MASTER GARDENER

CORE COURSE

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State Master Gardener Coordinator
January 2007

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Welcome Master Gardener!

We are very glad to welcome you to the University of Minnesota Extension Service and to the Master Gardener Program. The program has been growing steadily since the first year, 1977, it was taught in Minnesota. We are very excited to have you join the program.

You will have 48 hours ahead of you of training in various subjects relating to horticulture, followed by the 50 hour on- the-job internship. This course has been carefully selected to provide you with a good foundation of knowledge with which to begin your work as a Master Gardener. Enjoy the time you spend with your instructors. They truly care about you and will be a source of information throughout the years to come.

The State Office of the Master Gardener Program is here to assist you in any way we can. You will be working closely with your County Extension Office in volunteering your hours, but please feel free to contact the State Office if you have any questions or concerns.

Thank you for volunteering to participate in the Master Gardener Program. Best Wishes for your success!

Sincerely,

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TABLE OF CONTENTS

Chapter 1	Botany	1b - 34b
Chapter 2	Soils	1s - 41s
Chapter 3	Fruits	1f - 11f
Chapter 4	Vegetables	1v - 29v
Chapter 5	Entomology	1e - 12e
Chapter 6	Plant Pathology	1pp - 21pp
Chapter 7	Landscape	1L - 10L
Chapter 8	Lawn Care	1Lw - 40Lw
Chapter 9	Indoor Plants	1ip - 14ip
Chapter 10	Herbaceous	1h - 24h
Chapter 11	Pesticides	1p - 45p
Chapter 12	Wildlife	1w - 8w
Chapter 13	Woody Plants	1wp - 23wp
Appendix 1	Master Gardener Program Information	
Appendix 2	Climate maps	
Appendix 3	Soils	
Appendix 4	Vegetables	
Appendix 5	Fruits	
Appendix 6	Plant Pathology	

chapter

I

botany

chapter I

BOTANY

by Gary Johnson, Associate Professor
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INTRODUCTION

In order to identify a plant and have an understanding of how to grow healthy plants, it is important to understand the structure and function of plants and the environmental factors affecting plant growth.

LEARNING OBJECTIVES

Learning objectives of this section for Master Gardeners are to:

1. Gain a general understanding of botany.
2. Be able to identify the basic parts of a plant.
3. Gain an understanding of how a plant functions.
4. Appreciate how environmental factors affect plant growth and development.
5. Become familiar with the basic botanical terms used in plant classification.

PLANT CLASSIFICATION

Modern plant classification, or taxonomy, is based on a system developed by the Swedish physician Carl von Linne, also known as Linnaeus. Linnaeus's classification is based on the flowers and/or reproductive parts of a plant. Each plant is given a genus and species name. This has proven to be the best system because flowers are the plant part least influenced by environmental changes. The combination of the genus and species names is called the botanical, scientific, or Latin name.

Taxonomy

Every plant can be classified into the following categories or taxa:

Kingdom
- Division
  - Class
    - Order
      - Family
        - Genus (plural: genera)
          - Species (abbreviated sp. or spp.)
            - Cultivar or variety

botany

The following table illustrates classification for several common plants.

Classification Unit	Common Name Colorado Blue Spruce	Common Name Bradford Pear	Common Name Cauliflower	Common Name Corn
Kingdom	Plantae	Plantae	Plantae	Plantae
Division	Tracheophyta	Tracheophyta	Tracheophyta	Tracheophyta
Class	Gymnospermae[1]	Angiospermae[2]	Angiospermae	Angiospermae
Subclass		Dicotyledones	Dicotyledones[3]	Monocotyledones[4]
Order	Coniferales	Rosales	Papaverales	Cyperales
Family	Pinaceae	Rosaceae	Crucifarae	Gramineae
Genus	Picea	Pyrus	Brassica	Zea
Species	pungens	calleryana	oleracea	mays
Botanical variety	glauca			
Cultivar		'Bradford'	'Purple Head'	'Silver Queen'

[1]Gymnosperms have naked seeds (not enclosed in an ovary)
[2]Angiosperms have covered seeds (borne within a matured ovary or fruit)
[3]Two seed leaves or cotyledons
[4]One seed leaf or cotyledon

Common names can be very confusing because one plant may have several common names. Common names often differ from one region of the country or world to another. The same common name can also apply to more than one plant. Botanical names, in contrast, are unique and relatively permanent.

Terms that are often used in plant descriptions include:

Variety (botanical): A fairly consistent, naturally occurring variety of the species. Ex: *Gleditsia triacanthos* var. *inermis* (Thornless honeylocust)

Cultivar: Originated in cultivation and persists under cultivation.
Ex: *Fraxinus pennsylvanica* `Marshall's Seedless' or *Fraxinus pennsylvanica* cv. Marshall's Seedless (Marshall's Seedless green ash)

Strain: A variation within a cultivar. Ex: `Spur Red Delicious' apple

Hybrid: Cross between two species. Hybrids are denoted by `x' in front of species. Ex: *Forsythia* x *intermedia* is a cross between *F. suspensa* and *F. viridissima*

Clone: An individual or individuals which were started by asexual propagation and are genetically identical to each other.

Line: Plants of uniform appearance grown from seed.

F1 hybrid: Cross between two inbred lines.

Other Terms Used to Classify Plants

Plants are classified by the number of growing seasons required to complete a life cycle.

Annuals: Entire life cycle from seed germination to seed production occurs in one growing season, and then the plant dies.

Biennials: Plants start from seeds, producing vegetative structures and food storage organs the first season. During the first winter a hardy evergreen rosette of basal leaves persists. During the second season, flowers, fruit, and seed develop to complete the life cycle. The plant then dies.

Plants which typically develop as biennials may in some cases complete the cycle of growth from seed germination to seed production in only one growing season. This situation occurs when drought, variations in temperature, or other climatic conditions cause the plant to pass through the equivalent of two growing seasons physiologically in a single growing season. Examples of biennials:

carrots, beets, cabbage, celery, onions, hollyhock, Canterbury bells, and Sweet William

Perennials: Live for many years and after reaching maturity typically produce flowers and seeds each year. Perennials are classified as:

Herbaceous: the top dies back to the ground each winter and new stems grow from the roots each spring.

Woody: the top persists, as in shrubs or trees.

Deciduous: will shed their leaves and be leafless during a portion of the year.

Evergreen: leaves persist throughout the year.

Tender or hardy: refers to cold temperature tolerance; tender perennials are often grown as annuals.

Plant Keys

Dichotomous plant keys help us identify plants by giving us a series of choices between pairs of alternatives. Each pair refers to a specific plant characteristic such as arrangement of leaves on the stem, type of leaf margin, type of fruit, etc. Selecting the option that accurately describes the plant will lead you to the next choice until you determine the genus or species. If a result is ambiguous, final verification is made by comparison with a known example of that species, usually found in an herbarium. There are several major plant keys available including:

Bailey, L.H. 1977. *Manual of Cultivated Plants Most Commonly Grown in the Continental United States and Canada*. New York: MacMillan Publishing Co., Inc.

Gleason, Henry A., *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. 2nd ed. Bronx, NY: New York Botanical Gardens, 1991.

Petrides, George A., *A Field Guide to Trees and Shrubs*. 2nd ed. Boston: Houghton Mifflin, 1972.

Many reference books for specific types of plants such as ferns, wildflowers or shrubs contain their own special plant keys.

PLANT STRUCTURES

In the plant kingdom, all flowering plants have certain structures and functions in common. They can be divided into two groups based on their major differences—monocotyledons (monocots) and dicotyledons (dicots).

	Monocots	Dicots
Seedlings	one seed leaf	two seed leaves
Stems[1]	Xylem and phloem are paired into bundles and randomly dispersed throughout the stem.	Continuous rings form inside the stem. Phloem is near the bark or external stem cover and is part of the bark in mature stems. Xylem forms inner ring and is sapwood and heartwood in woody plants.
Leaves	Parallel-veined	Net-veined
Flowers	Floral parts in 3's or multiples	Floral parts in 4's or 5's or multiples

[1]The difference in the vascular system of the two groups is of practical interest because certain herbicies are specific to either monocots or dicots. An example is 2,4-D, which only kills plants with a continuous vascular system. Therefore, 2,4-D is only effective in the control of dicots.

The parts of a plant can be:
Vegetative: leaves, roots, shoot buds, and stem. These parts are not directly involved in sexual reproduction. However, they are often used in asexual or vegetative forms of reproduction such as cuttings.

Sexually reproductive: These are parts involved in the production of seed and include flowers, fruit, flower buds, and seeds.

Vegetative Parts

Stems

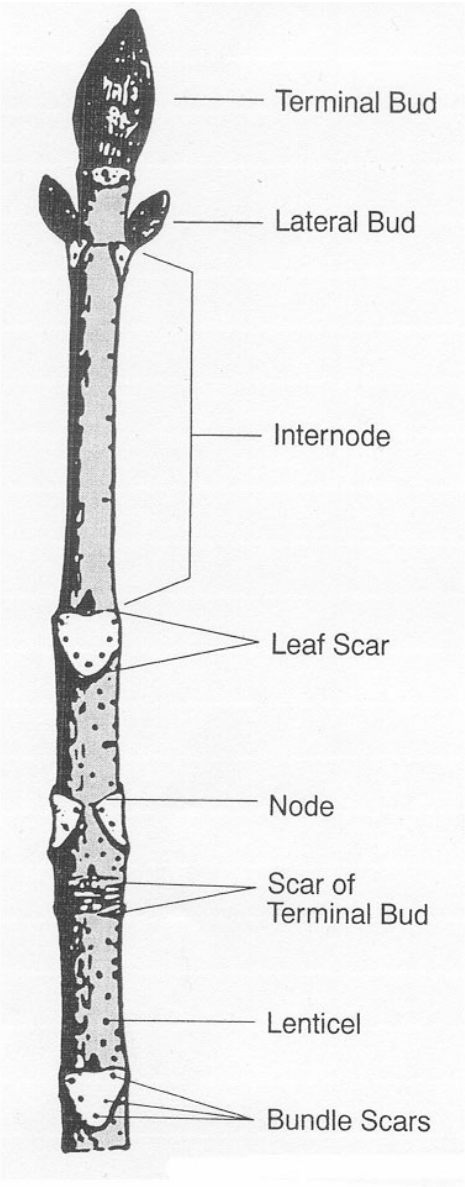
Structures that support buds and leaves and serve as conduits for carrying water, minerals, and sugars.

Three major internal parts of a stem are the xylem, phloem, and cambium:

Xylem and phloem: the major components of a plant's vascular system. Xylem tubes are the water- and mineral-conducting channels. Phloem tubes are the "food"-conducting channels. The term "food" is used to represent photosynthates and other products.

Cambium: a meristem, which is a site of cell division and active growth. It is located between the xylem and phloem inside the bark of a stem and is the tissue responsible for a stem's increase in girth, as it produces both the xylem and phloem tissues.

Stems nodes: nodes are areas of great cellular activity and growth where buds develop into leaves or flowers. The area between nodes is called an *internode*. Nodes are unique to stems, never found on roots.



A typical woody plant stem

The length of an internode may depend on many factors:

- Decreasing soil nutrients will decrease internode length.
- Internode length varies with the season.
- Too little light will result in a long internode causing a spindly stem.
- Growth produced early in the season has the greatest internode length.
- Internode length decreases as the growing season nears its end.
- Vigorously growing plants tend to have greater internode length than less vigorous plants.
- Internode length will vary with competition with surrounding stems or developing fruit.
- If energy for a stem is divided between three or four stems, or if the energy is diverted into fruit growth, internode length will be shortened.

Modified stems

Typical stems are aboveground trunks and branches. Modified stems may sometime be found both aboveground and belowground.

Aboveground modified stems

Crowns: compressed stems having leaves and flowers on short internodes (strawberries, dandelions, African violets).

Spurs: short, stubby, side stems that arise from the main stem and are common on such fruit trees as pears, apples, and cherries where they may bear fruit. If severe pruning is done close to fruit-bearing spurs, the spurs can revert to a non-fruiting long stem.

Thorns: may develop as modified twigs on stems. They may be single or branched.

Stolons: horizontal stems that are fleshy or semiwoody and lie along the top of the ground (strawberry runners and spider plants).

Belowground modified stems
Rhizomes: similar to stolons, but grow underground rather than above-ground. Some rhizomes are compressed and fleshy such as iris; they can also be slender with elongated internodes such as quackgrass.

Tubers: nodes that produce buds. The eyes of a potato are actually the nodes on the stem. Each eye contains a cluster of buds. Tuberous stems such as tuberous begonia and cyclamen are shortened, flattened, and enlarged underground stems. Buds and shoots arise from the top or crown and fibrous roots are found on the bottom of the tuberous stem.

Bulbs, such as tulips, lilies, daffodils, and onions, are shortened, compressed underground stems surrounded by fleshy scales (leaves) that envelop a central bud located at the tip of the stem.

Corms have shapes similar to bulbs, but do not contain fleshy scales. A corm is a solid, swollen stem whose scales have been reduced to dry, scale-like leaves.

Dahlias and sweet potatoes produce underground storage organs called tuberous roots which are often confused with bulbs and tubers. However, these are roots, not stems, and have neither nodes nor internodes.

Stems and plant propagation
Stems are one of the most commonly used parts for plant propagation purposes.

Aboveground stems can be divided into sections called cuttings that contain internodes and nodes and will produce roots, thus giving rise to new plants.

Belowground stems are also good propagative tissues. Rhizomes can be divided into pieces. Bulbs form small bulblets at the base of the parent bulb. Cormels are miniature corms that form under the parent corm. Tubers can be cut into pieces containing eyes and nodes.

