frost Probability			Fall Frost Probability			Length of Growing Season		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**10%**	**50%**	**90%**
Craig	32º threshold	May 10	**May 17**	May 29	Sept 4	**Sept 18**	Oct 1	92	**111**	131
	28º threshold	Apr 29	May 9	May 20	Sept 16	Sept 27	Oct 8	123	140	158
	24º threshold	Apr 10	Apr 25	May 11	Sept 22	Oct 6	Oct 20	145	163	182
Hayden	32º threshold	May 17	**June 3**	June 20	Aug 29	**Sept 14**	Oct 1	79	**104**	128
	28º threshold	Apr 24	May 16	June 6	Sept 9	Sept 24	Oct 9	103	132	160
	24º threshold	Apr 14	Apr 28	May 12	Sept 18	Oct 3	Oct 17	134	158	181
Steamboat	32º threshold	June 11	**June 26**	July 10	Aug 1	**Aug 24**	Sept 17	28	**60**	91
Springs	28º threshold	May 11	June 2	June 25	Aug 28	Sept 12	Sept 28	69	102	135
	24º threshold	Apr 23	May 15	June 5	Sept 11	Sept 22	Oct 3	104	130	156
Yampa	32º threshold	June 6	**June 21**	July 6	Aug 22	**Sept 8**	Sept 24	53	**79**	104
	28º threshold	May 20	June 5	June 22	Aug 31	Sept 16	Oct 2	79	102	126
	24º threshold	May 1	May 25	June 18	Sept 14	Sept 28	Oct 11	97	126	154

Site Information	Station	Number	Elevation	Latitude	Longitude
	Craig	51932	6440	40º 27''	107º 36'
	Hayden	53867	6340	40º 30'	107º 15'
	Steamboat Springs	57936	6770	40º 30'	106º 50'
	Yampa	59265	7890	40º 09'	106º 54'

Typical planting and harvest period based on average frost dates and normal temperatures

<table>
<tr><th></th><th>Late April</th><th>Early May</th><th>Mid May</th><th>Late May</th><th>Early June</th><th>Mid June</th><th>Late June</th><th>Early July</th><th>Mid July</th><th>Late July</th><th>Early Aug.</th><th>Mid Aug.</th><th>Late Aug.</th><th>Early Sept.</th><th>Mid Sept.</th><th>Late Sept.</th></tr>
<tr><td>Craig</td><td colspan="8">40-50 day, cool season crops (spinach, lettuce)</td><td></td><td></td><td></td><td></td><td></td><td></td><td>FROST</td><td></td></tr>
<tr><td></td><td colspan="9">55-60 day cool season crops (beets, broccoli, cabbage, carrots, cauliflower, chard),</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="10">65-70 day, cool season crops (peas)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="11">75 day, cool season crops</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="9">50 day, semi-tender, warm season crops (summer squash)</td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td colspan="12">70 day, semi-tender, warm season crops (beans)</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="13">75 day, semi-tender, warm season crop (corn)</td><td></td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">45-55 day, cool season crops (lettuce, kohlrabi)</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">40 day, cool season crops (spinach)</td><td></td><td></td></tr>
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<tr><td>Steamboat Springs</td><td></td><td></td><td></td><td></td><td></td><td></td><td>FROST</td><td></td><td></td><td></td><td></td><td></td><td>FROST</td><td></td><td></td><td></td></tr>
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<tr><td>Yampa</td><td></td><td></td><td></td><td></td><td></td><td></td><td>FROST</td><td></td><td></td><td></td><td></td><td></td><td></td><td>FROST</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td colspan="7">40-45 day, cool season crops (spinach, lettuce)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td colspan="8">50-55 day, cool season crops (kohlrabi)</td><td></td><td></td><td></td><td></td></tr>
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Prepared by David Whiting Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University
Source: Colorado Climate Center at www.wrcc.dri.edu/summary/climsmco.html

CMG GardenNotes #750

Climate Summary: Southwest Colorado

Monthly Temperatures

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Yellow Jacket	average extreme high	51	56	64	72	81	92	95	92	87	77	64	53	
	normal daily high	**38**	**43**	**50**	**59**	**69**	**82**	**87**	**84**	**76**	**63**	**48**	**40**	**62**
	normal daily low	**15**	**19**	**26**	**31**	**40**	**48**	**54**	**54**	**47**	**37**	**25**	**18**	**35**
	average extreme low	-2	1	10	18	27	35	47	47	34	21	8	1	
Cortez	average extreme high	52	59	67	75	82	94	96	93	88	78	65	56	
	normal daily high	**40**	**45**	**53**	**61**	**71**	**83**	**88**	**86**	**78**	**66**	**51**	**41**	**64**
	normal daily low	**13**	**18**	**25**	**30**	**38**	**46**	**54**	**53**	**44**	**33**	**23**	**15**	**33**
	average extreme low	-5	1	11	18	25	33	44	46	32	20	9	0	
Mancos	average extreme high	51	56	68	74	80	88	91	88	85	78	66	55	
	normal daily high	**40**	**45**	**53**	**59**	**69**	**79**	**83**	**82**	**76**	**65**	**51**	**40**	**61**
	normal daily low	**15**	**19**	**25**	**29**	**38**	**44**	**51**	**52**	**44**	**32**	**23**	**14**	**32**
	average extreme low	-1	5	9	18	25	34	41	46	32	17	48	-4	
Durango	average extreme high	51	60	65	76	84	93	95	93	88	78	70	55	
	normal daily high	**39**	**46**	**53**	**62**	**71**	**82**	**87**	**84**	**77**	**66**	**51**	**42**	**63**
	normal daily low	**11**	**16**	**23**	**29**	**36**	**43**	**51**	**49**	**41**	**31**	**21**	**13**	**31**
	average extreme low	-6	-1	10	19	25	33	43	41	29	19	6	-2	

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Ignacio	average extreme high	49	57	66	74	84	94	96	93	88	77	65	53	
	normal daily high	**39**	**45**	**52**	**62**	**71**	**83**	**88**	**85**	**76**	**65**	**51**	**41**	**63**
	normal daily low	**7**	**13**	**21**	**26**	**34**	**42**	**50**	**48**	**40**	**30**	**20**	**10**	**28**
	average extreme low	-9	-2	8	15	22	31	40	40	28	20	6	-4	
Pagosa Springs	average extreme high	51	57	64	72	79	88	90	88	84	75	63	53	
	normal daily high	**38**	**44**	**50**	**58**	**68**	**78**	**83**	**80**	**73**	**63**	**49**	**40**	**60**
	normal daily low	**3**	**9**	**18**	**24**	**31**	**37**	**45**	**45**	**37**	**26**	**16**	**6**	**24**
	average extreme low	-17	-10	0	11	20	28	36	36	25	14	-2	-13	

Total Monthly Precipitation (inches)

Yellow Jacket	normal	1.2	1.2	1.4	0.9	1.3	0.6	1.6	1.6	1.6	1.9	1.5	1.1	16.0
	maximum	4.3	5.0	3.8	3.0	5.4	2.5	4.0	4.5	4.1	8.1	3.9	4.4	22.6
Cortez	normal	1.0	0.9	1.4	0.9	1.0	0.5	1.2	15	1.4	1.6	1.2	1.0	13.1
	maximum	3.2	3.2	4.6	2.5	3.7	1.8	2.4	3.3	3.4	6.6	2.8	3.0	19.9
Mancos	normal	1.4	1.3	1.9	1.2	1.5	0.6	1.6	1.8	1.8	1.6	1.6	1.2	17.0
	maximum	4.0	3.5	4.0	2.8	5.0	1.7	3.7	3.8	3.6	7.0	3.3	3.1	22.2
Durango	normal	1.6	1.4	1.9	1.3	1.1	0.7	1.8	2.3	2.1	2.2	1.9	1.5	19.9
	maximum	6.9	4.8	3.7	3.0	3.0	2.0	5.4	4.3	5.1	11.8	4.6	4.2	27.3
Ignacio	normal	1.2	1.1	1.3	0.7	0.9	0.5	1.9	1.7	1.7	1.5	1.3	1.2	16.0
	maximum	4.7	3.4	3.8	2.3	2.3	1.7	14.7	3.5	4.5	7.0	3.5	4.4	35.2
Pagosa Springs	normal	1.9	1.4	1.8	1.3	1.4	0.9	1.8	2.3	2.2	2.3	1.7	1.5	21.0
	maximum	5.3	4.0	4.7	3.8	4.3	2.5	3.8	5.4	5.7	7.8	3.4	3.5	33.8

Total Monthly Snowfall (inches)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Yellow Jacket	normal	17.1	13.5	10.7	3.2	1.2	0	0	0	0	1.4	7.9	13.3	63.7
	maximum	61.0	45.4	59.0	24.0	19.0	0	0	0	0	11.0	28.0	38.0	137.4
Cortez	normal	5.9	3.1	1.8	1.0	0	0	0	0	0	0.3	1.4	3.7	11.1
	maximum	27.5	15.5	16.0	6.2	0.3	0	0	0	0	6.2	10.5	20.5	38.0
Mancos	normal	9.7	7.9	4.8	1.8	0.6	0	0	0	0	0.4	5.2	6.6	37.2
	maximum	39.1	20.4	20.5	8.4	5.1	0	0	0	0	4.4	18.8	20.3	95.0
Durango	normal	17.0	12.7	10.7	3.3	0.7	0	0	0	0	1.2	5.4	13.9	65.5
	maximum	58.5	34.5	29.5	16.0	11.0	0	0	0	0	17.0	22.5	33.5	130.6
Ignacio	normal	6.8	2.9	2.2	0.3	0	0	0	0	0	0.4	0.5		15.8
	maximum	34.00	17.0	26.0	50	0	0	0	0	0.1	6.5	5.0		70.1
Pagosa Springs	normal	27.2	18.7	18.0	6.3	1.0	0	0	0	0	3.1	13.2	20.1	105.7
	maximum	76.0	51.0	47.0	23.0	14.0	0	0	0	0	16.0	39.4	46.0	212.0

Site Information	Station	Number	Elevation	Latitude	Longitude
	Yellow Jacket	59275	6860	37° 33’	108° 44’
	Cortez	51886	6180	37° 21’	108° 34’
	Mancos	55327	7040	37° 21’	108° 17’
	Durango	52432	6550	37° 17’	107° 53’
	Ignacio	54250	6420	37° 08’	107° 38’
	Pagosa Springs	56258	7110	37° 16’	107° 01’

Frost Probability and Growing Season Length Summary

		Spring Frost Probability			Fall Frost Probability			Length of Growing Season		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**10%**	**50%**	**90%**
Yellow Jacket	32° threshold	May 8	**May 25**	June 10	Sept 22	**Oct 8**	Oct 23	112	**136**	160
	28° threshold	Apr 21	May 5	May 19	Sept 29	Oct 17	Nov 4	140	165	191
	24° threshold	Apr 1	Apr 20	May 10	Oct 9	Oct 26	Nov 13	163	189	215
Cortez	32° threshold	May 10	**May 26**	June 11	Sept 12	**Sept 27**	Oct 12	107	**124**	141
	28° threshold	Apr 26	May 7	May 18	Sept 25	Oct 12	Oct 29	136	158	181
	24° threshold	Apr 12	Apr 26	May 10	Oct 4	Oct 20	Nov 5	157	177	198
Mancos	32° threshold	May 21	**June 4**	June 18	Sept 15	**Sept 29**	Oct 13	93	**117**	141
	28° threshold	Apr 25	May 13	May 31	Sept 17	Oct 2	Oct 17	115	142	169
	24° threshold	Apr 16	Apr 25	May 4	Oct 60	Oct 17	Oct 29	164	175	187
Durango	32° threshold	May 9	**May 25**	June 11	Sept 8	**Sept 22**	Oct 7	98	**120**	142
	28° threshold	May 3	May 11	May 19	Sept 16	Oct 5	Oct 25	126	147	169
	24° threshold	Apr 5	Apr 22	May 9	Sept 23	Oct 13	Nov 2	143	174	205
Ignacio	32° threshold	May 23	**June 9**	June 26	Sept 7	**Sept 21**	Oct 6	78	**104**	131
	28° threshold	May 7	May 21	June 4	Sept 11	Oct 1	Oct 20	103	133	164
	24° threshold	Apr 21	May 9	May 27	Sept 18	Oct 13	Nov 7	119	157	195
Pagosa Springs	32° threshold	June 9	**June 22**	July 4	Aug 15	**Sept 7**	Sept 30	48	**77**	107
	28° threshold	May 18	June 5	June 23	Sept 9	Sept 23	Oct 6	89	110	130
	24° threshold	May 1	May 17	June 2	Sept 23	Oct 5	Oct 16	121	141	160

Prepared by David Whiting Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University
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Typical planting and harvest period based on average frost dates and normal temperatures

<table>
<tr><th></th><th>Mid
April</th><th>Late
April</th><th>Early
May</th><th>Mid
May</th><th>Late
May</th><th>Early
June</th><th>Mid
June</th><th>Late
June</th><th>Early
July</th><th>Mid
July</th><th>Late
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Aug.</th><th>Late
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Sept.</th><th>Mid
Sept.</th><th>Late
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Oct.</th></tr>
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<tr><td colspan="7">50-55 day, cool season crops (kohlrabi)</td><td rowspan="4"></td><td colspan="6">60-70 day, cool season crops (beets, broccoli, cabbage, carrots, cauliflower, chard, peas)</td></tr>
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<tr><td rowspan="6"></td><td colspan="8">50-55 day, semi-tender, warm season crops (summer squash)</td><td rowspan="5"></td><td rowspan="6"></td><td rowspan="6"></td><td rowspan="6"></td></tr>
<tr><td colspan="9">60-70 day, semi-tender, warm season crops (cucumbers, beans)</td></tr>
<tr><td colspan="10">75-85 day, semi-tender, warm season crops (corn)</td></tr>
<tr><td rowspan="3">FROST</td><td rowspan="3"></td><td colspan="8">70-75 day, tender, warm season crops (tomatoes, peppers, eggplant)</td></tr>
<tr><td colspan="9">80-85 day, tender, warm season crops (cantaloupe, watermelon, winter squash)</td></tr>
<tr><td colspan="10">90-100 day, tender, warm season crops (winter squash)</td></tr>
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Prepared by David Whiting Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University

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Revised April 2008

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #751

Climate Summary: Pueblo, Colorado

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Monthly Temperature (degrees F)													
Average high	46	52	59	67	76	88	93	90	82	70	54	46	69
Average low	14	19	26	35	45	54	59	58	49	35	22	15	36
Monthly Precipitation (inches)	0.3	0.4	0.9	1.2	1.6	1.3	2.0	2.2	0.9	0.7	0.6	0.4	12.4
Monthly Snowfall (inches)	5.4	3.9	5.9	3.6	0.4	0.0	0.0	0.0	0.6	1.4	3.8	4.7	29.7

		Spring Frost Probabilities			**Fall Frost Probabilities**			**Length of "Frost Free" Season** (day)		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**90%**	**50%**	**10%**
Pueblo	32° threshold	Apr 14	May 1	May 13	Sept 21	Oct 8	Oct 24	134	158	189
	28° threshold	Apr 8	Apr 18	May 1	Sept 30	Oct 17	Oct 30	159	180	198
	24° threshold	Mar 25	Apr 8	Apr 22	Oct 11	Oct 25	Nov 9	176	200	227

Typical planting and harvest period based on average frost dates and normal temperatures

<table>
<tr><th></th><th>Mid April</th><th>Late April</th><th>Early May</th><th>Mid May</th><th>Late May</th><th>Early June</th><th>Mid June</th><th>Late June</th><th>Early July</th><th>Mid July</th><th>Late July</th><th>Early Aug.</th><th>Mid Aug.</th><th>Late Aug.</th><th>Early Sept.</th><th>Mid Sept.</th><th>Late Sept.</th><th>Early Oct.</th></tr>
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MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #752

Climate Summary: Chaffee County

Salida and Buena Vista, Colorado

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Monthly Temperatures (degrees F)														
Buena Vista	Average high	40	43	49	55	65	76	81	78	72	61	46	40	59
	Average low	10	14	20	26	34	42	47	46	38	27	18	10	28
Salida	Average high	27	32	39	46	58	69	74	73	65	54	38	28	50
	Average low	12	16	22	28	36	43	48	47	39	28	20	13	29
Average Monthly Precipitation (inches)														
Buena Vista		0.3	0.4	0.7	1.0	1.1	0.9	1.5	1.7	1.0	0.8	0.6	0.4	10.2
Salida		0.2	0.3	0.6	0.8	1.0	0.8	1.3	1.8	1.2	0.9	0.4	0.2	9.6
Average Monthly Snowfall (inches)														
Buena Vista		4.9	5.6	7.4	5.5	2.6	0.1	0.0	0.0	0.9	2.7	5.2	4.7	39.6
Salida		4.8	5.8	8.4	6.8	2.6	0.0	0.0	0.0	0.7	5.5	7.6	5.5	47.6

Frost Probability and Growing Season Summary

		Spring Frost Probability			Fall Frost Probability			Length of "Frost Free" Season (days)		
		90%	50%	10%	10%	50%	90%	90%	50%	10%
Buena Vista	**32º threshold**	May 20	**June 2**	June 12	Sept 3	**Sept 19**	Sept 27	90	**109**	120
	28º threshold	May 2	May 13	May 31	Sept 10	Sept 29	Oct 11	109	132	150
	24º threshold	April 17	April 30	May 13	Sept 4	Oct 9	Oct 24	134	160	177
Salida	**32º threshold**	May 14	**May 29**	June 15	Aug 30	**Sept 14**	Sept 29	87	**109**	127
	28º threshold	May 1	May 14	May 28	Sept 13	Sept 29	Oct 9	118	134	146
	24º threshold	April 16	May 5	May 21	Sept 25	Oct 8	Oct 30	140	156	176

Prepared by David Whiting Extension Consumer Horticulture Specialist (retired), Department of Horticulture and LA, Colorado State University
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CMG GardenNotes #753

Climate Summary: San Miguel Basin

Norwood and Telluride, Colorado

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Monthly Temperatures (degrees F)														
Norwood	Average high	38	43	50	58	67	78	83	81	73	62	46	39	60
	Average low	11	16	23	28	36	44	50	49	42	32	20	12	30
Telluride	Average high	38	41	45	53	62	73	78	75	69	59	45	38	56
	Average low	6	10	16	23	31	37	42	42	35	26	15	7	24
Average Monthly Precipitation (inches)														
Norwood		1.0	0.8	1.1	1.2	1.3	0.9	1.8	2.0	1.8	1.7	1.4	1.0	15.9
Telluride		1.7	1.6	2.1	2.1	2.0	1.3	2.3	2.7	2.4	2.0	1.8	1.6	23.4
Average Monthly Snowfall (inches)														
Norwood[2]		12.7	10.1	9.8	5.1	0.6	0.0	0.0	0.0	0.1	2.5	8.0	10.7	59.6
Telluride[3]		27.4	25.3	31.9	22.0	6.5	0.7	0.0	0.0	0.9	9.1	20.9	24.6	169.3

Frost Probability and Growing Season Summary

		Spring Frost Probability			Fall Frost Probability			Length of "Frost Free" Season (days)		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**90%**	**50%**	**10%**
Norwood	**32º threshold**	May 17	**June 9**	June 25	Sept 2	**Sept 21**	Oct 7	81	**108**	135
	28º threshold	May 3	May 22	June 11	Sept 15	Oct 2	Oct 14	114	137	159
	24º threshold	April 21	May 6	May 29	Sept 21	Oct 10	Oct 28	122	160	181
Telluride	**32º threshold**	June 15	**June 28**	July 13	Aug 11	**Aug 31**	Sept 17	33	**62**	89
	28º threshold	May 31	June 16	July 1	Aug 28	Sept 14	Sept 27	65	88	111
	24º threshold	May 5	May 22	May 14	Sept 13	Sept 25	Oct 14	99	127	149

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CMG GardenNotes #754

Climate Summary: San Luis Valley, Colorado

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Monthly Temperatures (degrees F)														
Alamosa	Average high	34	41	50	59	68	78	82	79	73	62	45	35	59
	Average low	-2	6	16	24	33	41	47	45	37	24	11	0	24
Del Norte	Average high	35	41	50	59	67	75	78	76	71	61	46	36	58
	Average low	7	13	21	27	36	43	48	47	40	30	18	9	28
Monte Vista	Average high	34	41	50	58	68	76	80	78	72	62	45	36	58
	Average low	1	8	17	24	34	41	46	45	37	26	13	3	25
Average Monthly Precipitation (inches)														
Alamosa		0.3	0.3	0.4	0.6	0.7	0.6	1.0	1.2	0.9	0.7	0.5	0.3	7.3
Del Norte		0.3	0.4	0.7	0.8	0.9	0.8	1.6	1.8	1.2	0.8	0.7	0.5	10.4
Monte Vista		0.2	0.3	0.5	0.6	0.7	0.6	1.3	1.5	1.0	0.6	0.6	0.3	8.2
Average Monthly Snowfall (inches)														
Alamosa		4.3	4.1	5.6	4.0	1.5	0.0	0.0	0.0	0.2	2.9	3.9	5.1	31.7
Del Norte		5.4	5.7	7.8	4.8	1.4	0.0	0.0	0.0	0.1	3.3	5.9	7.1	41.6
Monte Vista		3.6	3.4	4.4	2.3	0.6	0.0	0.0	0.0	0.0	1.4	3.6	3.8	23.1