It may sometimes be difficult to distinguish between roots and stems but one sure way is to look for the presence of nodes. Stems have nodes, roots do not. All stems must have buds or leaves present to be classified as stem tissue.

Leaves
The principal function of leaves is to absorb sunlight for the manufacture of plant sugars in a process called *photosynthesis*. Leaves develop into a flattened surface to present a large area for efficient absorption of light energy. The leaf is usually supported away from the stem by a stem-like appendage called a *petiole*. The base of the petiole is attached to the stem at the node. The smaller angle formed between the petiole and the stem is called the *leaf axil*. An active or dormant bud or cluster of buds is usually located in the axil.

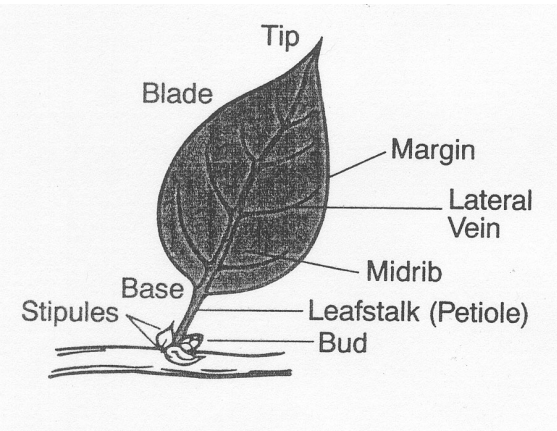
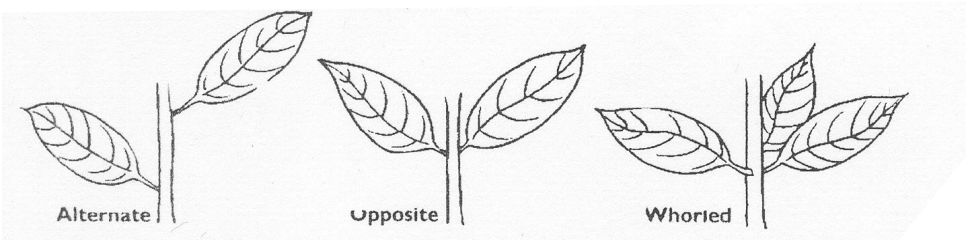
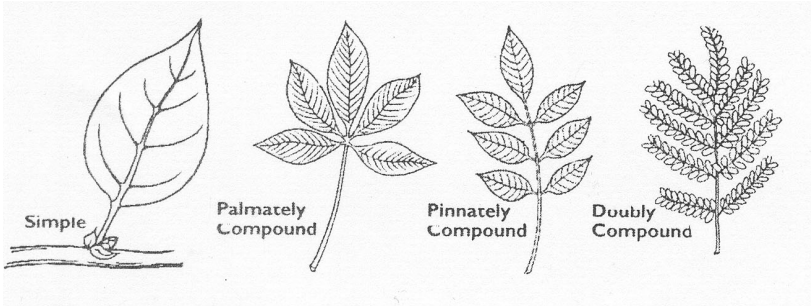


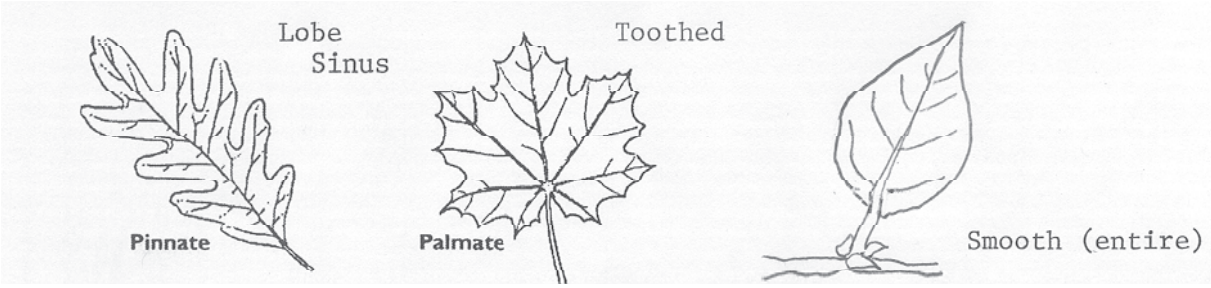
Diagram of Leaf Parts



Leaf Arrangements

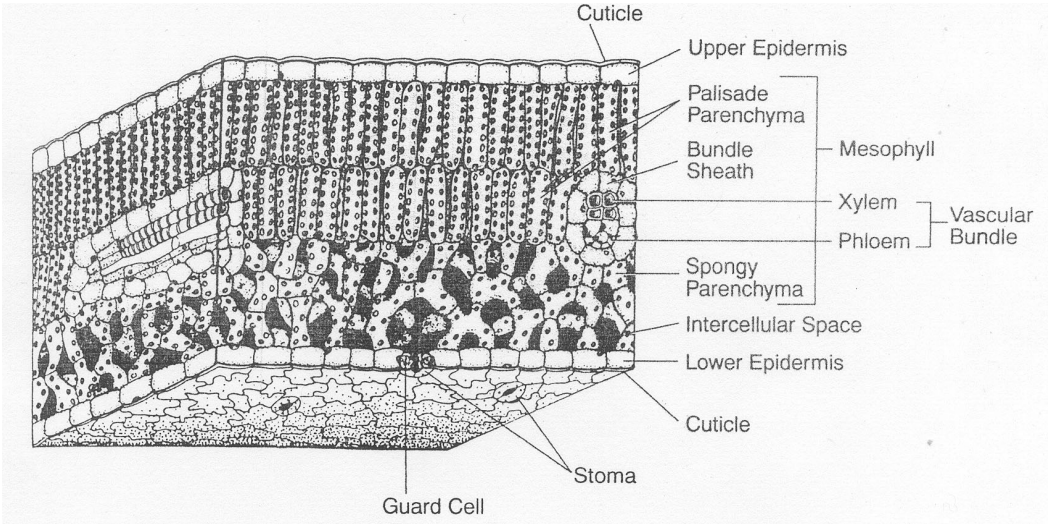


Leaf Types



Leaf Margins

The leaf blade is composed of several layers as shown in the following diagram.



On the top and bottom of the leaf is a layer of small tough cells called the *epidermis*. The primary function of the epidermis is to protect leaf tissue. The way in which the cells in the epidermis are arranged determines the texture of the leaf surface. Some leaves have hairs that are an extension of certain cells of the epidermis.

Part of the epidermis is the *cuticle* which produces a waxy layer called cutin that protects the leaf from dehydration and prevents penetration of some diseases. The amount of cutin is a direct response to sunlight, increasing with increasing light intensity. For this reason, plants grown in the shade should be moved into full sunlight gradually, over a period of a few weeks, to allow the cutin layer to build and to protect the leaves from the shock of rapid water loss or sunscald.

Cutin also repels water and can shed pesticides if spreader/sticker agents or soaps are not used. This is the reason many pesticide manufacturers include some sort of spray additive to adhere to or penetrate the cutin layer.

On the underside of leaves epidermal cells, called *guard cells*, are capable of opening and closing. These cells guard the interior of the leaf and regulate the passage of water, oxygen, and carbon dioxide through the leaf. They protect openings called *stomata* in the leaf surface.

The opening and closing of the cells is determined by the weather. Conditions that would cause large water losses from plants (high temperature, low humidity) stimulate guard cells to close. Mild weather conditions leave guard cells in an open condition. Guard cells will close in the absence of light.

The *mesophyll* is the middle layer of the leaf located between the upper and lower epidermis where photosynthesis occurs. In dicots, it is divided into a dense upper layer called the *palisade* and a spongy lower layer of cells that contains plenty of air space, called the *parenchyma* layer. The cells in these two layers contain chloroplasts in which the photosynthetic process takes place.

Types of leaves
A number of rather distinct types of leaves occur on plants.

Foliage—the most common and conspicuous leaves.

Scale leaves or cataphylls—found on rhizomes and are also on buds (the small leathery protective leaves which enclose and protect the bud).
Seed leaves or cotyledons—modified leaves which are found on the embryonic

plant and commonly serve as storage organs to feed the germinating seedling while true leaves develop.

Spines and tendrils—specialized modified leaves which protect the plant or assist in supporting the stems.

Storage leaves—found in bulbous plants and succulents which serve as food storage organs containing starch and water.

Bracts—specialized leaves which are often brightly colored. The showy structures on dogwood and poinsettias are bracts, not petals.

Parts of a leaf

Blade—the expanded thin structure on either side of the midrib. The blade usually is the largest and most conspicuous part of a leaf.

Petiole—the stalk which supports the leaf blade. It varies in length or may be lacking entirely (in which case the leaf blade is described as sessile or stalkless).

Veins— the network of phloem & xylem tissues (vascular bundles) that move water, minerals and photosynthates.

Venation of leaves

Venation—The patterns in which the veins are distributed in the blade.

Parallel-veined—numerous veins run essentially parallel to each other and are connected laterally by minute straight veinlets.

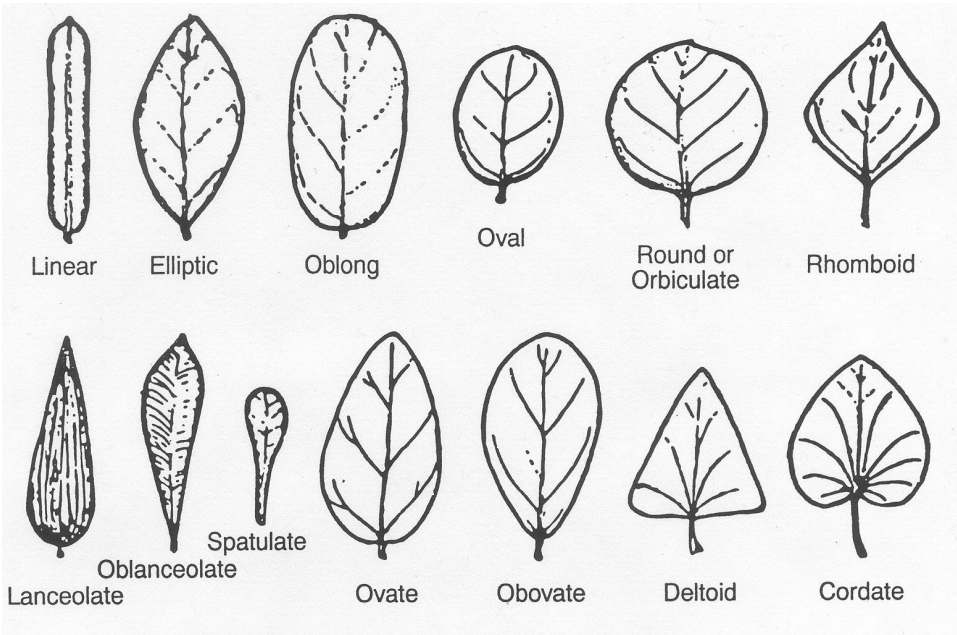
Net-veined (reticulate-veined)—veins branch from the main rib or ribs and then subdivide. Gives the leaf more resistance to tearing than is true for most parallel-veined leaves. Net-venation may be either pinnate or palmate.

Dichotomous—Veins branch off in pairs. This is similar to parallel, except that they branch off in two directions. (e.g., the leaves of the ginkgo tree).

Leaves as a means of identifying plants

Leaves are useful in identifying species and varieties of horticultural plants. The shape of the leaf blade and the type of margin are major identifying characteristics. The following illustrations outline the many different types of leaves.

Leaf shape:



Buds

A bud is an undeveloped shoot from which leaves or flower parts arise.

The buds of trees and shrubs of the temperate zone typically develop a protective outer layer of small leathery bud scales in late summer or fall. Annual plants and herbaceous perennials have naked buds in which the outer leaves are green and somewhat succulent.

Buds of many plants require exposure to a certain number of days below a critical temperature before they will resume growth in the spring. This time period varies for different plants. During rest, dormant buds can withstand very low temperatures, but after the rest period is satisfied, buds become more susceptible to weather conditions and can be damaged easily by cold temperatures or frost.

Roots

A thorough knowledge of the root system of plants is essential if their growth, flowering, and fruiting responses are to be understood. The structure and growth habits of roots have a pronounced effect on the size and vigor of the plant, method of propagation, adaptation to certain soil types, and responses to cultural practices and irrigation.

Roots typically originate from the lower portion of a plant or cutting. They possess a root cap, have no nodes, and never bear leaves or flowers directly.

The principal functions of roots are to:

- absorb nutrients and moisture.
- anchor the plant in the soil.
- furnish physical support for the stem.
- serve as food storage organs.
- be used as a means of propagation (in some plants).

Types of roots
A *primary root* originates at the lower end of the embryo of a seedling.

A *taproot* is formed when the primary root continues to elongate downward into the soil and becomes the central and most important feature of the root system with a somewhat limited amount of secondary branching. Some young trees have a long taproot with very few lateral or fibrous roots, which causes them to be difficult to transplant. This condition is usually unique only to young plants. As woody plants grow older (1-10 yrs of age), they normally lose their tap root.

If plants that normally develop a taproot are undercut so that the taproot is severed early in the plant's life, the root will lose its taproot characteristic and develop a branched and more fibrous root system. This is done commercially in nurseries so trees that naturally have tap roots will develop a compact, fibrous root system. This allows high transplanting success in the field.

A *lateral* or *secondary* root is a side or branch root which arises from another root.

A *fibrous root* system is one in which the primary root ceases to elongate, and numerous lateral roots develop, which branch repeatedly and form the feeding root system of the plant.