Frost Probability and Growing Season Summary

		Spring Frost Probability			Fall Frost Probability			Length of "Frost Free" Season (days)		
		90%	50%	10%	10%	50%	90%	90%	50%	10%
Alamosa	**32º threshold**	May 25	**June 10**	June 20	Aug 28	**Sept 10**	Sept 25	76	**95**	112
	28º threshold	May 11	May 27	June 14	Sept 9	Sept 21	Oct 3	100	117	137
	24º threshold	April 29	May 12	May 25	Sept 18	Sept 30	Oct 13	123	142	158
	177									
Del Norte	**32º threshold**	May 15	**May 30**	June 14	Sept 8	**Sept 22**	Oct 4	92	**116**	134
	28º threshold	April 30	May 15	June 2	Sept 18	Oct 4	Oct 16	115	142	162
	24º threshold	April 6	May 1	May 14	Sept 28	Oct 15	Oct 31	142	165	189
Monte Vista	**32º threshold**	May 20	**June 6**	June 22	Aug 26	**Sept 11**	Sept 28	66	**97**	122
	28º threshold	May 10	May 20	June 13	Sept 8	Oct 22	Oct 9	96	124	150
	24º threshold	April 28	May 10	May 26	Sept 19	Oct 4	Oct 15	121	147	162

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Revised April 2008

MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #755

Climate Summary: Cañon City, Colorado

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Monthly Temperature (degrees F)													
Average high	49	52	58	64	73	83	88	86	78	69	55	49	67
Average low	21	24	30	37	45	54	60	58	50	39	28	22	39
Monthly Precipitation (inches)	0.4	0.5	0.9	1.5	1.7	1.2	1.8	2.1	1.2	0.8	0.8	0.5	13.3
Monthly Snowfall (inches)	5.3	6.3	7.5	4.2	0.3	0.0	0.0	0.0	0.3	1.8	4.7	6.2	36.5

		Spring Frost Probabilities			**Fall Frost Probabilities**			**Length of "Frost Free" Season** (day)		
		90%	**50%**	**10%**	**10%**	**50%**	**90%**	**90%**	**50%**	**10%**
Cañon City	32º threshold	Apr 15	May 2	May 18	Sept 22	Oct 9	Oct 25	132	159	179
	28º threshold	Mar 31	Apr 18	May 11	Oct 6	Oct 22	Nov 8	156	183	210
	24º threshold	Mar 19	Apr 10	Apr 27	Oct 14	Nov 4	Nov 23	190	211	242

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Revised April 2008

Typical planting and harvest period based on average frost dates and normal temperatures

Grand Junction

Early March	Mid March	Late March	Early April	Mid April **FROST**	Late April	Early May	Mid May	Late May	Early June	Mid June	Late June	Early July	Mid July	Late July	Early Aug.	Mid Aug.	Late Aug.	Early Sept.	Mid Sept.	Late Sept.	Early Oct.	Mid Oct. **FROST**
40-45 day, cool season crops (spinach, lettuce)	▨	▨	▨	▨											65-75 day, cool season crops (peas)	▨	▨	▨	▨	▨	▨	Cold-hardy crops, like spinach & lettuce, can also be planted in the fall for a spring Crop
50-60 day, cool season crops (kohlrabi, beets, broccoli, cabbage,	▨	▨	▨	▨	▨											55-60 day, cool season crops (beets, broccoli, cabbage, carrots,	▨	▨	▨	▨	▨	
65-70 day, cool season crops (peas)	▨	▨	▨	▨	▨	▨											40-50 day, cool season crops (spinach, lettuce, kohlrabi)	▨	▨	▨	▨	
75-80 day, cool season crops	▨	▨	▨	▨	▨	▨	▨															
				50-55 day, semi-tender, warm season crops (summer squash)	▨	▨	▨	▨	▨	▨												
				60-65 day, semi-tender, warm season crops (cucumbers)	▨	▨	▨	▨	▨	▨	▨											
							70-75 day, semi-tender, warm season crops (beans, corn) Warm soil needed.	▨	▨	▨	▨	▨	▨	▨	▨							
							80 day, semi-tender, warm season crops (corn)	▨	▨	▨	▨	▨	▨	▨	▨	▨						
							70 day, tender, warm season crops (tomatoes, peppers, eggplant)	▨	▨	▨	▨	▨	▨	▨								
							80-85 day, tender, warm season crops (cantaloupe, watermelon)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
							90-95 day, tender, warm season crops (winter squash)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			

Delta

Early March	Mid March	Late March	Early April	Mid April	Late April **FROST**	Early May	Mid May	Late May	Early June	Mid June	Late June	Early July	Mid July	Late July	Early Aug.	Mid Aug.	Late Aug.	Early Sept.	Mid Sept.	Late Sept.	Early Oct. **FROST**
		40-45 day, cool season crops (spinach, lettuce)	▨	▨	▨	▨	▨							65-70 day, cool season crops (peas)	▨	▨	▨	▨	▨	▨	▨
			50-60 day, cool season crops (kohlrabi)	▨	▨	▨	▨	▨	▨							50-55 day, cool season crops (kohlrabi)	▨	▨	▨	▨	▨
			60-70 day, cool season crops (beets, broccoli, cabbage, carrots, cauliflower, chard, peas)	▨	▨	▨	▨	▨	▨	▨			75 day cool season crops	▨	▨	▨	▨	▨	▨	▨	▨
			75 day cool season crops	▨	▨	▨	▨	▨	▨	▨	▨					40-45 day, cool season crops (spinach, lettuce)	▨	▨	▨	▨	▨
						50 day, semi-tender, warm season crops (summer squash)	▨	▨	▨	▨	▨	▨	▨								
						55-60 day, semi-tender, warm season crops (cucumbers)	▨	▨	▨	▨	▨	▨	▨	▨	▨						
						65-70 day, semi-tender, warm season crops (beans) Warm soil needed.	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨					
						75-80 day, semi-tender, warm season crops (corn)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
						85-90 day, semi-tender, warm season crops (corn)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
							70-75 day, tender, warm season crops (tomatoes, peppers, eggplant)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
							80-85 day, tender, warm season crops (cantaloupe, watermelon)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
							90-95 day, tender, warm season crops (winter squash)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		

Montrose

Early March	Mid March	Late March	Early April	Mid April	Late April **FROST**	Early May	Mid May	Late May	Early June	Mid June	Late June	Early July	Mid July	Late July	Early Aug.	Mid Aug.	Late Aug.	Early Sept.	Mid Sept.	Late Sept.	Early Oct.	Mid Oct. **FROST**
	40-45 day, cool season crops (spinach, lettuce)	▨	▨	▨	▨	▨								60-70 day, cool season crops (beets, broccoli, cabbage, carrots, cauliflower, chard, peas)	▨	▨	▨	▨	▨	▨	▨	▨
	50-55 day, cool season crops (kohlrabi)	▨	▨	▨	▨	▨	▨								50-55 day, cool season crops (kohlrabi)	▨	▨	▨	▨	▨	▨	▨
	55-60 day, cool season crops (beets, broccoli, cabbage, carrots, cauliflower, chard)	▨	▨	▨	▨	▨	▨	▨									40-45 day, cool season crops (spinach, lettuce)	▨	▨	▨	▨	▨
	65-75 day, cool season crops (peas)	▨	▨	▨	▨	▨	▨	▨	▨					75 day cool season crops	▨	▨	▨	▨	▨	▨	▨	▨
						50-60 day, semi-tender, warm season crops (summer squash, cucumbers)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨					
						65-70 day, semi-tender, warm season crops (beans)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
						75 day, semi-tender, warm season crops (corns)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
						80 day, semi-tender, warm season crops (corn)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
						85 day, semi-tender, warm season crops (corns)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
							70-75 day, tender, warm season crops (tomatoes, peppers, eggplant)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
							80 day, tender, warm season crops (cantaloupe, watermelon)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
							85 day, tender, warm season crops (winter squash)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	

Ouray

Mid March	Late March	Early April	Mid April	Late April	Early May	Mid May **FROST**	Late May	Early June	Mid June	Late June	Early July	Mid July	Late July	Early Aug.	Mid Aug.	Late Aug.	Early Sept.	Mid Sept.	Late Sept.	Early Oct. **FROST**
			40 day, cool season crops (spinach)									60-70 day, cool season crops (beets, broccoli, cabbage, carrots, cauliflower, chard, peas)								
			45-50 day, cool season crops (lettuce, kohlrabi)										50-55 day, cool season crops (kohlrabi)							
			55-60 day, cool season crops (beets, broccoli, cabbage, carrots, cauliflower, chard)												40-45 day, cool season crops (spinach, lettuce)					
			65-75 day, cool season crops (peas)																	
					50-60 day, semi-tender, warm season crops (summer squash, cucumbers)															
					65-70 day, semi-tender, warm season crops (beans)															
					75 day, semi-tender, warm season crops (corns)															
					80 day, semi-tender, warm season crops (corn)															
					85 day, semi-tender, warm season crops (corns)															
						70-75 day, tender, warm season crops (tomatoes, peppers, eggplant)														
						80 day, tender, warm season crops (cantaloupe, watermelon)														
						85 day, tender, warm season crops (winter squash)														

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Small Fruits

Reference / Supplemental Reading

CSU Extension Publications available online at www.cmg.colostate.edu

- Blackberries – *Growing Blackberries in Colorado Gardens* – CMG GardenNotes #762
- *Currants* - Plant*talk* #1214
- *Currants, Gooseberries and Jostaberries* - Fact Sheet #7.005
- *Elderberries* - Plant*talk* #1212
- Gooseberries - *Currant, Gooseberries and Jostaberries* - Fact Sheet #7.005
- *Gooseberries* - Plant*talk* #1215
- Grapes – *Growing Grapes in Colorado Gardens Garden* – CMG GardenNotes #764
- *Grapes* - Plant*talk* #1203
- *Japanese Beetles* - Fact Sheet #5.601
- Raspberries – *Growing Raspberries in Colorado Gardens* – CMG GardenNotes #761
- *Raspberries* - Plant*talk* #1207
- *Raspberry Cane Borer* - Plant*talk* #1478
- *References and Review Questions: Small Fruits*, CMG GardenNotes #760
- *Root Weevils* - Fact Sheet #5.551
- *Serviceberries* - Plant*talk* #1213
- Spider Mites - Fact Sheet #5.507
- *Strawberries* - Plant*talk* #1208
- *Strawberries for the Home Garden* - Fact Sheet #7.000
- Strawberries – *Growing Strawberries in Colorado Gardens* – CMG GardenNotes #763
- *Strawberry Diseases* - Fact Sheet #2.931
- *Strawberry Pests and Diseases* - Plant*talk* #1441

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Small Fruits

Learning Objectives

At the end of this unit, the student will be able to describe:

- Planting of raspberries.
- Pruning of fall-bearing (primocane-fruiting) raspberries and summer-bearing (floricane-fruiting) raspberries.
- Trellising systems for raspberries
- General care of raspberries.
- Trellising and pruning of trailing, erect, and semi-erect type blackberries
- Planting and renewal of June-bearing strawberry cultivars.
- Planting and renewal of fall bearing and day neutral strawberry cultivars.
- General care of strawberries
- Trellising and pruning of grapes in a single curtain system (include first spring, second spring, third spring, and forth spring and beyond.