The quantity and distribution of plant roots is very important because these two factors have a major influence on the absorption of moisture and nutrients by roots. The depth and spread of the roots are dependent on the inherent growth characteristics of the plant and the texture and structure of the soil. Roots will penetrate much deeper in a loose, well-drained soil, where there is adequate soil oxygen and moisture, than in a heavy, poorly-drained soil. A dense compacted layer in the soil will restrict or terminate root growth.

A plant's roots usually spread well beyond the branches and leaves if it is growing in an unrestricted site. Grass roots may spread for great distances, especially if the plant has rhizomes. Woody plant roots commonly spread 2-4 times the height of the plant.

Plants do not need all of their roots to survive. Determining the maximum spread of a plant's root system may aid the diagnoses of problems, for instance, a chemical spill well beyond the plant but within the root system. The roots within the dripline of plants are often used to determine which roots should be protected during construction, fertilized, mulched or irrigated.

The critical root area identifies the area around a tree or shrub that contains the most important roots for survival, health, care and protection. This area is determined by the thickness of the tree or shrub's stem. For small trees and all shrubs, measure the stem width at a distance of 6-12 inches above ground. For larger trees, measure the stem width at a height of 4.5 feet above ground. For each inch of stem width, a radius of 1-1.5 feet of root system is considered critical.

For instance, small tree or large shrub with a stem width of 3 inches will have a critical root area with a diameter of 6-9 feet (radius of 3 x 1-1.5 feet = 3-4.5 feet x 2 = diameter of 6-9 feet). This is a better method of determining where the most important roots are, and helps determine which roots should be fertilized, mulched and irrigated. It also determines the root area of a tree or shrub that should be protected during construction. In addition to these practical uses, it can also define the maximum amount of roots necessary for successful transplanting.

The range (1-1.5 feet per inch of stem width) allows for species (vigor) and health (vitality) variances. A young, healthy plant should easily survive with the lower range of critical root area (1 foot per inch of stem width). An older and/or larger and less healthy plant will be better off if the higher end of the range is used to calculate the critical root area (1.5 feet per inch of stem width).

During early development, a seedling plant absorbs nutrients and moisture from the soil within a few inches of the seed from which the plant grew. As plants become well established, the root system develops laterally and usually extends somewhat beyond the spread of the branches.

For most cultivated crops, roots meet and overlap between the rows. The greatest concentration of fibrous roots occurs in the top foot of soil, but a significant number of laterals may grow downward from these roots to provide an effective absorption system several feet or more deep.

Parts of a root
Internally, the root has three major parts.

The *meristem* is at the tip and manufactures new cells; it is an area of cell division and growth.

In the *zone of elongation* cells increase in size through food and water absorption. As they grow these cells push the root through the soil.

The *maturation zone* is where cells undergo changes to become specific tissues such as:

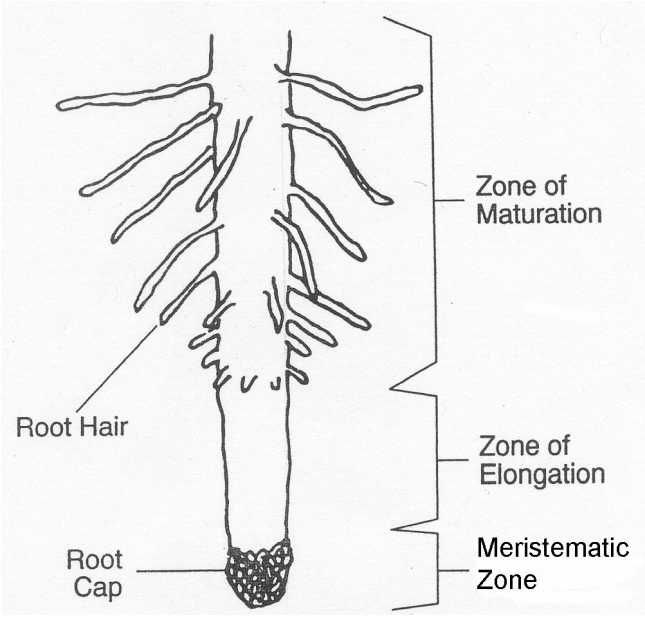
> The *epidermis*—the outermost layer of cells surrounding the root responsible for the absorption of water and minerals dissolved in water.
>
> *Cortex cells*—involved in the movement of water from the epidermis and in food storage.
>
> *Vascular tissue*—located in the center of the root and conducts food and water.

Externally, the root has three areas of importance.

Root hairs—found along the main root. They are short-lived, are continually produced and perform much of the actual work of water nutrient absorption.

In most woody plant roots, root hairs are replaced by *mycorrhizae*, literally "fungus roots." These mycorrhizal roots are much more efficient at absorbing water and nutrients than root hairs. They can also protect plants from some pathogens and promote healthier roots.

Root cap—the outermost tip of the root consisting of cells that are sloughed off as the root grows through the soil. The meristem, the area of cell division, is behind the root cap and is protected by it. The parts of a root are illustrated in the following figure.



A typical root

Sexually Reproductive Parts

Flowers

The flower, which is generally the showiest part of the plant, has sexual reproduction as its sole function. Although pleasing to people, fragrance and color are really devices to attract pollinators, animals that play an important role in the reproductive process.

Parts of the flower

As the reproductive part of the plant, the flower contains the male pollen and/or the female ovule plus accessory parts such as petals, sepals, and nectar glands.

Sepals—small green leaf-like structures on the base of the flower to protect the flower bud. The sepals collectively are called the *calyx*. Sometimes the sepals are as highly colored and showy as the petals, as in the daylily, for example. These sepals are called tepals.

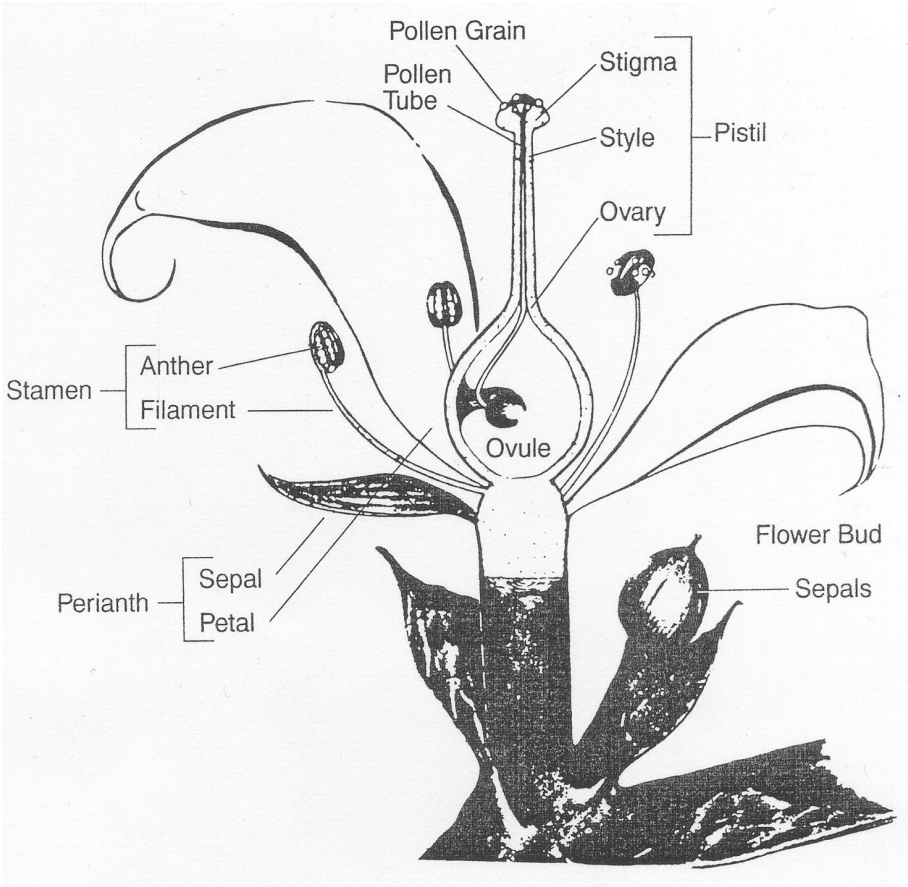
Petals—highly colored portions of the flower. They may contain perfume as well as nectar glands. The number of petals on a flower is often used in the identification of plant families and genera. The petals collectively are called the *corolla*.

The calyx and corolla make up the *perianth*.

Pistil—the female part of the plant. It is generally shaped like a bowling pin and located in the center of the flower. It consists of the *stigma*, *style*, and *ovary*. The stigma is located at the top and is connected by the style to the ovary, which contains the eggs residing in the *ovules*. After an egg is fertilized, an ovule develops into a seed.

Stamen—the male reproductive organ consists of a pollen sac called the *anther* and a long supporting *filament* which holds the anther in position so that the pollen it contains may be disbursed by wind or carried to the stigma by pollinating insects or birds.

Parts of a flower



Types of flowers

Complete—has stamens, pistils, petals, and sepals. If one of these parts is missing, the flower is incomplete.

Perfect—contains functional stamens and pistils. These are considered the essential parts of a flower and are involved in the seed-producing process. If either of the essential parts is lacking, the flower is imperfect.

Pistillate (female)—possesses a functional pistil or pistils but lack stamens.

Staminate (male)—contain stamens but no pistils.

Dioecious—separate plants bear only male flowers (staminate plants) or only female flowers (pistillate plants). Most holly trees and bittersweet vines are either male or female plants. Therefore, to get berries it is necessary to have a female plant with a male plant nearby to provide pollen.

Monoecious—have separate male and female flowers on the same plant. Some plants bear only male flowers at the beginning of the growing season but later develop both sexes; for example, cucumbers and squash.

How seeds form

Pollination—the transfer of pollen from an anther to a stigma. This may occur by wind or by pollinators. Wind pollinated flowers lack showy floral parts and nectar since they don't need to attract a pollinator. Flowers are brightly colored or patterned and contain a fragrance or nectar when they must attract insects, animals, or birds.

The stigma contains a chemical which activates the pollen, causing it to germinate and grow a long tube down the inside of the style to the ovules inside the ovary. The sperm is released by the pollen grain and *fertilization* then occurs. Fertilization is the union of the male sperm nucleus from the pollen grain and the female egg found in the ovary. If fertilization is successful, the ovule will begin development into a seed.

Fruits

Fruit consists of the fertilized and mature ovules called *seeds* and the ovary wall which may be fleshy as in the apple or dry and hard as in a maple fruit. The only parts of the fruit which contain genes of both the male flower and female flower are the seeds. The rest of the fruit is actually part of the maternal plant and is therefore genetically identical to it. Some fruits have seeds enclosed within the ovary (apples, peaches, oranges, squash, cucumbers). Others have seeds that are on the outside of the fruit (corn, strawberry).

Types of fruits

Simple fruits develop from a single ovary. These include cherries and peaches (drupes), pears and apples (pomes), and tomatoes (berries). Tomatoes are a botanical fruit since they develop from a flower as do squash, cucumbers, and eggplants. All of these fruits develop from a single ovary. Other types of simple fruits are dry. The fruit wall in these fruits becomes papery or leathery and hard as opposed to the fleshy examples just mentioned. Examples are peanuts (legumes), poppies (capsules), maples (samaras), and walnuts (nuts). Ovaries may be simple (cherries) or compound (tomatoes, cucumbers).

Aggregate fruits come from a single flower which has many ovaries. The flower appears as a simple flower with one corolla, one calyx, and one stem but with many pistils or ovaries. Examples are strawberries, raspberries, and blackberries. The ovaries are fertilized separately and independently. If ovules are not pollinated successfully, the fruit will be misshapen.

Multiple fruits originate from a tight cluster of separate, independent flowers borne on a single structure. Each flower will have its own calyx and corolla. Examples of multiple fruits are pineapples, figs, and beets.

Seeds

The seed or matured ovule is made up of three parts:

Embryo—a miniature plant in an arrested state of development.

Endosperm—a built-in food supply for the embryo. The endosperm can be made up of proteins, carbohydrates, or fats.

Seed coat—hard outer covering which protects the seed from disease and insects and prevents water from entering the seed and causing germination before the proper time.

Germination

Germination is the resumption of active growth of the embryo. Before anything else, the seed must take up water through the seed coat. In addition, the seed must be in the proper environmental conditions; that is, exposed to oxygen, favorable temperatures, and, for some, correct light; the seed must be ripe or mature; and dormancy be broken either physically or chemically.

Factors that can limit germination include when seed was harvested, age of seed, moisture content of the seed, and success of fertilization. Sometimes seeds must be scarified (scratched, nicked) before water can enter the seed and begin the germination process. Seeds may also need to be stratified (cold, heat treatments, or both).

Parts of the seedling:
Radicle—the first part of the seedling to emerge from the seed. It develops into the primary root from which root hairs and lateral roots will develop.

Hypocotyl—the portion of the seedling between the radicle and the first leaf-like structure.

Seed leaves or *cotyledons*—encase the embryo and are usually different in shape from the leaves that the mature plant will produce.

PLANT GROWTH AND DEVELOPMENT

Plant Functions That Influence Growth

The three major plant functions that are the basis for plant growth and development are photosynthesis, respiration, and transpiration.

Photosynthesis

One of the major differences between plants and animals is the plant's ability to manufacture its own food. To produce food for itself (and ultimately for people), a plant requires:

- energy from sunlight.
- carbon dioxide from the air.
- water from the soil.

If any of these ingredients is lacking, photosynthesis, or sugar production, will stop. If any factor is removed for a long period of time, the plant will die.

Only cells in the mesophyll layer of the plant leaves and stems can convert light energy to chemical energy (sugars) through the process called photosynthesis. These cells, which contain chloroplasts, are located between, and protected by, the upper and lower epidermis (skin) of the leaf. The green pigment, chlorophyll, that is found in the chloroplasts of these cells traps light energy so it can be used to manufacture sugar.