Review Questions

1. What is the difference in raspberry fruit and blackberry fruit?

2. Describe planting for red raspberries.

3. Describe pruning for summer crop raspberries.

4. Describe pruning for fall-bearing raspberries if you want both the summer and fall crops. Describe pruning for fall-bearing raspberries if you want only the higher quality fall crop.

5. Describe irrigation and fertilization needs of raspberries.

6. Describe planting and care of June-bearing strawberries. How is the patch renewed?

7. Describe planting and care of ever-bearing and day-neutral strawberries. How is the patch renewed?

8. Describe grape pruning at planting, year 1, year 2, year 3, and year 4+. Why are grapes pruned so heavily?

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CMG GardenNotes #761

Growing Raspberries in Colorado Gardens

Outline:

Types and Cultivars

Fall-bearing (primocane-fruiting) red raspberry cultivars are typically more hardy than summer crop cultivars. Suggested cultivars include *Autumn Britten*, *Polana*, *Jaclyn*, *Caroline*, and *Heritage*. *Joan-J* and *Himbo-Top* have not performed well in Colorado trials.

Summer-bearing (floricane-fruiting) red raspberry cultivars have some winter hardiness problems in climates like Colorado, with frequent winter to spring and back to winter temperature swings. Suggested cultivars include *Nova*, *Boyne*, and *Killarney*.

Black raspberry or **"blackcap" –** Suggested cultivars include *MacBlack* and *Jewel*.

Purple raspberries are a hybrid of red and black. Suggested cultivars include *Royalty*.

Yellow raspberries are a mutation of red. Suggested cultivars include *Anne*.

Figure 1. Raspberries are a good crop for the home gardener.

Planting Raspberries

With good growing conditions, a raspberry patch may last 10 to 15 years. Viral diseases and hardiness problems frequently shorten the life of a patch. Raspberries need full sun, but avoid reflected heat in areas with hot summer temperatures. In open windy areas, wind protection is important as dry winds can dehydrate and kill exposed canes.

Raspberries prefer a deep, well-drained, sandy loam soil. They perform poorly on compacted clayey soils and soils with poor drainage. On clayey soils, plant in a raised bed. Because raspberries are a long-term crop, extra efforts to improve the organic content of the soil to 5% gives good dividends.

Due to soil borne diseases, do not plant raspberries where raspberries, strawberries, tomatoes, peppers, eggplant, potatoes, or vine crops (cucumbers, squash and melons) have been grown in the past four years. To reduce virus potential, do not plant raspberries next to blackberries. To help manage virus problems, purchase certified virus-free nursery stock.

In the home garden, raspberries are generally planted in a hedgerow. Place plants in a row 12 to 18 inches between plants with four to eight feet between rows (depending on trellising system and equipment used. If planting bare-root plants, soak plants in water for a few hours before planting. Dig shallow holes large enough to spread out the root mass and set plant with the top root one to two inches below soil level. Water plants to settle the soil. Cut newly planted canes to 6 inches. Care of the new planting should be similar to vegetable transplants with frequent, light irrigation until the plants become established.

Allow canes to fill in making the hedgerow. By hoeing or cultivation, routinely remove any canes that come up outside of the hedgerow. For higher yields and reduced pest problems, keep the hedgerow width to only 8 to 12 inches for fall cultivars and 12-18 inches for summer cultivars. [Figure 2]

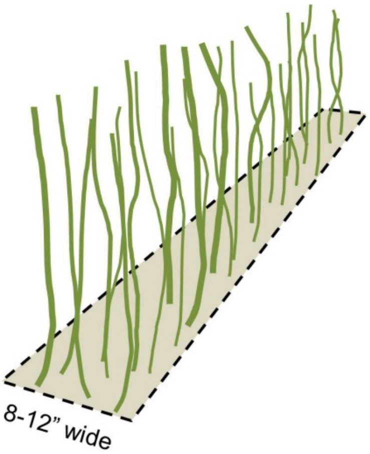


Figure 2. Red raspberries in a hedgerow. For higher yield, keeps width of hedgerow to only 8 to 12 inches wide for fall bearing cultivars.

Pruning

Primocane vs. Floricane – The crown and roots system of raspberries are perennial. The canes are biennial. *Primocane* refers to the first year canes; *floricane* refers to the second year canes.

Fall-Bearing (Primocane-Fruiting) Raspberries

In fall-bearing cultivars, the fall crop starts at the top of the *primocane* (new cane this summer), working its way down the cane with each picking. Next summer, the crop starts at the point where the fall crop ended the previous season, continuing downward.

For best yields and high fruit quality, prune to a fall crop only. In February/March, prune all canes to the ground. This eliminates the summer crop, putting all the growth into the superior fall crop. This also helps eliminate winter injury problems and many common insect pests.

For a fall and summer crops, prune the same as summer-bearing cultivars.

Summer-Bearing (Floricane-Fruiting) Raspberries

1. *Primocanes* (new canes the first year) are not pruned.
2. In spring (February/March), prune as follows:
    - Remove spindly canes, leaving stocky canes ¼ inch in diameter and larger. Thin stocky canes to about 10 canes per foot of hedgerow.
    - **For larger fruit size**, tip canes at a convenient height where they will be self-supporting, typically around 5 feet. Canes may be tied in clusters to a trellis.
    - **For larger yields,** do not tip canes. Canes may be tied in clusters to a trellis
3. Mid summer when the fruiting is finished, remove all *floricanes* (flowering/fruiting canes) to the ground. They will not fruit again. This makes room for the new crop of *primocanes*.

Trellising

Raspberries are easier to manage if trellised. Examples of trellising systems are given in figures 3-5. [Figures 3-5]

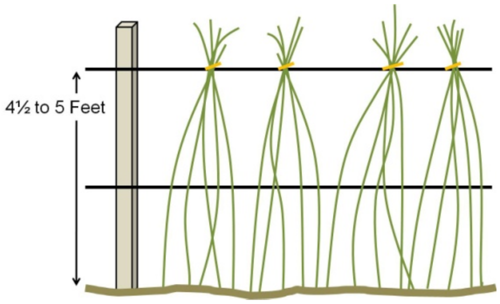


Figure 3. The **one-line trellis** system has wires running at 30 inches and 4½ to 5 feet. Canes are tied to the lines in bundles.

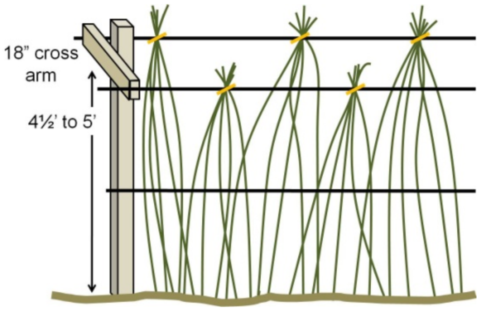
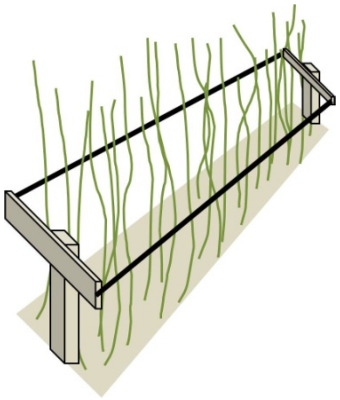


Figure 4. The **two-line trellis** system added an 18-inch cross arm at 4 ½ to 5 feet. Wires are run at the edge of the cross-arm forming a box. Canes are tied in bundles on the two lines.

Figure 5. The **T-trellis** system is popular for fall bearing (primocane-fruiting) cultivars. At knee height, a cross arm and wire form a box. Canes are free floating inside the box.

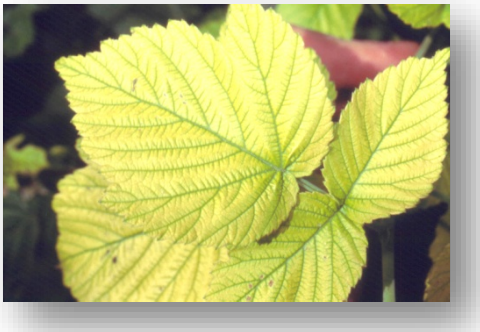


Irrigating

Raspberries need about one-inch of water (rain and irrigation) per week during blooming/fruiting. Depending on soil type, this may require irrigation once to twice a week. When watering, avoid wetting the leaves and fruit as this can cause disease problems. Raspberries work well with drip irrigation under wood chip mulch.

Water use is significantly less during nonfruiting times. Iron chlorosis (yellowing of leaves with veins remaining green) is a common symptom of over-watering. [Figure 6]

Figure 6. Iron chlorosis (yellowing of leaves with veins remaining green) is a common symptom of over-watering. Raspberries are commonly over watered in the spring.



Fertilizing

A good guide for fertilization is to observe plant growth. Leaves should be healthy green and primocane should grow to 5-8 feet. Adjust actual fertilizer rate if plants grow too tall or are too short.

Fertilize all raspberries in the spring as growth starts and repeat in early June. For fall bearing cultivars, make a third application in August. Apply ½ to 1 cup of ammonium sulfate (21-0-0) or similar fertilizer per 10 feet of hedgerow. The fertilizer may be broadcast over the hedgerow area and watered in or placed in a band one foot to the side of the row.

If using compost or manure, make application in the late fall or early winter, but avoid early fall applications which can push late fall growth.

Common Raspberry Pests

Abiotic

- **Winter dehydration** is less of a problem in fall bearing cultivars where they are pruned to the ground each spring.

- **Sunburn of fruit** (light color patches on the top side of fruit) is common in hot weather. Raspberries prefer cooler temperatures.

- **Iron chlorosis** (yellow leaves with veins remaining green) is a common symptom of springtime over-watering. Correct watering problems. For additional information on iron chlorosis, refer to CMG GardenNotes #623, *Iron Chlorosis.*

Insects and mites

- **Spottedwing drosophila flies** can affect ripening raspberries, in particular fall bearing cultivars.

- **Grasshoppers** eat raspberries.

- **Spider mite** populations explode in hot summers and following the use of the insecticide Sevin (carbaryl). Leaves appear bronzed. For additional information, refer to CSU Extension Factsheet #5.507, *Spider Mites.*

- **Cane borer, crown borer,** and **stem borer** are common borers of cane crops. These are less of a problem in fall bearing cultivars where the canes are removed to the ground each spring. For additional information, refer to PlantTalk Colorado #1478, *Raspberry Cane Borers*.