Photosynthesis is dependent on the availability of light. Generally speaking, as sunlight increases in intensity, photosynthesis increases. This means greater food production. Many garden crops, such as tomatoes, respond best to maximum sunlight. Tomato production is cut drastically as light intensities drop. Only two or three varieties of tomatoes will produce any fruit at all in greenhouses in late fall and early spring months when sunlight is minimal.

Water plays an important role in photosynthesis in several ways.

First, it maintains a plant's turgor or the firmness or fullness of plant tissue. Turgor pressure in a cell can be compared to air in an inflated balloon. Water pressure or turgor is needed in plant cells to maintain shape and insure cell growth, and keep the stomata open, which allows carbon dioxide to enter the leaf.

Second, water is split into hydrogen and oxygen by the energy of the sun that has been absorbed by the chlorophyll in the plant leaves. The oxygen is released to the atmosphere and the hydrogen is used in conjunction with carbon from carbon dioxide to manufacture carbohydrates.

Third, water dissolves minerals from the soil and transports them from the roots and throughout the plant where they serve as raw materials in the growth of new plant tissues. The soil surrounding a plant should be moist, but not too wet or too dry. Water is pulled through the plant by evaporation of water from the leaves, a process called *transpiration*. When the guard cells in leaves swell, thus opening the stomata, water is lost from the leaf and carbon dioxide can enter.

Photosynthesis also requires carbon dioxide, which is used in the manufacture of carbohydrates. Carbon dioxide in the air is plentiful enough so that it is not a limiting factor in plant growth.

Although not a component of photosynthesis, temperature is an important factor. Photosynthesis occurs at its highest rate in a temperature range of 65º to 85º F and decreases with temperatures above or below this range.

Respiration

Plants store the energy from light in sugars and carbohydrates such as starches for use during days when light is limited or they transport these chemicals to the roots. The chemical process by which sugars and starches produced by photosynthesis are converted to energy is called oxidation. It is similar to the burning of wood or coal to produce heat. Controlled oxidation in a living cell is known as *respiration*.

Respiration is the reverse of photosynthesis. Unlike photosynthesis, respiration occurs at night as well as during the day. Respiration occurs in all life forms and in all living cells. The release of carbon dioxide and the uptake of oxygen occurs at the cell level. There is diffusion of oxygen and carbon dioxide into the open spaces within the leaf and to and from the stomata where they exchange with the air.

The differences between photosynthesis and respiration are:

Photosynthesis	**Respiration**
1. Produces sugars	1. Uses sugars for plant energy
2. Energy is stored	2. Energy is released
3. Occurs in cells that contain chloroplasts	3. Occurs in all living cells
4. Oxygen is released	4. Oxygen is used
5. Water is produced	5. Water is used and produced
6. Carbon dioxide is used	6. Carbon dioxide is produced
7. Occurs in sunlight	7. Occurs in dark as well as light

Transpiration

Transpiration is the process by which a plant loses water primarily from leaf stomata. Transpiration is a necessary process that involves the use of about 99 percent of the water that enters the plant through the roots. The other 1 percent of the water is used in chemical reactions and in plant tissues. Transpiration is necessary for mineral transport from the soil to the plant parts, for the cooling of plant parts through evaporation, for moving sugars and plant chemicals, and for the maintenance of turgor pressure. The amount of water lost from the plant depends on several environmental factors such as temperature, humidity, and wind or air movement. As temperature or air movement increases, transpiration increases. As humidity decreases, transpiration increases.

Growth regulators

Growth regulators are plant hormones or other chemicals that initiate, stop, or otherwise influence growth in plants. Growth regulators can be naturally occurring or synthetic. The effects of plant growth regulators depend largely on the target tissue and the chemical environment. They are active in extremely small amounts and can cause a variety of plant responses. Plant growth regulators with some of their resulting effects include:

Auxins—cause cell elongation, inhibit growth of lateral buds, retard abscission of leaves and fruits

Gibberellins—restore normal growth in dwarf plants, cause rosette plants to bolt and seed germination in grasses

Cytokinins—promote growth of lateral buds, prevent leaf senescence

Abscisic acid—causes fruit and leaf drop

Ethylene—causes ripening in fruit

Environmental Factors That Affect Growth

Plant growth is limited by the environment. Many plant problems are caused by environmental stress. Therefore, it is important to understand the environmental aspects that affect plant growth. Three important environmental factors are light, temperature, and water.

Light has three principal characteristics affecting plant growth: quantity, quality, and duration.

Quantity refers to the intensity or concentration of sunlight and varies with the season of the year. The maximum is present in the summer and the minimum in winter. The more sunlight a plant receives, up to a point, the greater capacity it has to produce plant food through photosynthesis. Light quantity can be decreased in a garden or greenhouse by using shadecloth above the plants or growing plants in the shade of a tree. It can be increased by surrounding plants with reflective material, white backgrounds, or supplemental lights.

Quality refers to the color or wavelength reaching the plant surface. Sunlight can be broken up by a prism into red, orange, yellow, green, blue, indigo, and violet. Red and blue light have the greatest effect on plant growth. Red light, when combined with blue light, encourages flowering in plants. Green light is least effective to plants as they absorb less of it.

Blue light is primarily responsible for vegetative growth or leaf growth. Fluorescent or cool white light is high in the blue and red range of light quality and is used to encourage leafy growth and short plants.

Incandescent light is high in the red or orange range, but generally produces too much heat and too much stem elongation in plants to be a valuable light source.

Duration refers to the amount of time a plant is exposed to sunlight or the lack of it's designated photoperiod. It is not the length of the light period but the length of uninterrupted dark periods that is critical to floral development. The ability of many plants to flower is controlled by photoperiod. Plants can be classified into three categories, depending upon their flowering response to the duration of light or darkness.

Short-day plants form flowers only when the day length is less than about 12 hours in duration (long nights). Short-day plants include many fall flowering plants such as chrysanthemum and poinsettia.

Long-day plants form flowers only at day lengths exceeding about 12 hours (short nights). They include almost all of the summer flowering plants, as well as many vegetables including beet, radish, lettuce, spinach, and potato.

Day-neutral plants form flowers regardless of day length. Some plants do not really fit into any category but may be responsive to combinations of day lengths. The petunia will flower regardless of day length, but flowers earlier and more profusely under long daylight.

Temperature

Temperature affects various plant processes including:

Photosynthesis:	increases with temperature to a point
Respiration:	increases with temperature
Transpiration:	increases with temperature
Flowering:	triggered by low temperature
Sugar storage:	low temperatures reduce energy use and increase sugar storage
Dormancy:	broken after a period of low temperature, the plant will resume active growth

Temperature affects the productivity and growth of a plant, depending upon whether the plant is a warm- or cool-season crop. If temperatures are high and day length is long, cool-season crops such as spinach will flower. Temperatures that are too low for a warm-season crop such as tomato will prevent fruit set. Adverse temperatures also cause stunted growth and poor quality vegetable production; for example, bitterness in lettuce is caused by high temperatures.

Sometimes temperatures are used in connection with day length to manipulate the flowering of plants. Chrysanthemums will flower for a longer period of time if daylight temperatures are 59º F. The Christmas cactus forms flowers as a result of short days and low temperatures. Temperatures alone also influence flowering. Tulips are forced to flower by putting the bulbs in cold storage in October at 35º to 40º F. The cold temperatures allow the flower to develop and its stalk to elongate as the bulb matures.

Thermoperiod refers to a daily temperature change. Plants respond to and produce maximum growth when exposed to a day temperature that is about 10º to 15º F higher than a night temperature. This allows the plant to photosynthesize (build up) and respire (break down) during an optimum daytime temperature and to curtail the rate of respiration during a cooler night. Higher temperatures cause increased respiration, sometimes above the rate of photosynthesis. This means that the products of photosynthesis are being used more rapidly than they are being produced. For growth to occur, photosynthesis must be greater than respiration.

Too low temperatures can also produce poor growth. Photosynthesis is slowed down at low temperatures. Since photosynthesis is slowed, growth is slowed, and this results in lower yields. Not all plants grow best under the same temperature range. For example, snapdragons grow best at nighttime temperatures of 55º F and the poinsettia at 62º F. Florist cyclamen does very well under very cool conditions while many summer annual bedding plants prefer a higher temperature.

However, in some cases, a certain number of days of low temperature are needed by plants in order to break dormancy and grow properly. This is true of crops originating in cold regions. Apples are a prime example: most varieties require 1,000 to 1,200 hours below 45º F but above 32º F before they break their rest period and begin growth. Lilies and daffodils need 6 weeks of temperatures at 33º F before blooming.

Plants can be classified as either hardy or nonhardy depending upon their ability to withstand cold temperatures. Winter injury can occur to nonhardy plants if midwinter temperatures are too low or if unseasonably low temperatures occur early in the fall or late in the spring. Winter injury may also occur because of desiccation or drying out. Plants need water during the winter. When the soil is frozen, the movement of water into the plant is severely restricted. On a windy winter day, evergreens can become water-deficient in a few minutes and the leaves or needles then turn brown. Unseasonably high winter temperatures can cause premature bud break in some plants and consequent fruit bud freezing damage. Late spring frosts can ruin entire crops. If temperatures drop too low during the winter, entire trees of some species are killed by freezing and desiccating plant cells and tissue.

Water

Watering plants correctly is vital for developing and maintaining a landscape planting. Lack of water can cause a plant to wilt and ultimately dry up and die. Excessive water can cause roots to die and rot, in which case the plant wilts because it is oxygen starved, and consequently is unable to take up moisture. As a rule, plants are capable of withstanding moderate drought more easily than too much moisture. For this reason, it is important to water thoroughly and then allow the soil to become fairly dry between waterings.

Wilting is a condition brought about in plants when roots are unable to supply sufficient moisture to the stems and leaves. Wilting for short periods of time will not harm plants; over a prolonged period, however, it will cause permanent damage. Sometimes a plant will wilt on a hot day because moisture is evaporating from the leaves faster than the roots can supply it. If there is ample soil moisture, the plant will absorb water in the evening to firm up the stems and leaves.

In mid- and late summer or early fall it is not uncommon to experience a sustained period of wilting. When the leaves hang down, do not recover overnight,

and no rain is predicted, it is advisable to provide prolonged, deep watering to keep the leaves turgid. To wet the soil at least 6 inches deep requires 1 to 2 inches of surface water depending on soil type.

Container-grown landscape plants may be susceptible to drought stress after they are transplanted to the landscape. Drought stress occurs because the well-drained organic mix in which the plants are grown in the nursery is prone to rapid loss of moisture due to plant transpiration (loss of water from plant leaves) and evaporation from the soil surface. Even though moisture is available in the soil surrounding the organic mix, it does not move into the transplanted root ball rapidly enough to prevent moisture stress from developing. Research has shown that the available moisture in the container mix can be depleted in about two days in the absence of irrigation. For this reason, these plants are watered at least every other day while in the nursery. This routine should be followed after transplanting (if the landscape soil drains properly) until the root system penetrates the surrounding soil backfill (approximately three to four weeks) which provides a greater reservoir of water than the original container soil.

Care must be taken not to allow the transplant root ball to dry out because the organic mix is very difficult to rewet once it becomes dry. Water applied to a drought-stressed plant where the root ball has become very dry may not successfully relieve the moisture stress because the medium does not readily absorb the applied water. In this case, water two or three times each day until the root ball has been rewet.

Maximizing watering effectiveness

Know the condition of the soil. It is important to observe how quickly soil dries out after a rain or watering. For example, a clay soil will need less frequent watering than a sandy one. Clay soil drains slowly, porous sandy soil quickly. The addition of organic matter to the soil will increase drainage in clay soil and moisture retention in sandy soil. When preparing a hole for planting, break up the subsoil at the bottom of the hole with a shovel or pick if it is very hard and prevents water from draining quickly.

Learn the cultural requirements of plants being grown. Different plants have different water needs; azaleas require more moisture than cacti. Good reference books will provide the gardener with this information. It is particularly important to provide a relatively high soil moisture supply for evergreen plants during the fall before the ground freezes. The leaves of such plants continue to lose water during the winter, especially when the temperature is above 40º F. If the soil is dry, the plants may become desiccated, turn brown, and die. Therefore, if the soil moisture supply is low water shrubs several times during the late fall.

Mulch plantings to reduce the frequency of watering during dry spells. Mulches help keep soils cool and reduce water loss through evaporation.

If the soil is dry when preparing a hole for a new plant, dig the hole and fill it with water the day before the plant goes into the ground. This allows the soil time to absorb water and avoids a muddy condition during the planting. Once a tree or shrub has been planted, shape the soil around the diameter of the root ball to form a berm enclosing a depression. Fill the depression with water. This permits water to go straight to the root zone rather than runoff the surface. Thorough soaking after planting eliminates air pockets around roots.

When there is an extended period without rain during the summer, new plants should be deeply watered once a week. Allow the soil surface to dry out somewhat between waterings, so major root development will be at greater depths where soil moisture is highest. Plants watered frequently but lightly will have roots close to the surface, making them more vulnerable to wilting. They will not become well-established and will have little drought tolerance. This happens with automatic overhead sprinkler systems that are designed to go on for a short period of time each night and only moisten the surface. This practice also encourages foliar diseases in midsummer.

During cool periods less watering is necessary because evaporation from the leaves and soil is slower than during hot periods. Normally, abundant rainfall during spring and autumn diminishes the need for watering. During a dry autumn, before the ground freezes all garden plants should have a thorough watering to help prevent root damage from cold winter temperatures. Damage from unusually cold temperatures around the roots shows up in the spring in the form of leaf drop because there are not enough roots to support the foliage.

The best time to water is in the morning or evening when air temperatures are lower than at midday, thus reducing evaporation. In the evening do not wet foliage because this can encourage fungus or mildew, making plants unsightly and jeopardizing their health.

Reducing water demands

Water may not be available to plants, particularly if the soil is a heavy clay. Clay particles hold soil moisture tightly. If, for example, there are 4-1/2 inches of water per foot of this type of soil, there may be as little as 1-1/2 inches available for plants. A relatively high level of humus in the soil, brought about by the addition and breakdown of organic matter, can improve this proportion to some extent. By causing clay particles to form aggregates, large clumps or groups of particles, humus also adds air spaces to tight clays, allowing moisture to drain to lower levels as a reserve, instead of puddling and running off the surface of the soil.

The moisture-holding capacity of sandy soils is improved by additions of organic matter. Though most soil water in sandy soil is available, it drains so quickly that plants are unable to obtain water after even a few days following a rain. Humus in sandy soil gives the water something to cling to until it is needed by plants. Addition of organic matter is the first step in improving moisture and aeration conditions in the garden soil.

Mulching is a cultural practice which can significantly decrease the amount of water that must be added to the soil. A 6-8” organic mulch can reduce water needs by as much as one-half by smothering weeds (which take up and transpire moisture) and by reducing evaporation of moisture directly from the soil. Organic mulches themselves hold some water and increase the humidity level around the plant. Black plastic mulch also conserves moisture but may increase soil temperatures dramatically during the summer (to the detriment of some plants and the benefit of others) if not covered by organic mulch materials or foliage.

Shading and the use of windbreaks are other moisture-conserving techniques. Plants that wilt in very sunny areas can benefit from partial shade during the afternoon in summer. Small plants, in particular, should be protected. Air moving across a plant carries away the moisture on the leaf surfaces, causing more water to be used by the plant. In very windy areas the roots often cannot keep up with leaf demands, and plants wilt. Temporary or permanent windbreaks can help tremendously.

During those times when cultural practices simply aren’t enough and when rainfall is sparse and the sun is hot, watering can benefit the garden with higher yields, or may save the garden altogether in severe drought years.

Watering methods

The home gardener has several options for applying water to plants: a watering sprinkler can, a garden hose with a fan nozzle or spray attachment, portable lawn sprinklers, a perforated plastic soaker hose, drip or trickle irrigation, or a semi-automatic drip system. Quality equipment will last for a number of years when properly cared for.

Adjust the flow or rate of water application to about 1/2 inch per hour. Much faster than this will cause run off, unless the soil has exceptionally good drainage. To determine the rate of application for a sprinkler, place small containers at various places within the sprinkler’s reach, and check the depth of water in

the containers at 15-minute intervals. Multiplying the depth by 4 will give the application rate per hour. The uniformity of depth in the containers is an indication of uniformity of water application.

When using the oscillating type of lawn sprinklers: (1) place the sprinkler on a platform higher than the crop to prevent water from being diverted by plant leaves; and (2) try to keep the watering pattern even by frequently moving the sprinkler and overlapping about one-half of each pattern. Move the sprinkler when 1 to 1-1/2 inches of water has been applied depending on soil type. This amount of water will wet the soil about 1 foot deep.

Do not sprinkle foliage in the evening. Wet foliage overnight can encourage diseases. Morning watering is preferred.

Perforated plastic hoses or soaker hoses should be placed with holes down (if there are holes), along one side of the crop row, or underneath mulch. Water is allowed to soak or seep into the soil slowly.

It is best to add enough water to soak the soil to a depth of 6-12" depending on the crop. It takes approximately 2/3-gallon of water for each square foot or about 65-130 gallons for 100 square feet of garden area to wet to a 6" depth. This varies with the nature of the soil. Frequent, light waterings will only encourage shallow rooting which will cause plants to suffer more quickly during drought periods, especially if mulches are not used. On the other hand, too much water, especially in poorly drained soils, can be as damaging to plant growth as too little water.

By knowing the critical watering periods for selected vegetables or vegetable types, you can reduce the amount of supplemental water you add. This can be important where water supplies are limited. In general, water is most needed during the first few weeks of development, immediately after transplanting, and during the development of edible storage organs.

In areas prone to repeated drought, look for drought-resistant varieties when buying seed or plants.

If water supplies are short in your area and you wish to use grey water, or water from household uses, on your vegetable garden, a few rules should be observed:

- It is preferable not to use kitchen waste water that contains grease or harsh cleaners, ammonia, bleach, softeners, or non-biodegradable detergents.
- If using water from the bathtub or washing machine, use only mild, biodegradable soaps. Omit softeners and bleaches. Allow wash and rinse water to mix, if possible, to dilute the soap content.
- Never use a borax-containing product (such as washing soda) in water to be used on a garden because of the danger of applying plant-toxic levels of boron.
- Apply greywater to the soil, not to plant leaves.

Weed Control

Weeds are remarkably adapted to conditions in the area where they grow. Weed seeds may remain viable for seven years or more when conditions are not right for their growth. Then, brought to the surface by tilling, and uninhibited by sod, shade or other factors, they germinate and become the pests that take water, nutrients, sunlight and space from plants.

Cultivation

Remove weeds when they are young and tender. Hand-pulling and digging are okay for small gardens and raised beds. Those with larger spaces usually prefer at least a hoe.

There are manual-powered rotary cultivators that do a good job on long rows and pathways as long as the soil is not too wet or dry and the weeds are small.

Manual and powered rotary cultivators are usually unable to turn under weeds very close to plants without damaging the plants. Hand-pulling or hoeing with a light touch are best for removing weeds near plants. Deep cultivation with any instrument is likely to damage roots or stems of plants.

Turning under weeds, especially before they flower and seed, provides organic matter to the soil. Hand-pulled weeds, except for rhizomatous grasses, may be laid on top of the soil to dry out and will eventually have the same effect. If rain is predicted in the area within a day or two of pulling, it's best to collect the weeds and add them to the compost pile; rain will wash soil around the roots and some weeds will survive.
If weeds have started to go to seed, leaving them in the garden is not a good idea. Composting may not destroy weed seeds if the pile doesn't heat up enough after the weeds are added. Grasses that spread by
rhizomes or stolons also present a problem if not completely dried up.

Reducing weed growth around the garden by mowing or other means will also help prevent the spread of weeds and seeds to the garden area. Hoeing and pulling is best done when the soil is somewhat moist, but not wet. Working wet soil will change the structure, especially of heavy soils. When it is too dry, weeds are difficult to pull and hoeing is also hard. A day or two after a rain or irrigation is probably the best time to cultivate.

Close spacing

Established plants that have been planted close enough to each other will shade the soil and prevent the growth of many weed seedlings.

Herbicides

The wrong herbicide can destroy a garden's productivity for years. Even when used properly, drift from herbicide sprays used on lawns or in areas surrounding the garden can cause damage to other plants.

Spray on windless days and erect barriers to protect garden plants if necessary. Drift from pre-emergence herbicides does not damage growing plants, but may prevent seeds from germinating. Treatment with a herbicide for one type of weed may result in the area being colonized by other weeds which are tolerant of the chemical.

Never use an herbicide in the same sprayer used for insect and disease control. Keep a separate sprayer for plant-killers only.

Mulching

For year round benefits of mulching, apply a 2" mulch of shredded bark, wood chips, or peat moss around shrubs, roses, and recently planted trees. This mulch will conserve moisture and help suppress the growth of weeds and grass. A 2" layer should be used under the branches of shrubs and roses of all ages.

Sawdust or shredded bark from the inside of a large pile may have been through anaerobic decomposition and be very acid, with a pH of about 3.0 and a pungent odor. Such material is toxic to plants.

In some cases, mice may tunnel in the mulch and cause damage by chewing the bark from the stems of shrubs. This is more likely to happen when coarse materials like straw, hay, or pine needles are used. The best control is to keep the mulch back about 6" from the stems, but trapping or poisoning the mice may be necessary for control. A circle of crushed stone or coarse sharp cinders about 6" wide around the stems may also be helpful.

Mulch should be maintained for at least three or four years around newly planted ornamental trees. It should start 3" from the trunk and cover the soil disturbed in planting, and be renewed as often as necessary to maintain a layer 2"

thick. Such a circle of mulch will make it easier to mow around young trees in a lawn without damaging the bark. The layer of mulch should be renewed to a 2" depth, if necessary, after a killing frost in the fall.

Both organic and inorganic mulches can be useful in the home landscape. Some of the more readily available ones include:

Sawdust: A 2" layer of sawdust provides good weed control. If applied around growing plants, add 1/2 pound of actual nitrogen per 10 cubic feet of sawdust to prevent nitrogen deficiencies; fresh sawdust contains a great deal of carbon and very little nitrogen, and while it breaks down very rapidly, it requires that microorganisms take nitrogen from the soil. A very thin layer of sawdust (1/4") is useful in starting seeds because it helps retain moisture; but, be sure nitrogen is adequate. There is often a problem with fresh sawdust, crusting and becoming impermeable to rainfall. Sawdust is best used for garden paths and around permanent plantings. It is available from sawmills or lumber yards.

Bark: A 2-3" layer of one of several types of bark provides good weed control. Bark is slow to decompose and will stay in place. Shredded bark decomposes more quickly than the stone types. Bark and wood chips are often available free or for a small charge from professional tree pruning services, or may be purchased in large bags at retail stores. Bark makes a very attractive mulch, and is especially recommended for mulching around trees and shrubs. When used over landscape fabric around perennials, bark provides effective weed control for long periods of time.

Hay or straw: A 3-4" layer of hay provides good annual weed control. Some people use a 1' thick layer of compacted straw. These materials decompose quickly and must be replenished to keep weeds down. They stay in place and will improve the soil as they decay. Avoid hay that is full of weed seed and brambles. Fresh legume hay, such as alfalfa, supplies nitrogen as it quickly breaks down. Hay and straw are readily available in rural areas and also in bales at nurseries and garden centers in the fall.

Pine needles: Baled pine needles make an excellent mulch for acid-loving plants, but can release too much acid for many vegetable plants. Pine needles are best used around shrubs and trees, particularly acid-loving types.

Grass clippings: A 2" layer of grass clippings provides good weed control. Build up the layer gradually, using dry grass, to prevent formation of a solid mat. Clippings will decompose rapidly and provide an extra dose of nitrogen to growing plants, as well as making fine humus. Avoid crabgrass clippings and grass full of seed heads to prevent unwanted weeds. Also, do not use clippings from lawns which have been treated that season with herbicide or a fertilizer-herbicide combination ("weed and feed" types). Grass clippings may be used directly as mulch around vegetables or fruit plants, or they may be composted if added to the pile a little at a time. They are an excellent source of nitrogen to help increase microbial activity in the compost pile, especially for those gardeners without access to manures.

Leaves: A 2-3" layer of leaves, after compaction, provides good weed control. Leaves will decompose fairly quickly, but are easily blown away unless partially decomposed. Leaves are usually easy to obtain, attractive as a mulch, and will improve the soil once decomposed. Highly recommended as a mulch.

Peat moss: A 2-3" layer of peat moss will give fair to good weed control. This material is slightly acid, and thus suitable for use with acid-loving plants. However, peat tends to form a crust if used in layers thick enough to hold weeds down, or it may be blown away. Peat is also a relatively expensive mulching material, probably more suitable for incorporation into the soil where a decrease in soil pH is needed.

Compost: A 2-3" layer of composted organic materials provides fair weed control. Most compost, however, provides a good site for weed seeds to grow. It, too, is probably better used by incorporating it into the soil, since it is an excel-

lent soil amendment. A layer of compost may be used for overwintering beds of perennials such as asparagus or berries to provide nutrients and help protect crowns from low temperatures.

Hulls and ground corncobs: A 2-4" layer of these materials will provide fair weed control, but both have a tendency to be easily blown by the wind. Hulls will stay in place somewhat better than ground corncobs. A heavier mulch, such as partially rotted hay or straw, may be used on top to hold the lighter materials down.

Gravel, stone, and sand: A 1" layer of rock will provide fair weed control. Rocks, of course, do not decompose noticeably. They make a good mulch for permanent plantings, as around foundation plants and in alpine gardens, but are not recommended for acid-loving plants, since alkaline elements within the rocks may dissolve and leach into the soil. None of these mulches is effective in controlling water erosion; soil will wash right out from under rocks, and sand will be swept away.

Black plastic: One layer of black plastic provides excellent weed control. It is relatively slow to decompose, but will be somewhat broken down by sunlight and must be replaced every two years at least. Black plastic mulch will increase soil temperature by about 8 degrees in the spring. It may cause soil temperatures to rise too much in mid-summer, "cooking" the roots of plants unless a good foliage cover or organic mulch prevents direct absorption of sunlight. Check periodically to see that soil remains moist beneath the plastic; cut holes in it if water doesn't seem to be getting through.

Clear plastic: One layer of clear plastic will provide little weed control; in fact, it makes an excellent greenhouse environment for growing weeds. This material is most often used to raise the soil temperature early in the spring to prepare an area for planting. It will raise the soil temperature by 10 degrees or more. It is not recommended as a weed-controlling mulch.

Paper: Using 2-4 layers of newspaper provides good weed control. It decomposes within a season and is readily available and cheap. Cover with an organic mulch, such as hay or bark to hold paper in place. Excellent for use in pathways and around newly set strawberry plants. Lead in printers' ink has been a concern of some gardeners desiring to use newspaper; however, printers no longer use lead compounds in ink for black and white newsprint, though colored inks may contain lead.

Aluminum coated plastic and foil: One layer of either of these materials provides excellent weed control. Decomposition is very slow. Soil temperatures are decreased by up to 10 degrees. They provide additional reflection of light to help speed up fruiting of such vegetables as peppers and eggplant in not-so-sunny gardens. The reflective quality of aluminum foil has been shown in university tests to inhibit the colonization of plants by aphids. Expensive and unattractive.