- **Plant bugs** cause misshapen fruit.

- **Raspberry sawflies** are caterpillar-like insects that feed on leaves.

- **Leaf rollers**

Diseases

- **Virus complex** – Raspberries are prone to a variety of viruses. Simply remove the patch when the fruit become small and the patch is less productive. Start the new patch in another area of the garden using new, virus-free plants.

Authors: David Whiting (CSU Extension, retired), with Merrill Kingsbury (CSU Extension).
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CMG GardenNotes #762

Growing Blackberries in Colorado Gardens

In blackberries, the receptacle (white core of the fruit) is part of the fruit when picked. In raspberries the receptacle remains on the plant when picked.

Types and Cultivars

Trailing blackberries produce vigorous *primocanes* (first-year vegetative cane) from the crown of the plant rather than roots. Second year *floricanes* produce long shaped fruit with relatively small seeds and a highly aromatic, intense flavor. They are not hardy in climates like Colorado, experiencing damage at temperatures of 13°F in mid winter, and in the 20s°F in late winter/early spring.

Erect blackberries have stiff arching canes that are somewhat self-supporting. However, they are much easier to handle when trellised and pruned. Summer prune or tip primocanes to encourage branching and increase fruit production on the second-year floricanes. Plants can become invasive to an area as they can produce new primocanes (suckers) from roots.

Erect blackberries produce fruit with relatively large seeds. Flavor and aroma are not as intense as in the trailing blackberry cultivars. They are semi-hardy in climates with rapid springtime temperature shifts, like Colorado.

Primocane-fruiting cultivars of erect blackberries produce fruit on the new canes. This make management easier as the canes can be cut to the ground each winter. Suggested cultivars include *Prime Jan* and *Prime Jim*.

Semi-erect blackberry plants are thornless and produce vigorous, thick, erect canes from the crown. No primocanes are produced from the roots (suckering). Prune primocanes in the summer to encourage branching and increase fruit production on floricanes. A trellis is required to support the canes.

Semi-erect blackberries generally produce a higher yield than trailing or erect types. Fruit quality is similar to that of the erect blackberries. Suggested cultivars include *Triple Crown* and *Chester Thornless*.

Figure 1. Blackberries

Blackberry/red raspberry hybrids are generally natural crosses between blackberries and raspberries. Because the receptacle (white core) comes off with the fruit, they are generally considered a type of blackberry. Popular cultivars include *Boysen* (Boysenberry), *Logan* (Loganberry), and *Tay* (Tayberry).

Planting and Care of Blackberries

Blackberries produce best in full sun, but are tolerant of partial shade. They are more tolerant of clayey soils than raspberries. However, good drainage is essential. Because blackberries may last for 10 to 15 years, extra attention to improving the soil organic content to 5% gives big dividends.

For semi-erect cultivars, space plants five to six feet apart. Space erect cultivars two to three feet apart. Space trailing cultivars four to six feet apart. Start with certified disease-free nursery stock. Planting would be similar to raspberries. To reduce virus problems, do not plant blackberries adjacent to raspberries.

Irrigation, fertilization, and pest management would be similar to raspberries. Refer to *CMG GardenNotes* #761, **Growing Raspberries in Colorado Gardens.**

Trellising and Pruning

Trellising is recommended for all blackberries.

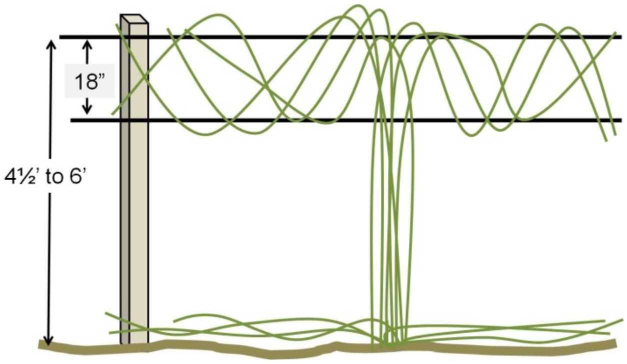
Trailing blackberries are easy to grow on a two-wire system. Run a top wire at five to six feet with a second line 18 inches below the top wire.

After the first year, there will be fruiting floricanes along the wires. Train the new primocanes into a narrow row below the fruiting canes. Directing all canes in one direction may make it simpler.

After the fruit harvest period, the old fruiting (floricanes) are removed. However, unless there is a lot of disease, it's best to delay removing the old fruiting canes until they have died back considerably. This allows the dying canes to move nutrients back into the crown and roots. After old fruiting canes are removed, train the primocanes up on the wires. Work with one or two canes at a time in a spiral around the trellis wires. Canes from adjacent plants may overlap a little. No pruning of primocanes is necessary.

In areas with low winter temperatures, leave the primocanes on the ground for the winter where they can be mulched for winter protection. In the spring, after chance of extreme cold has passed, train the old primocanes (now floricanes) up on the wires. Avoid working with the canes in cold weather, as they are more prone to breaking. [Figure 2]

Figure 2. Two wire trellis for trailing blackberries. Spread floricanes up on a two-wire system.

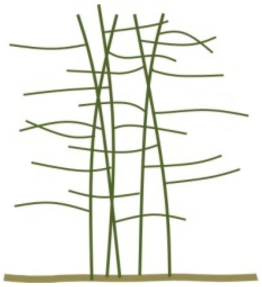


Erect blackberries produce stiff, shorter canes that come from the crown and root suckering (forming a hedgerow). A T-trellis supports erect blackberries well.

Erect blackberries require summer pruning. Remove the top one to two inches of new primocanes when they are four feet tall. This causes the canes to branch, increasing next year’s yields. This will require several pruning sessions to tip each cane as it reaches the four foot height. Primocanes (suckers) that grow outside the hedgerow should be regularly removed.

In the winter, remove the dead floricanes (old fruiting canes) from the hedgerow. Also shorten the lateral branches to about 1½ to 2½ feet. [Figure 3]

Figure 3. Pruning of erect blackberries after winter pruning.



Primocane-fruiting erect blackberries –   For best quality fruit, cut all canes off just above the ground in the late winter. In the summer, when the primocanes are 3½ feet tall, removed the top 6 inches. The primocanes will branch, thereby producing larger yields in the fall.

Semi-erect blackberries are vigorous and easier to manage on a Double T Trellis. Install four-foot cross arms at the top of a six foot post. Install a three-foot cross arm about two-feet below the top line. String high-tensile wire down the rows, connecting to the cross arms.

Semi-erect blackberries require summer pruning. When the primocanes are five feet tall, remove the top two inches to encourage branching. This will require several pruning sessions to prune canes as they reach this height.

In the winter, remove the dead floricanes (old fruiting canes). Spread the primocanes (new floricanes) out along the trellis. Canes do not need to be shortened. However, they can be if they are difficult to train.

Authors: David Whiting (CSU Extension, retired), with Merrill Kingsbury (CSU Extension).

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CMG GardenNotes #763

Growing Strawberries in Colorado Gardens

Types and Cultivars

June-bearing cultivars have one large crop in early summer (late June to early July along the Colorado Front Range) with larger fruit and higher yields. They are less hardy in climates like Colorado because of rapid springtime temperature swings. They are often damaged by late spring frosts. Strawberries are popular for freezing and jams with flavorful, aromatic berries. Suggested cultivars include *Honeoye*, *Guardian*, *Kent*, *Redchief*, *Delite*, *Jewel*, *Mesabi*, *A.C. Wendy*, *Cabot*, *Bloominden Gem*, *Carskill*, and *Geneva*.

Ever-bearing cultivars have two crops, one in early summer and a second crop in the fall. They tend to be more reliable than June bearing cultivars in cold climates like Colorado. Berries are smaller than the June bearing types. Suggested cultivars include *Quinalt*, *Ogallala*, and *Fort Laramie*.

Day-neutral cultivars blossom most of the summer and fall in cycles lasting around six weeks each. Blossoming will slow or stop during hot weather. Fruit is typically small. These provide a light, daily harvest through most of the summer and fall. They need constant, light fertilization and regular removal of runners. Suggested cultivars include *Tribute*, *Tristar*, and *Fern*.

Figure 1. Day-neutral cultivars provide a small, continual harvest of fresh strawberries throughout the summer and fall (except in extreme heat).

Plantings

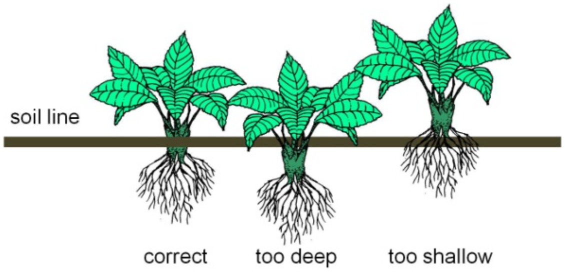
The key to a good strawberry patch is well-drained soil high in organic matter. Strawberries need full sun (8 hours minimum), but do not perform well in reflected heat. They need protection from wind. In clayey soils, they grow better in raised-beds that provide better drainage. Strawberries are shallow rooted and intolerant of weed competition.

Due to soil borne diseases, avoid soils where strawberries, raspberries, tomatoes, peppers, eggplant, potatoes, and vine crops (squash, melons, pumpkins and cucumbers) have been growing in the past four years.

Blossom potential for the following year is based on plant health in the fall. The strawberry patch may need covering for spring frost protection.

Strawberry plant crowns (short segment with roots below and leaves above) need to be at the soil line. If the plant is too deep (leaf stems buried), the plant rots. If too shallow (roots exposed), the plant dehydrates. [Figure 2]

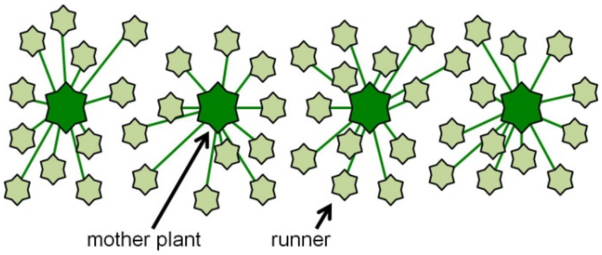
Figure 2 Strawberries are fussy about planting depth. The short crown section needs to be at the soil surface.



June-Bearing Cultivars

Planting – Since June-bearing cultivar set a lot of runners, they are planted in a matted row system. Set plants 18-24 inches apart in rows four plus feet apart. Allow runners from the "mother" plant to fill in a matted row, to a plant population of five to six plants per square foot. Remove excessive runners. Prune off runners outside the matted row and all new runners after September 1st. [Figure 3]

Figure 3. June-bearing cultivars in matted row system. Runners from the mother plant fill in a block 18-36 inches wide.



First Season Care – Remove all flowers the first year. Flowering the first year decreases the growth and next season's yields. If growth is weak and leaves are light green, fertilize lightly in June, July, and August. Use water-soluble fertilizes (like Miracle-Gro, Peters, Rapid Gro, etc.) or one cup of 21-0-0 per 100 square feet (broadcast over bed and water in).

General Care – Fertilize after the summer crop is off with water solubles or one cup 21-0-0 per 100 square feet (broadcast over the patch and water in). Strawberries need one inch of water (rain plus irrigation) per week during blossoming/fruiting. Water needs will be significantly less when not in fruit production. Iron chlorosis (yellow leaves with veins remaining green) is a symptom of over watering. Renovate every year or restart bed every two to four years

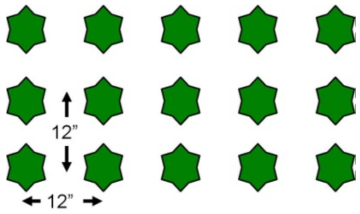
Renovation of June-bearing growing bed

1. After the fruiting period, mow or cut foliage to two inches. Remove all plant debris.
2. With shallow cultivation, create alternating strips (eight to ten inches wide) of plant left and plants removed.
3. Allow runners to spread into the cleaned area, up to an optimum plant density of five to six plants per square foot.
4. Remove excessive runners and all runners after September 1.
5. In future years, alternate the strips by taking out the plants the plant strips left the previous year.

Everbearing and Day-Neutral Cultivars

Planting – Because ever-bearing and day-neutral strawberries have fewer runners, the hill system is typically used. Set plants 12 inches apart in a double or triple wide row bed. Remove all runners as they develop. [Figure 4]

Figure 4. In the Hill System, plants are space 12 inches apart in double or triple rows 12 inches apart. All runners are removed.



First Season Care – Removed the first flush of flowers, and allow flowers to develop after July 1st.

General Care – Periodically remove all runners. Fertilize lightly throughout the growing season using water-soluble or ¼ cup 21-0-0 per 100 square feet (broadcast and water in). Start a new patch every three to four years.

Harvesting

Pick strawberries every other day during the peak of the season. If berries are eaten or preserved immediately, harvest only red-ripe fruit and leave the caps on the plants. If the fruit will not be used for a few days, harvest the berries, caps and all, while still pink.

Winter Care

Keep soil damp until fall frost. Then, withhold water to help harden off the plants. A final November watering before soils freeze helps prevent winter-kill from drying.

In cold winter climates, like Colorado, a winter mulch of clean, seed-free straw (or similar material) is recommended. Apply it when the ground freezes (around December 1st along the Colorado Front Range). Apply two inches, but not more as it could smother the plants. In windy areas, bird netting over the mulch helps hold it in place. Mulching helps protect plants from drying winter winds and from root damage by alternative freezing and thawing of the ground.

In climates with late spring frosts (like Colorado), leave the mulch on as long as possible to restrain plant growth in the early spring. In March, start checking plants under the mulch for growth. As growth begins, remove mulch over time, allowing sunlight into the plants. Some may remain on the soil to keep strawberry fruit off the ground.

Summer Mulch

Because strawberries are shallow rooted, summer mulch helps stabilize soil moisture and also helps suppress weeds. Use grass clippings (that contain no weed killers), seed-free straw, or other mulching materials. On ever-bearing and day-neutral cultivars (where runners are not allowed to set), black plastic mulch may be used. Plants must spread and cover the plastic mulch before summer heat sets in or it will be too hot.

Common Strawberry Pests

Abiotic

- **Iron chlorosis** (yellow leaves with green veins) is a symptom of over-watering. For additional information, refer to CMG GardenNotes #223, *Iron Chlorosis*.
- **Winter injury** often kills plants.
- **Drought injury** (Strawberries are shallow rooted, requiring frequent, light irrigations).
- **Hail** readily defoliates strawberries.
- **Wind**

Insects and Insect Relatives

- **Lygus bugs** feed on fruit. – Control weeds, alfalfa and legumes. Use insecticidal soap, avoid treating during bloom
- **Aphids**
- **Slugs and millipedes** – Decrease free moisture with proper watering. Remove fruit and decaying debris. Mulch to raise fruit up off the soil.
- **Spider mites** bronze leaves. Populations explode in hot weather and following the use of the insecticide Sevin (carbaryl).
- **Spottedwing drosophila flies can** affect ripening strawberries.

Diseases

- **Strawberry leaf spots** show as red spots with tan centers on leaves.
- **Powdery mildew** appears as white mold on leaves.
- **Botrytis gray mold** is the fuzzy mold on fruit.
- **Red stele** and **black root rot complex** are common root disorders.
- **Verticillium wilt** is a common soil borne disease.
- **Virus complex** – strawberries are prone to a variety of viruses.

Wildlife

- **Birds –** Bird netting may be necessary spread above and over the strawberry patch.
- **Rabbits**
- **Deer**

For addition information, refer to the following CSU Extension Publications:

- Factsheet #2.931, *Strawberry Diseases*
- PlantTalk Colorado #1441, *Strawberry Pests and Diseases*

Authors: David Whiting (CSU Extension, retired), with Merrill Kingsbury (CSU Extension).
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MASTER GARDENER
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CMG GardenNotes #764

Growing Grapes in Colorado Gardens

Outline:

Types and Cultivars

Types of Grapes

- **Table grapes** are used for fresh eating. Most popular cultivars are seedless. Popular cultivars include *Himrod*, *Interlaken*, *Canadice*, *St. Theresa*, and *Reliance.*
- **Juice and jelly grapes** – Popular cultivars include *Concord*, *Valiant*, *Niagra*, and *St. Croix*.
- **Wine grapes**
- **Raisin grapes**

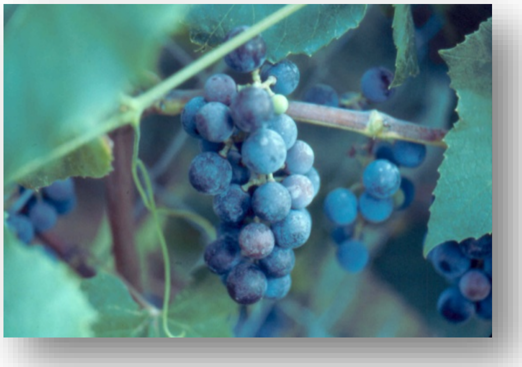

Figure 1. Grapes on a trellis make a living fence.

Types of Cultivars

- **American cultivars,** *Vitis labaarusca*, have a strong “foxy” (musty) flavor and aroma. They are use for juice, fresh eating, and some wines.
- **European cultivars,** *Vitis vinifera*, with tight clusters, thin skins, and a wine-like flavor, are used for wines. They require more heat units for maturity and have limited potential in Colorado.
- **French-American hybrids** are popular for wine. Characteristics depend on parentage.

Planting Grapes

Grapes need full sun and protection from wind. Space plants 6 to 8 feet apart, in rows 6 to 10 feet apart (depending on trellising system). Strong trellising systems are required to support the heavy vines and fruit. Use treated posts and 12-gauge or heavier wire.

Trellising and Pruning

Grapes fruit on one-year-old wood (canes that grew the previous summer). Thus, pruning is a balance between growing fruit and renewing the one-year-old wood. Correct pruning is essential for production. Un-pruned or under-pruned grapes give many, small-clusters of tiny grapes. Correctly pruned, grapes give high yields of large clusters of large grapes. Over-pruning simply cuts the yield.

There are many methods to trellis grapes. A simple method for the home gardener is the Single Curtain System.

Single Curtain System

Pruning at Planting – At planting, prune back to two to three buds. Allow the summer growth to develop what will become the primary trunk. [Figure 2]

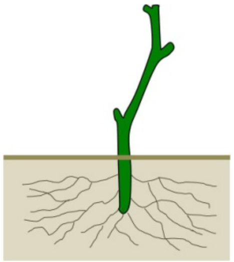

Figure 2. At planting, prune the grape back to just two to three buds. This heavy pruning pushes growth of lone canes. One of the canes will become the trunk.

Pruning the Second Spring – In the spring, select one of the last summer's canes to become the trunk. Remove the others, leaving one or two renewal spurs (buds close to the trunk). Renewal spurs allow for replacement growth of potential trunk wood if something damages the trunk. If growth was poor (not generating the desired trunk), start over by pruning back to two to three buds. [Figure 3]

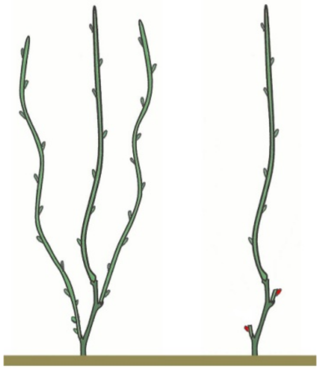

Figure 3. Second spring pruning: Left: Before pruning with three canes. Right: After pruning with one canes selected to become the trunk and other canes pruned back to a renewal spur (shown in red).

Pruning the Third Spring

1. Select two one-year-old canes (one to the left and one to the right) to become the ***fruiting canes*** and ***cordon arms*** along the trellis. The ideal cane is about pencil diameter with moderate spacing between buds. [Figure 4]

2. Select two canes (one to the left and one to the right) to become ***renewal spurs*** by pruning them back to two buds each. The purpose of renewal spurs is to give more options near the trunk in selection fruiting canes in future years.

3. Remove all other canes!

4. Prune the two <u>fruiting canes</u> back to 40-60 buds per plant (more buds for smaller fruit clusters, or less buds for larger fruit clusters).

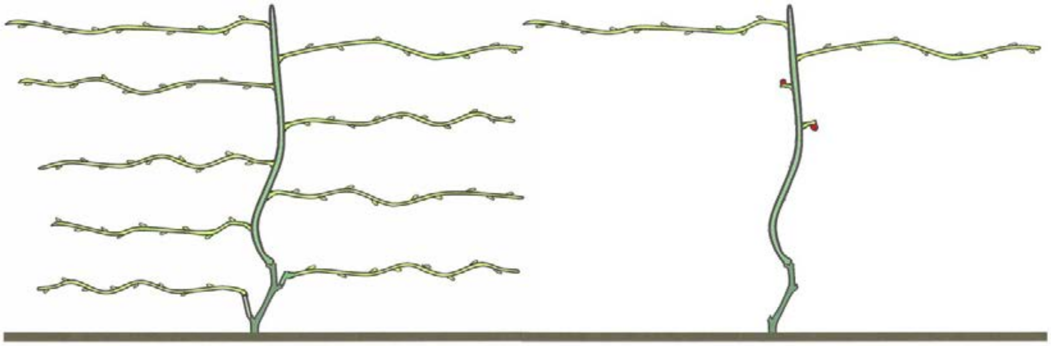

Figure 4. Pruning the third spring: Left: Before pruning. Right: After pruning. A one-year-old fruiting cane is selected to go to the left and another to the right. These become the *cordon arms* along the grape trellis. Another cane to the left and to the right (near the trunk) are pruned back to two buds as renewal spurs. All the other wood is removed. This heavy pruning balances fruit production with renewing the one-year-old wood for next year's crop.