YARD WASTE MANAGEMENT

Waste disposal is a serious problem nationwide. Landfills are being filled rapidly and it is difficult and expensive to find and prepare sites for new ones. In 1990 in Minnesota, about 40 landfills were closed. The U.S. Environmental Protection Agency estimates that yard waste comprises about 18 percent of the annual mixed solid waste stream (MSWS) nationally. During peak seasons this figure rises to 25-50 percent. In Minnesota the annual average in the metropolitan area is at about 18 percent and out-state around 9 percent of the MSWS. Virtually all of this material is decomposable, which means that there are options to putting it in a landfill.

Many states including Minnesota have responded to the problem by banning disposal of yard waste in landfills. This law became effective statewide on January 1, 1992. As Master Gardeners you will be asked about how to deal with this problem. This information will help you understand some of the options and opportunities for reducing yard waste production and for turning a waste product into a valuable resource.

The Three R's: Reduce, Reuse, Recycle

Reduce—Reduction of yard waste at its source is possible. Plant parts that are diseased or whole plants that are dead contribute to yard waste. Landscaping practices that put the right plant in the right place and encourage vigorous plant health can help reduce yard waste production. The following are gardening practices that help reduce yard waste:

- Select disease- and insect-resistant plant varieties.
- Match plant cultural requirements to existing microclimate.
- Use good diversity of plant materials.
- Match mature plant size to available space.
- Use fertilization, watering, pruning practices that encourage plant vigor but not rampant growth.

Reuse—Much of the organic waste from your yard can be reused as a mulch on garden beds or around trees or shrubs. Grass clippings can be used as a mulch after they have been allowed to partially dry. Leaves or woody wastes that have been chipped can also be used. Short grass clippings can be left on the lawn to serve as a mulch and to provide additional nutrition. Light coverings of dry leaves can be chopped with rotary mower and left on the lawn too.

Recycle—Backyard composting is an excellent way to recycle yard waste. Composting is a process that uses microbes which are commonly present in soil or on organic materials to decompose those materials into a beneficial soil amendment. The addition of compost will improve soil structure, improve drainage in heavy (clay) soils, improve retention of soil moisture in light (sandy) soils, and provide a small amount of nutritive value. However, material that is not completed decomposed may induce nitrogen deficiency.

Composting

It may be helpful to think of the compost pile as a microbe farm where you want to provide optimum conditions for microbes to thrive. Their needs include: air, water, a food source properly balanced in carbon-rich and nitrogen-rich materials.

STARTING FLOWER AND VEGETABLE SEEDS INDOORS

Light

To start seeds indoors, it is important to have enough light. More homegrown seedlings are probably lost to this one factor than to any other. Seedlings grown under low-light conditions are likely to be leggy and weak, and many will fall over under their own weight after they are 3-4" tall. If you do not have a sunny room or porch with a southern exposure, you will probably need supplemental lights. A simple fluorescent shop light with one warm white and one cool white bulb (or with grow lights) will suffice.

Soil

The best media for starting seeds is loose, well drained, fine textured, low in nutrients, and free of disease-causing fungi, bacteria, and unwanted seeds. Many commercial products meet these requirements.

It is probably easiest to use a soilless or peat-lite mix to start seedlings, since garden soil contains disease organisms which can be highly destructive to small plants and does not drain well in shallow containers.

Any soil containing garden loam should be pasteurized. This can be done easily at home. Spread the soil on a cookie tray and bake it in the oven at 200º F. until the soil temperature is 180º F. It should be held at that temperature for 30 minutes. Do not heat it longer than 30 minutes. This is a smelly process, but it works. Garden soil that is high in clay should be conditioned with compost or perlite to prevent excess moisture and/or shrinkage. You can mix your own peat-like mix if you prefer using 50 percent vermiculite or perlite and 50 percent fine sphagnum peat. Fertilizer mixed at half the recommended strength may be added to the mixture. Mix together well.

Materials commonly used for starting seedlings and growing house plants are the peat-lite mixtures, consisting of peat moss and either vermiculite or perlite. Here are some characteristics of the ingredients for these mixes.

Peat moss: Readily available baled or bagged sphagnum peat moss has good texture. Such materials as Michigan peat, peat humus, and native peat are usually too decomposed to provide necessary structural and water-drainage characteristics for mixes but are good for seed germination. Most sphagnum peat moss is acid in reaction, with a pH ranging from 4.0 to 5.0. It usually has a very low fertility level but does have capacity to retain nutrients. Do not shred sphagnum peat moss too finely.

Vermiculite: This is a sterile, light-weight mica product. When mica is heated to approximately 1800º F, it expands its plate-like structure. Vermiculite will hold large quantities of air, water, and nutrients needed for plant growth. Its pH is usually in the 6.5 to 7.2 range. Vermiculite is available in four particle sizes. For horticultural mixes, sizes two or three are generally used for mixes, but small particles are best for germinating small seeds. Larger-sized particles give much better soil aeration. Vermiculite is available under a variety of trade names.

Perlite: This is a sterile material produced by heating volcanic rock to approximately 1800º F resulting in a very light-weight, porous material that is white in color. Its principal value in soil mixtures is aeration. It does not hold water and nutrients as well as vermiculite. The pH is usually between 7.0 and 7.5. Perlite can cause fluoride burn on some foliage plants. Fluoride damage is usually seen on the tips of the leaves. The burn progresses from the tip up into the leaf. Fluoride burns can be prevented by adding 1-1/2 times the recommended amount of lime when mixing the soil.

Here are two good artificial mixes containing no outside garden soil.

Home Mix #1
1/2 bushel (4 gallons) of #2 grade vermiculite
1/2 bushel (4 gallons) of shredded sphagnum peat moss
4 tablespoons ground limestone
1 cup (1/2 pound) 5-10-5 or 1/2 cup (1/4 pound) 10-10-10

Mix thoroughly and store in plastic or nonmetal container. For better drainage, add one gallon of medium perlite.

Home Mix #2
1 gallon of milled sphagnum peat moss
1 gallon of #2 grade vermiculite
1 gallon of medium perlite
Mix thoroughly and store in a closed container.

Commercial Mixes Suitable for Starting Seeds
Redi Earth
Heco 1
Jiffymix
Pro Mix A

Containers

Many types of containers can be used to start seeds. Seeds in flats or other large containers may be planted in rows and the seedlings grown until they have one or two sets of true leaves. At this point they are transplanted into other containers for growing to the size to transplant outdoors. Or, seedlings may be started in pots, old cans, cut-off milk cartons, margarine tubs, egg cartons, or other throwaways if drainage holes are provided. The pop-out trays found at garden centers are easy to use and reusable. Peat pots are nice, especially for large seeds and herbs. Sow one or two large seeds, or 10-12 small herb seeds, directly in each peat pot. Thin the former to one seedling per pot, but allow all the herb seeds to grow together. They hold each other up and grow much better than if sown singly. When transplant time comes, they are strong enough to take some dividing if desired. Peat pots may be planted directly in the garden; remove one side and do not allow the edges of the pot to stick out above the soil, since they will act as a wick and moisture will evaporate from this exposed surface.

Planting

Regardless of the type of container chosen, fill clean containers about two-thirds full with moist potting medium. Level and compact the medium. It should be damp but not soggy. Make a furrow one-fourth of an inch deep. Sow large seed directly in the bottom of the furrow. Before sowing small seed, fill the furrow with vermiculite; sow small seed on the surface of the vermiculite. Seed may be sown in flats following seed package directions or directly in individual peat pots or pellets, two seeds to the pot. After seed is sown, cover all furrows with a thin layer of vermiculite, then water with a fine mist. Put a label with the name, variety, and date of planting on or in each container.

Watering

After planting, gently soak the soil with water by subirrigation or misting, being careful not to wash out or displace seeds. Seeds and seedlings are extremely sensitive to drying out. If your home is dry, it may help to cover the containers with plastic wrap to maintain a steadier moisture level. Set them in an area away from sunlight where the temperature is between 60º and 75º F. As soon as seeds have germinated, remove plastic sheeting and place seedlings in the light. If natural light is poor, fluorescent tubes can be used. Place seedlings close to the tubes. After plastic is removed from container, the new plants need watering and fertilizing, since most planting material contains little or no plant food. They should not be kept soaking wet, however, since this condition is conducive to damping-off, a fungus disease deadly to seedlings. Damping-off can be prevented or diminished by sprinkling milled sphagnum moss, which contains a natural fungicide, on top of the soil. Use a mild fertilizer solution after plants have been watered. When seedlings develop two true leaves, thin plants in individual pots to one seedling per pot. Transplant seedlings in flats to other flats, spacing 1-1/2 inches apart, or to individual pots.

Another option is to use peat pellets or cubes, which are preformed and require no additional soil mix. The pellets or cubes are soaked until thoroughly wet, then seeds are planted in the holes provided. The whole pellet or cube may then be planted without disturbing the roots. A disadvantage to this method is the expense.

Damping-Off of Seedlings

Damping-off is a fungal disease that causes seeds to rot and seedlings to collapse and die. The disease is carried in soil and may be present on planting containers and tools. Soil moisture and temperature necessary for germination of seeds are also ideal for development of damping-off. Once the disease appears in a seed flat, it may travel quickly through the flat and kill all seedlings planted there. This can be prevented by treating the seed with a fungicide, sterilizing the soil, and using sterile containers. Treat the seed by tearing off the corner of the seed packet, and through the hole in the packet, inserting about as much fungicide dust as you can pick up on the tip of the small blade of a penknife. Close

the hole by folding over the corner of the packet, then shake the seed thoroughly to coat it with the fungicide dust. Some packets have already been treated with fungicides when purchased.

Unless you use artificial soilless mixes, sterilize the soil in an oven.

To avoid introducing the damping-off organism on containers, use fiber seed flats or peat pots. These containers are sterile, inexpensive, and easily obtained from garden shops. Fiber flats are light and strong. They cost so little that they can be thrown away after one use. Peat pots can be set out in the garden along with the plants they contain; roots of the plants grow through the walls of the pots. Plants grown in peat pots suffer no setback when they are transplanted to the garden. Larkspur and poppy, which ordinarily do not tolerate transplanting, can be grown in peat pots satisfactorily.

If wooden boxes or clay flowerpots are used for soil containers, clean them well. Soak clay pots in water and scrub them to remove all the white fertilizer crust from the outside. Sterilize clay pots by swabbing them with a solution of 1 part chlorine bleach to 10 parts water. Allow containers to dry thoroughly before filling them with soil. If, despite precautions, damping-off appears in seedlings, discard the containers and soil and start again.

Thinning

Thin seedlings to obtain proper spacing when the plants have two or three leaves. If cages, stakes, or other supports are needed, provide them when the plants are very small to avoid root damage.

GARDENING IN CONTAINERS

There are many possible containers for gardening. Clay, wood, plastic, metal are some of the suitable materials. Containers for plants must (1) be big enough to support plants when they are fully grown, (2) hold soil without spilling, (3) have adequate drainage, and (4) never have held products that would be toxic to plants or people. Consider using barrels, flowerpots, cut-off milk and bleach jugs, recycled styrofoam coolers, window boxes, baskets lined with plastic (with drainage holes punched in it), even pieces of drainage pipe or cinder block. If you are building a planting box out of wood, you will find redwood and cedar to be the most rot-resistant, but bear in mind that cedar trees are much more plentiful than redwoods. Wood for use around plants should never be treated with creosote or pentachlorophenol (Penta) wood preservatives. These may be toxic to plants and harmful to people as well.

Some gardeners have built vertical planters out of wood latticework lined with black plastic and then filled with a lightweight medium, or out of welded wire shaped into cylinders lined with sphagnum moss and then filled with soil mix. Depending on the size of your vertical planter, 2” diameter perforated plastic pipes may be needed inside to aid watering.

Whatever type of container you use, be sure that there are holes in the bottom for drainage so that plant roots do not stand in water. Most plants need containers at least 6-8” deep for adequate rooting.

As long as the container meets the basic requirements described above it can be used. The imaginative use of discarded items or construction of attractive patio planters is a very enjoyable aspect of container gardening. For ease of care, dollies or platforms with wheels or casters can be used to move the containers from place to place. This is especially useful for apartment or balcony gardening so that plants can be moved to get maximum space and sunlight, and to avoid destruction from particularly nasty weather.

Watering

Pay particular attention to watering container plants. Because the volume of soil is relatively small, containers can dry out very quickly, particularly as the plants increase in size and especially if located on a concrete patio in full sun. Daily or even twice daily watering may be necessary. Apply water until it runs out the drainage holes. Large trays filled with coarse marble chips work nicely for drainage underneath containers. However, the soil should never be soggy or have water standing on top of it.

When the weather is cool, container plants may be subject to root rots if kept too wet. Clay pots and other porous containers allow additional evaporation from the sides of the pots and watering must be done more often than with plastic or glazed containers. Small pots also tend to dry out more quickly than larger ones. If the soil appears to be getting excessively dry (plants wilting every day is one sign), group the containers together so that the foliage creates a canopy to help shade the soil and keep it cool.

On a hot patio, you might consider putting containers on pallets or other structures that will allow air movement beneath the pots and prevent direct contact with the concrete. Check containers at least once a day and twice on hot, dry, or windy days. Feel the soil to determine whether or not it is damp. Mulching and windbreaks can help reduce water requirements for containers. If you are away a lot, consider an automatic drip emitter irrigation system.