Spring Pruning the Fourth Spring and Beyond

1. Select two, one-year old canes (one to the left and one to the right) to become the new ***fruiting canes*** and spread them out along the trellis as *cordon arms*. The ideal cane is about pencil diameter with moderate spacing between buds. To keep the fruiting wood near the trunk, these could be selected from the first couple of canes on last year's cordon arm or from the renewal spurs. [Figure 5]

2. Select two canes (one to the left and one to the right) to become ***renewal spurs*** by pruning them back to two buds each. These could be selected from the renewal spurs of the first couple of canes on last year's fruiting cane. The purpose of the renewal spurs is to give options to select future fruiting canes/cordon arms close to the trunk.

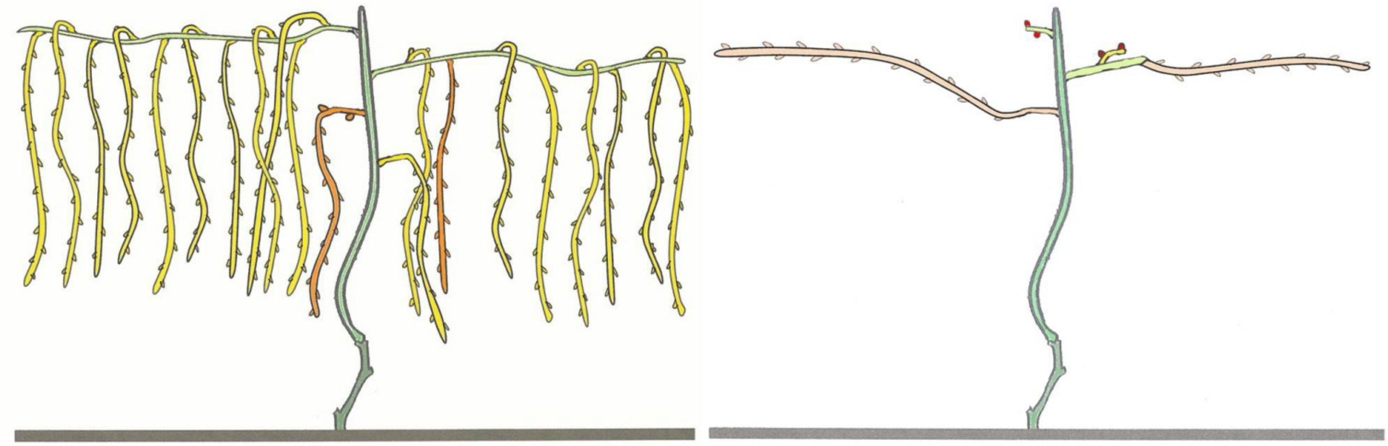

Figure 5. Fourth spring and beyond pruning: Left: Before pruning: One-year-old fruiting canes shown in yellow. The one-year-old fruiting canes that have been selected to become the new cordon arm are shown in orange.

Right: After pruning. A one-year-old fruiting cane is selected to go to the left and another to the right. On the left, a cane from the renewal spur was selected. On the right, a cane from last year's cordon arm was selected. These become the *cordon arms* along the grape trellis. Another cane to the left and to the right (near the trunk) are pruned back to two buds as renewal spurs. All the other wood is removed. This heavy pruning balances fruit production with renewing the one-year-old wood for next year's crop.

3. Remove all other canes! This heavy pruning balances fruit growth with growing new fruiting wood for next year's production.

4. Prune the two fruiting canes back to 40-60 buds per plant (more buds for smaller fruit clusters, less buds for larger fruit clusters).

General Care of Grapes

- Grapes perform best with a four-foot wide weed-free bark/wood chip mulch strip under the grape trellis. They perform poorly with lawn competition.

- Avoid over-watering. Iron chlorosis is a symptom of springtime overwatering.

- Go light on grape fertilization. Apply one-fourth cup of 21-0-0 (or equivalent) per established plant. Broadcast it under the trellis and water in.

- For home gardeners, flavor is the best method to evaluate harvest time.

Common Grape Pests

Fruit

- **Birds** – Bird netting over the plants may be necessary.
- **Botrytis bunch rot** (generally becomes a problem with excessively heavy canopy (due to inadequate pruning) and the lack of good air circulation.
- **Spotted wing drosophila flies** can affect ripe grapes.

Plants

- **Powdery mildew,** refer to CSU Extension Fact Sheet #2.902, *Powdery Mildew*
- **Iron chlorosis** (symptom of over-watering) refer to CMG GardenNotes #223 *Iron Chlorosis*
- **Poor soil drainage** with related root rots.
- **Inadequate control of weeds and diseases** (Grapes do not tolerate the competition.)

Authors: David Whiting (CSU Extension, retired), with Merrill Kingsbury (CSU Extension).
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Tree Fruit

Reference / Supplemental Reading

<u>CSU Extension Publications</u> available online at www.cmg.colostate.edu

- *Apple and Pear Insects* - Fact Sheet #5.519
- *Apples* - Plant*talk* #1201
- *Apricots* - Plant*talk* #1209
- *Backyard Orchard: Apples and Pears* [pest management] - Fact Sheet #2.800
- *Backyard Orchard: Stone Fruits* [pest management] - Fact Sheet #2.804
- *Cherries* - Plant*talk* #1202
- *Coryneum Blight* - Fact Sheet #2.914
- *Coryneum Blight* - Plant*talk* #1444
- *Fertilizing Fruit Trees* - Fact Sheet #7.612
- *Fertilizing Fruit Trees* - Plant*talk* #1216
- *Fire Blight* - Fact Sheet #2.907
- *Fire Blight* - Plant*talk* #1411
- *Growing Tree Fruits in Colorado Gardens*, CMG GardenNotes #771
- *Insect Control: Horticultural Oils* - Fact Sheet #5.569
- *IPM: Plant Health Care* - GardenNotes #101
- *Oystershell Scale* - Plant*talk* #1414
- *Peach Tree Borer* - Fact Sheet #5.566
- *Peaches* - Plant*talk* #1204
- *Pear Slug* - Fact Sheet #5.560
- *Pears* - Plant*talk* #1205
- *Plums* - Plant*talk* #1206
- *Pollination of Tree Fruits* - Fact Sheet #7.002
- Pruning - *Training and Pruning Fruit Trees* - Fact Sheet #7.003
- Pruning - *Training Young Fruit Trees* - Plant*talk* #1211
- *Pruning Mature Fruit Trees* - Plant*talk* #1210
- References and Review Questions: Tree Fruits, CMG GardenNotes #770
- *Spider Mites* - Fact Sheet #5.507
- *Tent Caterpillar* - Plant*talk* #1484
- *Training and Pruning Fruit Trees* - Fact Sheet #7.003
- *Training Young Fruit Trees* - Plant*talk* #1211

Curriculum developed by David Whiting, Extension Consumer Horticulture Specialist (retired), Department of Horticulture & LA, Colorado State University

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- Colorado State University, U.S. Department of Agriculture and Colorado counties cooperating.

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Tree Fruits

Learning Objectives

At the end of this unit, the student will be able to:

- Discuss considerations in planting fruit trees in the home landscape.
- Describe structural training and annual pruning of dwarf, semi-dwarf and standard size apples.
- Describe structural training and annual pruning of peaches.

Review Questions

1. Describe consideration in planting fruit trees in the home landscape.

2. What fruits are generally self-fruitful? What fruits generally require cross pollination by another compatible cultivar?

3. Describe the structural training of standard apples, semi-dwarf apples, and dwarf apples.

4. Describe the annual pruning of apples.

6. Describe the structural training of peaches.

7. Describe the annual pruning of peaches.

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CMG GardenNotes #771

Growing Tree Fruit in Colorado Gardens

Outline:

Tree fruits are less suited to the home garden than small fruits. They require more space than can be allocated in the small home yard. Space can be saved by growing dwarf cultivars and by training trees into an espalier form. [Figure 1]

Figure 1. Espalier apple tree

To be productive they require specific training and annual pruning. In most areas, they require routine sprays to manage insect and disease problems. In regions with late spring frosts, crops are often lost to frost.

Planting Considerations

Size and Suggested Spacing

Fruit trees can be large, particularly if not carefully trained and pruned. The typical size of fruit trees is given in Table 1.

Table 1. Typical Size of Fruit Trees

		Typical Spread (Pruned)	**Typical Height (Pruned)**	**Unpruned Spread and Height with No Competition**
Apple[1]	Standard Semi-dwarf Dwarf[2]	20 feet 10 feet 6 feet	20+ feet 12-15 feet 5-10	40 feet by 40 feet
Pear	Standard Dwarf[3]	18 feet 12 feet	15 feet 12 feet	40 feet by 25 feet 25 feet by 15 feet
Peach and Nectarine	Standard Dwarf[4]	20 feet 8-10 feet	15 feet 5-10 feet	25 feet by 25 feet 8 feet by 4-6 feet
Apricot	Standard Dwarf[4]	20+ feet 8feet	15 feet 6-8 feet	30 feet by 30 feet 6-8 feet by 6-12 feet
Sweet Cherry	Standard Dwarf[5]	30 feet 4 feet	25 feet 6-8 feet	30 feet by 40 feet 4-8 feet by 6-12 feet
Sour Cherry	Standard Dwarf	18-24 feet 8-10 feet	15 feet 6-8 feet	30 feet by 20 feet 8-10 feet by 20 feet
European Plums and Prunes	Standard	20 feet	15 feet	25 feet by 30 feet
Japanese Plums	Standard	18 feet	15 feet	25 feet by 30 feet

1 Size of apples is controlled by the rootstock and pruning techniques. Depending on rootstock, size may run from standard size down to 40% of standard size trees.
2 Dwarf apples are recommended for home gardeners. However, they require careful training to be highly productive and staking.
3 Dwarf pears have not proven overly successful and are not recommended.
4 Dwarf peach and apricot require careful training to be highly productive. Dwarf apricots are not recommended. Some dwarf peach trees are very small.
5 Dwarf cherries require careful training to be highly productive.

Pollination

Pollination is a common problem for many gardeners growing tree fruits. Bees do not fly in cool, rainy weather, common in many springs.

Apricots, sour cherries, peaches, nectarines, and European plums and prunes are generally self-pollinated. That is, pollen from most cultivars will pollinate itself.

Apples, sweet cherries, pears, and Japanese plums are generally cross-pollinated. That is, two compatible cultivars must be planted within 100 feet for good pollination.