Fertilizers

If you use a soil mix with fertilizer added, your plants will have enough nutrients for 8-10 weeks. If plants are grown longer than this, add a water-soluble fertilizer at the recommended rate. Repeat every 2-3 weeks. An occasional dose of fish emulsion or compost will add trace elements to the soil. Do not add more than the recommended rate of any fertilizer, since a higher rate may cause fertilizer burn and kill the plants. Container plants do not have the buffer of large volumes of soil and humus to protect them from over fertilizing or over liming. Just because a little is good for the plants does not guarantee that a lot will be better.

Best Planting Practices for Trees and Shrubs (aka, Planting for Long Term Health)

Step One: Purchase high quality plant material.

- Buds should be alive, moist and evenly dispersed throughout the plant.
- Leaves should be characteristic for the species in size and color, be free of infectitious diseases and evenly distributed throughout the plant.
- Stems should be straight, single-leadered in most cases for trees, and free of large or multiple wounds and/or cankers.
- Roots should be alive, not broken, not encircled or j-rooted, and if the plants are balled-and-burlapped or containerized, roots should be at or near the surface of the soil ball.

Step Two: Transport the plants with care.

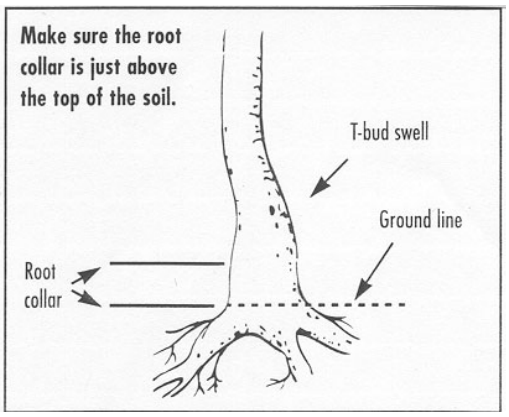
- Move, lift, load trees and shrubs with hooks, tree carts or front end loaders, if the plants cannot be easily lifted by hand. No dropping, plopping, dragging or rolling.

- Wrap the branches and foliage with plastic, burlap or paper before driving away from the nursery…no mater how close you live.

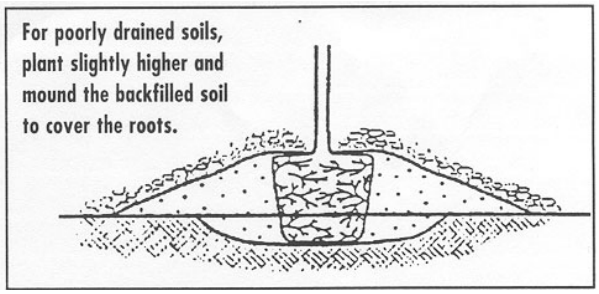
Step Three: Digging the hole, planting the tree (or shrub).

- For normal (not compacted, clayey soils), dig a saucer-shaped hole, 2-3 times the width of the soil ball or root spread (if bare-rooted). If the soils are compacted and clayey, dig the hole 5 times the width of the soil ball or root spread.

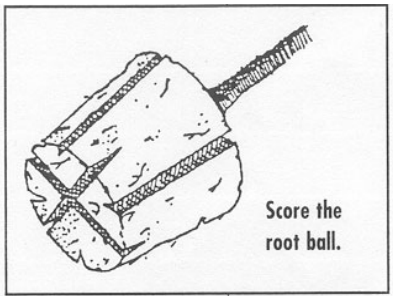
- The root collar flare should be at the soil surface. If not bare-rooted, determine the depth to the first branch roots by probing down into the soil ball with a stiff wire. Subtract that distance from the soil ball/container depth. This should be considered to be the deepest that the planting hole is dug.



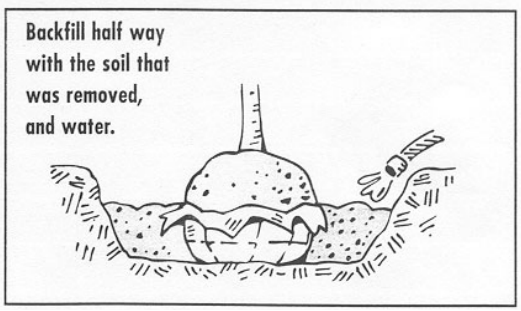
- Do Not Dig Deeper Than This Measurement! Don't dig deeper and then add loose soil to the bottom. First, roots will be growing horizontally out of the soil ball, not down. Second, that loose soil WILL settle, effectively planting the tree or shrub too deep.



- Remove trees and shrubs from their containers, root prune if necessary (3-4 vertical slices, going into the soil ball about 1 inch will cut through encircling, woody roots), and remove the soil over the root collar flare prior to planting…if the plant was growing in a container.



- With balled-and-burlapped (B&B) trees and shrubs, place the plant in the hole, backfill with the excavated soil to a point about 1/2 the height of the soil ball, remove all twine around the soil ball and stem, cut the wire basket back about 1/2 way (down to the back-filled soil line), roll back or cut off the burlap, and then remove any excess soil over the root collar flare.



Complete the backfilling operation along the sides of the soil ball… not on top of the root/soil balls. To gauge how deep the roots should be, take a walk in the woods and see how they are growing naturally…root collar flare and branch roots right at the soil surface.

- Water where the roots are…not where they will be in a few months. Use 1-1.5 gallons per inch of stem width at each watering. The frequency of watering will be determined by the weather, the size of your plant, the species of the plant, the drainage rate of the soil, and most importantly …….your finger. Stick it in the soil where the roots are. If it's getting dry, water it, no matter how soon or long ago the last irrigation took place. There is no magical formula for frequency.

- Mulch with 2-4 inches of coarse mulch, but don't pile it up against the stem.

- Stake only if necessary. If you do stake, place the attachments on the stem at a point from 1/3 to 2/3 the distance from the ground to the first set of branches. The attachments should be wide, a little loose, and rarely left on for more than one growing season.

- Prune broken and dead branches off, remove codominant (multiple) leaders to a single, straight leading branch, and remove all weakly attached branches. Remove the "prune out 1/3 of branches" myth from your memory…it has no scientific research to back it up.

RESOURCES

University of Minnesota Extension Service Publications

Master Gardeners receive many of these publications as a part of their training or Core Course. New publications are continually added to the Distribution Center. The most up-to-date listing is available online at http://www.extension.umn.edu. Click on Publications, or search the site for publications of interest. Many of these fact sheets can be read online and are also available from county extension offices. Longer publications or those containing many photographs or illustrations may not be available online. Master Gardeners should order publications through their home county extension office. Public orders may be placed by calling: 1-800-876-8636 (outstate) or 612-624-4900 (local).

MI 0776	Weed Seedling Identification
FO 0897	Selecting Preservative-Treated Wood (with Special Emphasis on Landscape Timbers)
MI 1349	Annual Broadleaf Weed Seedling Identification
MI 1350	Annual Broadleaf Weed Identification
MI 1351	Annual Grass and Perennial Weed Seedling Identification
MI 1352	Annual Grass and Perennial Weed Identification
BU 1357	Edible Wild Mushrooms
FO 2543	Lead in the Home Garden and Urban Soil Environment
MI 2664	Dial U Information Request
FS 2923	Preventing Pollution Problems from Lawn and Garden Fertilizers
FO 3238	Plants in Prairie Communities
FO 3296	Composting and Mulching: A Guide to Managing Organic Yard Wastes
MI 3733	Pesky Plants
MI 3821	Fertilizing Garden & Landscape Plants & Lawns
FS 3899	Backyard Composting
FS 3949	Home Yard Waste Chippers/Shredders: Safety Is Important!
MI 3951	Be a Master Gardener
FO 5553	Structures for Backyard Composting
FS 5570	Options for Disposing of Leaves
FO 5620	Identification of Primary Noxious Weeds of Minnesota
FO 5655	Plants Poisonous to Livestock
FS 5774	Characteristics of Natural & Manufactured Fertilizers for Lawns
FO 6709	Sustainability in Urban Ecosystems
FO 6757	Accessible Gardening for Therapeutic Horticulture
MI 6992	Minnesota Gardening Calendar

Videos of Minnesota Gardening TV Programs

These are 30-minute videos developed as a series of programs aired in the Twin Cities for the general public. They are available from the University of Minnesota Extension Service Distribution Center call 612-624-4900 (local) or 1-800-876-8636 (outstate).

VH 5981	Starting Seeds
VH 5987	Yard Waste
VH 5994	MN State Horticultural Society
VH 5999	Dried Flowers and Crafts
VH 6004	Andersen Horticultural Library
VH 6005	Minnesota Agricultural Experiment Stations
VH 6006	Tools
VH 6008	Climatology
VH 6014	Pesky Plants
VH 6015	Season Extenders
VH 6016	Minnesota Prairies
VH 6025	Gifts from the Garden
VH 6027	Horticulture Around the World
VH 6028	Como Park Conservatory
VH 6030	Contemporary Flower Arranging, Part I
VH 6031	Horticultural Therapy
VH 6032	Planting From Seeds

VH 6033 Contemporary Flower Arranging, Part II
VH 6244 Breeding Hardy Plants for Northern Climates
VH 6250 Garden Gadgets & Gifts
VH 6252 Cut Flowers: More than Roses
VH 6253 Garden Birds
VH 6260 Garden Photography
VH 6264 Growing and Using Herbs
VH 6461 The Therapeutic Nature of Gardening
VH 6469 Educational Programs at the Arboretum
VH 6627 Minnesota's Master Gardeners
VH 6639 Sustainability in Urban Ecosystems

Minnesota Extension Service Slide Sets
These vary in length and depth. All have a script and/or audio tape. These are also available from the University of Minnesota Extension Service Distribution Center call 612-624-4900 (local) or 1-800-876-8636 (outstate).
SS 4347 How to Start a Garden
SS 5628 Be a Master Gardener: Minnesota Master Gardener Pro gram

Other MES Resources
EX 5636 Minnesota Master Gardener Display

Yard and Garden Briefs
Controlling Quackgrass in Gardens
Gardening in Raised Beds
Coping with Deer in Home Landscapes
Dodder
Edible Flowers
Fertilizing Evergreens
Growing Luffa Gourds
Iron Chlorosis
Perennials for Moist Soils
Perennials for Season-Long Bloom
Preserving Gourds for Lasting Color
Saving Vegetable Seeds: Tomatoes, Peppers, Peas & Beans
Shade Tree Decline
Starting Seeds Indoors
Trees and Shrubs for Clay Soil
Using Dog and Cat Manure on Home Gardens
Your Fall Lawn and Garden Checklist

Other Resources
Hennepin Regional Poison Center Plant Guide
Some Common Questions About Backyard Composting
12 Important Soil and Garden Benefits from the Use of Compost and Mulches Derived from Organic Yard Wastes

chapter 2

soils

SOIL RESOURCES AND FERTILIZERS

by Harlan Finney, Former Extension Soil Scientist;
Carl Rosen, Extension Soil Scientist;
Peter Bierman, Soil Scientist - revised 2003

chapter 2

soils

TABLE OF CONTENTS

Introduction 2
Learning Objectives 2
Soil Basics 2
Soil Components 2
Soil Forming Factors 3
Finding Information on MN Soils 4
Soil Physical Properties 5
Mineral Soils (texture) 5
Organic Soils 6
Structure 6
Organic Matter 7
Color 8
Depth of Rooting 8
Bulk Density 8
Soil Water 9
Temperature 10
Modifying Soil Physical Properties 11
Tillage 11
Incorporating Organic Matter 12
Incorporating Mineral Matter 12
Modifying Drainage 12
Water Management 13
Mulching 13
Soil Biological Properties 14
Microorganisms 14
Macroorganisms 14
Modifying Soil Biological Properties 15
Soil Chemical Properties 15
Essential Plant Nutrients 15
Chemical Form of Plant Nutrients 16
Soil pH 16
How Soils Hold and Release Nutrients 18
Nutrient Sources 18
Nutrient Loss 19
Modifying Soil Chemical Properties 19
Soil Testing 19
Changing the pH 22
Fertilizers 23
Advantages and Disadvantages of Fertilizers 28
Fertilizing 29
Calculating Fertilizer Applications 32
Example Fertilizer Calculation 33
Application Methods 34
Application Timing 35
Assessing Nutrient Disorders 36
Primary Nutrients 36
Secondary Nutrients 36
Micronutrients 37
Special Problems 38
Damage by Fertilizer Salts 38
Damage by Road Salts 39
Lead 39
Resources 40

SOIL RESOURCES AND FERTILIZERS

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INTRODUCTION

This chapter begins by defining soil components, followed by a description of soil forming factors and a discussion of how to find information on soils in your area. Next, we describe soil physical, chemical, and biological properties and provide examples of how to modify these properties. The chapter ends with a discussion of special problems in managing soil. The examples in this chapter will help guide you in using soil resources wisely and managing soils for better gardens and lawns.

LEARNING OBJECTIVES

After completing this chapter you should be able to:

- describe how soils are formed
- explain the difference between soil texture and soil structure
- define the composition of an ideal garden soil
- explain the relationship between soil components: mineral particles, water, air, nutrients, and organic matter
- list the nutrients needed by plants, their sources, and the significance of nitrogen, phosphorus, and potassium to plants
- understand how to take a soil sample and interpret the results of a soil test
- define pH and its significance to plants and be able to describe how pH can be modified over a range of soils
- describe what fertilizer is, and how nutrients get into plants, and the factors that regulate their availability
- calculate how much fertilizer is needed to achieve the desired amount of nutrients per unit area
- access additional information sources and learn how to produce compost and use it to improve garden soils

SOIL BASICS

Soil scientists' define soil as "the unconsolidated material on the earth's surface that has been subjected to and influenced by the factors of climate, living organisms, and topography, all acting over a period of time on parent material (i.e., geologic sediments)." Even though soil is generally only a few feet thick, it serves as an anchor for plant roots and supplies plants with nutrients, water, and air -- all necessary for growth.