Please see this CSU Extension fact sheet, “Pollination of Tree Fruits” for more details: http://extension.colostate.edu/topic-areas/yard-garden/pollination-of-tree-fruits-7-002/

Spring Frost

Frost damage is a common problem in climates with late spring frost, like Colorado. Commercial orchards are typically located on side hills, where cold air drains to the valley floors, giving some frost protection. Gardens located down in a valley floor typically have a shorter growing season than surrounding areas, and the tendency for late spring frosts makes the location unsuitable for tree fruits. Table 2 gives critical temperatures at various stages of bud development.

Table 2. Critical Springtime Temperatures

Fruit	Swollen Buds	Buds Showing Color	Full Bloom	Green Fruit
Apples	20-21ºF	24-28ºF	27-29ºF	29ºF
Apricots	23ºF	25ºF	28ºF	31ºF
Cherries	25ºF	28ºF	28ºF	30ºF
Peaches	23ºF	25ºF	27ºF	30ºF
Pears	23ºF	27ºF	29ºF	30ºF

Soils

Being prone to root rots, fruit trees are intolerant of soils with poor drainage or heavy irrigation. Fruit trees are not compatible with the frequent irrigation of a typical home lawn and should be located outside of the influence of the lawn area. Commercial orchards are often located on gravelly soils with good drainage.

Fertilization

Fruit trees must have adequate nutrient levels to grow and produce fruit. Which nutrients and the amount needed can be determined through a soil test. The nitrogen requirement can also be based on the amount of growth produced the previous year and it is applied in the spring just prior to or at bud break. Fertilizer products should be broadcast evenly underneath the tree and watered in. For more detailed information about fertilizing fruit trees, see this CSU Extension fact sheet, Fertilizing Fruit Trees, http://extension.colostate.edu/topic-areas/yard-garden/fertilizing-fruit-trees-7-612/

Insects and Diseases

Each region has their local list of insect and diseases associated with growing fruit. In most areas, routine sprays are typically necessary for pest free fruit. In Colorado, refer the following CSU Extension fact sheets for details:

- Backyard Orchard: Apples and Pears http://extension.colostate.edu/topic-areas/yard-garden/backyard-orchard-apples-and-pears-2-800/
- Backyard Orchard: Stone Fruits, http://extension.colostate.edu/topic-areas/yard-garden/backyard-orchard-stone-fruits-2-804/
- Fire Blight, http://extension.colostate.edu/topic-areas/yard-garden/fire-blight-2-907/
- Peach Tree Borer, http://extension.colostate.edu/topic-areas/insects/peach-tree-borer-5-566/
- Cytospora Canker in Tree Fruit Crops, http://extension.colostate.edu/topic-areas/agriculture/cytospora-canker-in-tree-fruit-crops-2-953/

Training and Pruning

For productivity and quality produce, fruit trees require both specific training and annual pruning. ***Training*** refers the general structural shape of the tree, achieved by pruning when the tree is young. ***Annual pruning*** refers to the pruning each year to grow quality fruit.

Pruning Basics

Detailed information about fruit tree pruning can be found in this CSU Extension Fact Sheet:

http://extension.colostate.edu/topic-areas/yard-garden/training-and-pruning-fruit-trees-7-003/

Details of specific pruning terms, techniques and styles mentioned here can be found in the CMG GardenNotes series:

- Pruning Cuts: http://cmg.colostate.edu/Gardennotes/612.pdf
- Structural Training of Young Shade Trees: http://cmg.colostate.edu/Gardennotes/613.pdf

Pruning of fruit trees is similar to the pruning of shade trees. The objective in annual pruning of fruit trees is to balance growing of fruit and growing of new fruiting wood. The percentage of wood removed is different in shade trees than in fruit trees. In shade trees, the amount of live wood removed is generally limited to 10-15% per season. In fruit trees, much higher percentages are removed to encourage the growth of new fruiting wood. To achieve this balance, fruit trees require 1) better general vigor with special attention to watering and fertilization, and 2) heavy pruning to promote fruiting wood. General pruning of fruit trees occurs in late winter, after the high potential for extreme cold (temperatures below zero) has passed but before bud swell and flowering.

Apples

Structural Training of Young Apple Trees

Dwarf apples are trained to a central leader Christmas tree shape with branches in whorls. Spread lower branches to near horizontal and upper branch to 45º. With proper training, dwarf apple trees can be kept to an eight to ten foot height. Due to increased sunlight through the tree, dwarf apples produce the best quality fruit on small trees. [Figure 2]

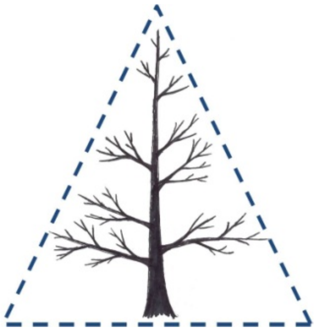

Figure 2. Train dwarf apples to a Christmas tree shape, spreading lower branches to near horizontal and upper branches at a 45º angle.

Semi-dwarf apples are trained to a modified central leader system. When trained, semi-dwarf trees may be kept to a 15-18 foot height. In selecting scaffold branches, develop openings for ladders.

Modified Central Leader Training – In this pruning style, a dominant central leader is maintained with three to five *scaffold branches* (vertically spaced at least six inches apart) which become the primary structure of secondary trunks. By definition, the diameter of a "scaffold branch" must be less than one-half the diameter of the adjacent trunk. Being structurally strong, this pruning style is preferred for larger trees. However, fruit production and quality will be low in the center canopy due to shading. [Figure 3]

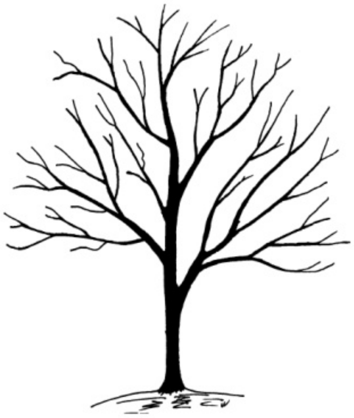

Figure 3. *Modified Central Leader Training* develops trees with a dominant trunk into the upper region of the trees and "scaffold branches" becoming secondary trunks. For structural strength, the scaffold branches must be space at least six inches apart and the diameter of the scaffold branches must be less than one-half of the adjacent trunk.

Standard size apples are generally trained to a modified central leader system. The majority of fruit on standard sized apple trees is of inferior quality due to shading of the majority of the tree's canopy. Standard size apples are rather large for home landscapes.

Annual Pruning of Fruiting Apples

Apples fruit on two or three year-old twigs and spurs that are no thicker than a pencil. Avoid cleaning out of the small twigs and spurs along the branches.

The primary purpose in annual pruning is to increase sunlight penetration and to remove less productive wood. Apples need light annual thinning of the canopy, opening the tree to light. Start at the top working down into the canopy using reduction cuts and thinning cuts. Avoid any heading cuts as this leads to a thicker canopy that shades out fruit production.

If left un-pruned, the quantity of fruit produced may temporarily be greater, but the quality will be much lower.

Remove any water sprouts back to the parent branch/trunk.

Pruning old neglected apple trees – Over a period of years, thin the canopy, thereby opening the tree to light. Over time, remove old wood and reduce tree height with reduction cuts.

Fruit thinning – For quality fruit, thin apples to six to eight inches between fruit, by mid-June.

Peaches and Nectarines

Structural Training for Young Peach Trees

Peaches and nectarines fruit in the top four to five feet of the tree. With careful pruning, height of a peach tree can be maintained at seven to ten feet. Untrained, it is common to find peach trees that fruit in the top four feet of a 12 to 16 foot tall tree.

Train young peach trees to an open center vase shape. Space four to five scaffold branches at least six inches apart. To keep the tree height low, branching typically starts 18 to 24 inches above the ground. [Figure 4]

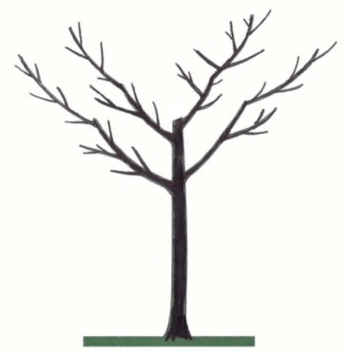

Figure 4. To open the tree to light, train peaches and nectarines to an open vase system.

Select scaffold branches with wide angle of attachment and evenly spaced around the tree. It is best to develop scaffold branches all at one time and from the same diameter twigs. Otherwise, older/larger ones will dominate the tree.

In early training, allow small twiggy growth along the scaffold branches.

Do not remove all the fruiting shoots in the center of the tree. The most productive trees have fruiting wood throughout the tree canopy.

Annual Pruning of Fruiting Peaches

The objective in annual pruning of fruiting peach trees is to balance fruit production with growth of new wood. Peaches fruit only on one-year-old wood. To promote growth of the fruiting wood, removed one-half to two-thirds of the growth each spring with a combination of thinning cuts and reduction cuts.

- Thin fruiting shoots to a spacing of four to six inches
- Long branches produce more fruit than short ones. Generally avoid heading cuts on the primary branches.
- The ideal fruiting shoots are 12 to 24 inches long and 3/16 to ¼ inch diameter at the base. Longer shoots may be headed back by one-forth.
- Remove three to six inch long shoots that are mixed with the more desirable 12 to 18 inch shoots.
- Leave small twigs that are not vigorous enough to offer competition in the tree's interior.
- Stimulate growth of one-year-old fruiting wood in the tree center by thinning-out and heading-back inside branches.
- Remove any water sprouts back to the parent branch with thinning cuts.
- Avoid cleaning out the small twiggy in the tree's interior. This eliminates the center of the tree from being fruitful.

Fruit Thinning – For quality fruit, thin peaches to six to ten inches between fruit, by the time the fruit reaches one-inch in diameter.

Figure 5. Peaches fruit only on one-year-old wood. Trees are heavily pruned to balance the growth between the fruit crop and production of new wood for next year's crop.

Sweet Cherries

Structurally Training – Sweet cherries are trained to a modified central leader system. Select scaffold branches that are outward growing rather than upward growing.

Annual Pruning – Cherries are borne on long-lived spurs that produce fruit for 10 to 12 years. Little annual pruning is needed on fruiting sweet cherries. Focus pruning on thinning the tree canopy, removing older wood with thinning and reduction cuts. Avoid making heading cuts in the top of the tree, as this leads to shading out of the interior.

Fruit Thinning – Cherry fruit is not generally thinned.

Figure 6. Sweet cherry trees are large and occupy a lot of space in the home landscapes. Most cultivars require a second cultivar for cross pollination.

Sour Cherries

Structural Training – Sour or pie cherries are generally much smaller trees or shrubs. Train sour cherries to a modified central leader system or delayed open center system.

Annul Pruning – Little pruning is needed on fruiting sour cherries. With routine thinning and removal of older wood, sour cherries may be kept less than 12 feet tall.

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