Soil Components

Soil is made of solids, liquids, and gases. Solids consist of both mineral (sand, silt, and clay) and organic matter (living and nonliving forms). Liquids (mostly water) and gases (more carbon dioxide and less oxygen than the atmosphere) fill the pores found between the solid particles.

Most soils have three major layers (see Figure 1):

1. the upper layer (also called the surface layer or topsoil)
2. the subsoil (found below the surface layer)
3. the lower layer (also called the substratum, which may be the same as the parent material from which the upper layers were formed)

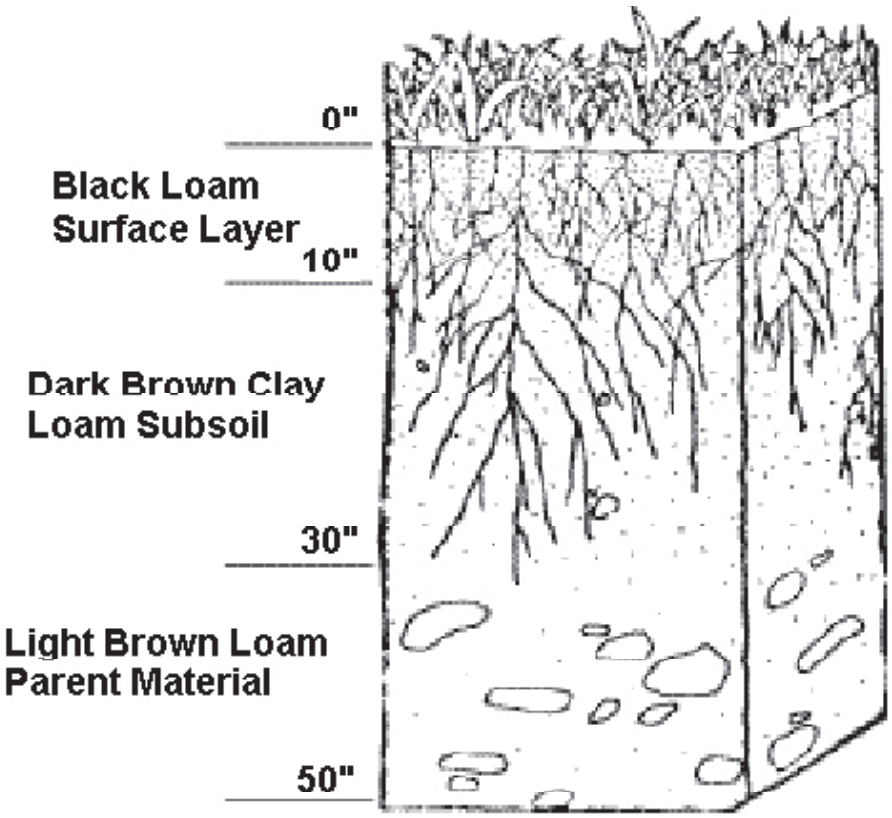


Figure 1. Schematic, three-dimensional drawing of a soil

FYI

The surface layer of a productive soil in an optimum condition for plant growth consists of about:

-50% solids
  45% mineral
  5% OM
-25% liquids
-25% gases

In Minnesota, the first two layers are commonly 2 to 5 feet thick.

Soil Forming Factors

The kind of soil at any given place results from the interaction of the following five soil forming factors. These five factors are what give Minnesota soils their unique characteristics.

Parent Material

Parent material is that material from which the soil is formed. Parent materials in Minnesota consist mostly of glacial sediments; sediments that differ greatly in texture and mineralogy. There are also significant areas of wind-transported sediments (loess) in southeastern and southwestern Minnesota, and alluvial sediments in stream valley floors. Old lake bottoms in western Minnesota have lacustrine sediments as parent material, and northeastern Minnesota's parent material is bedrock.

Vegetation/Living Organisms

Minnesota's native vegetation ranges from mid-grass prairie in the southwest to boreal forest in the northeast. Vegetation affects the amount and distribution of organic matter in the soil. Soils formed under prairies have a thick, fertile, organic-rich surface layer. Conversely, the surface layer formed under a forest is relatively thin.

Topography

Minnesota topography ranges from vast expanses of nearly level land to very steep slopes. Topography affects:

- the thickness of the surface layer and the subsoil --soils on slopes lose material by erosion and are thin, while soils in depressions collect sediments and are thick
- soil wetness -- soils on slopes are drier than soils on level topography or in depressions
- the rate of warming -- a soil surface with a north facing slope warms more slowly in the spring than a soil with a south facing slope

FYI

The Lester soil in Figure 1 formed from glacial till under a savannah (open forest with an understory of prairie plants). Its surface layer is intermediate in thickness compared to soils formed in prairie and soils formed in forest.

Climate
In Minnesota, precipitation decreases from the east to the west. This affects the depth of leaching of lime and other soluble constituents. Some soils in western MN have lime throughout, but lime has been leached to depths of 2 feet or more in most soils in eastern MN. Temperatures increase from north to south. Higher temperatures and precipitation increase weathering of parent material and the rate of soil formation.

Time
Minnesota soils are young in a geologic sense -- most glacial parent materials were deposited 10,000 to 20,000 years ago. Compared to other areas in the U.S., our soils are nutrient-rich and only slightly weathered.

Finding Information on MN Soils

While this chapter provides a general overview of properties of Minnesota's soils, you will need to become knowledgeable about soils in your area. You can do this by obtaining a Soil Survey report, by digging a hole, and/or getting a soil test.

County Soil Survey Reports
Soil surveys have been completed and published for most Minnesota counties. A copy of your county soil survey can be obtained at the county office of the University of Minnesota Extension Service or the Soil and Water Conservation District. Copies are also available from your local library. Each soil survey report has:

- descriptions of the different soil types found in the county
- text and tables about soil properties and how those properties affect major land uses
- maps showing the location of different soils

The soil maps will indicate dominant soils and soil texture in a given area. However, because the scale precludes showing small areas of given soils, and because considerable alteration of soils and parent materials commonly occurs during housing construction, the soil survey report does not give any information on the suitability of specific areas of soil in your yard for gardening.

FYI

Soil series are named after some geographic entity in the area where it was first identified. For example, the Nicollet series, which is a very productive loamy soil that formed under prairie in southern Minnesota, was named after the village of Nicollet.

Dig a Hole
You can make important inferences about the suitability of soil for plants by digging a hole (at least two feet deep) and examining the soil's texture, color, compaction, water table, and presence of lime. For example:

- If the surface layer is difficult to dig, even when moist, the soil may have compacted layers (high bulk density). Compacted layers also break into fragments with angular edges or platy shapes when removed.
- If you leave the hole open during wet periods and water seeps into the hole from the sides and remains in the hole for several days, after the wet period ends, the soil probably has a drainage problem.
- If gas evolves from the soil when treated with muriatic acid, lime is present in the soil (pH is at least 7.8).

Get a Soil Test
A soil test provides information on your soil’s nutrient status and helps you determine whether or not your soil needs nutrients or amendments. Detailed information on how to conduct and interpret a soil test is found later in this chapter.

SOIL PHYSICAL PROPERTIES

Physical properties often determine the soil's suitability for a given use as well as its management for that use. Soil scientists often use sophisticated equipment to accurately measure physical properties. However, with practice you can make reasonable estimates of physical properties by using your senses of sight and touch.

Mineral Soils (>80% mineral material)

Soils can be classified as mineral or organic. Mineral soils have greater than 80% mineral particles -- sand, silt, and clay. Mineral soils are classified based on their texture.

Soil Texture

Soil texture refers to the size and distribution of sand, silt, and clay (mineral particles) in a soil or mix (see Table 1).

Table 1. Names, sizes, and visibility of mineral soil particles

Names	Size (mm*)	Visibility
Sand	2.0 - 0.05	Without magnification
Silt	0.05 - 0.002	10x - 100x magnification
Clay	< 0.002	> 100x magnification

*25.4 mm equal 1 inch

Soil texture affects soil functions and behavior including:

- soil water (infiltration and percolation rates, and available water capacity)
- soil structure
- nutrient holding capacity
- ease of cultivation

Very few soils consist entirely of one particle size. Rather, most soils consist of a mixture of two or usually all three sizes of particles. Figure 2 summarizes the names assigned to various combinations of sand, silt, and clay particles. A description of the soil categories follows.

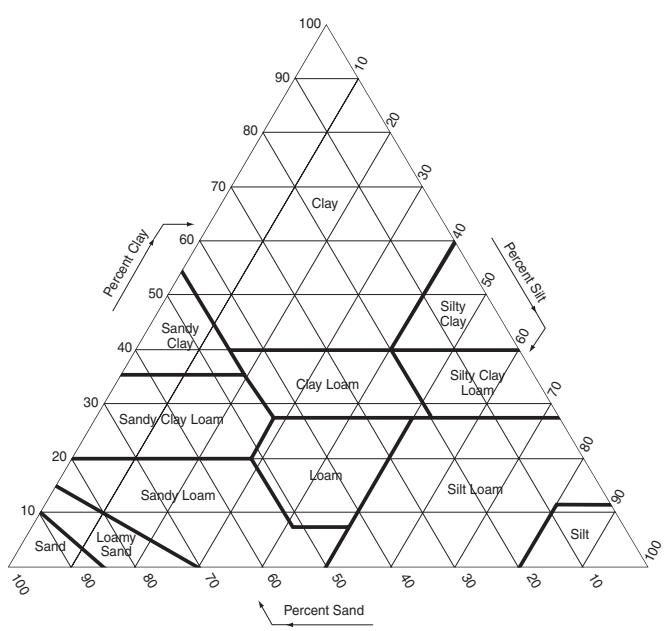


Figure 2. The Soil Texture Triangle

How to use the texture triangle

Given: a soil with 40% sand, 40% silt, and 20% clay

Follow the line of 40% silt downward (sloped down and to the left) until it intersects the 20% clay line (extending left and right) and the 40% sand line (sloped up and to the left). This soil is a "loam."

FYI

Loamy and clayey soils commonly have granular aggregation in the surface layer and blocky or prismatic peds in the subsoil.

Sandy soils that are low in organic matter may lack structure.

Common Myth

"Clay and sand are the most common textures in the surface layer of Minnesota soils."

Loam is the dominant texture in Minnesota's surface layers followed by clay loam, silt loam, silty clay loam, sandy loam, and muck. Clay is common only in the western counties that border the Red River.

Sandy or coarse texture

Coarse textured soils typically have low water holding capacity, excessive drainage, and are low in nutrients, especially nitrogen and potassium.

Sand and loamy sand

These soils are dominated by individual particles that can be seen without magnification. The particles feel gritty. When squeezed, a moist mass will form a cast, however, the cast will crumble when touched. Subclasses, based on the dominant size of the sand particles, include coarse sand and loamy fine sand.

Sandy loam

These soils have enough silt and clay to be slightly coherent. Sand grains are dominant and can be readily seen and felt. When squeezed, a moist mass will form a cast that will bear careful handling without breaking. Subclasses, based on the dominant size of the sand particles, include coarse sandy loam and fine sandy loam.

Loamy or medium texture

Medium textured soils typically have good drainage and nearly ideal water holding capacity.

Loam

These soils have a slight gritty feel and some sand is visible. When squeezed, a moist mass will form a cast that can be handled freely without breaking.

Silt loam

When a dry mass of these soils is pulverized, it will feel soft and floury. When squeezed, a moist mass will form a cast that can be readily handled without breaking.

Clayey or fine-texture

Fine textured soils may have poor drainage and are difficult to manage when wet.

Clay loam and silty clay loam

When squeezed, a moist mass of these soils will form a cast that will bear much handling, and forms a ribbon when squeezed between the thumb and forefinger. Sand grains can be felt in a clay loam, but not in a silty clay loam.

Sandy clay and silty clay

These soil textures are uncommon in Minnesota. Sandy clays have more sand and less silt than clay soils. Silty clays have more silt and less sand than clay soils.

Clay

When dry, these soils feel hard. When squeezed, a moist mass will form a durable cast, and forms a flexible ribbon when squeezed between the thumb and forefinger.

Organic Soils (>20% Organic Matter)

In contrast to mineral soils, organic soils have much smaller proportions of sand, silt, or clay. These soils are light in weight and dark in color. The types of organic soils (called peats and mucks) are based on the degree of decomposition of the organic fraction. While a muck has few or no visible remains of plant tissues, a peat is dominated by visible remains of plant tissues, and a peaty muck is intermediate. Organic soils typically have drainage problems, are low in phosphorus and potassium, high in nitrogen, and slow to warm up in the spring.

Soil Structure

Soil structure refers to the arrangement of soil particles (sand, silt, and clay) into groups called peds or aggregates. Soil structure is created when microbial gums, iron oxides, organic matter, and clay bind soil particles together. Soil scientists define structure in terms of the shape, size, and strength of aggregates.

Structure is a dynamic property that can be altered through management, such as plowing, rototilling, or adding organic matter. Well-developed structure enhances soil-plant relationships and affects the:

- exchange of soil air with the atmosphere
- rate of water movement through the soil
- size and amount of pore space
- amount of water a soil can hold
- ease with which plants extend their roots

At times, a phenomenon called crusting occurs on bare soils. Crusts are created when the impact of raindrops destroys the structure in the surface layer. Under these circumstances, the clay particles and organic matter that bind aggregates are washed away. Soils low in organic matter are most subject to crusting. Crusts may nearly stop the exchange of air between the soil and the atmosphere, impede water infiltration, and inhibit emergence of seedlings.

Organic Matter

The content of organic matter in soil is dynamic, consisting of the remains of plants and animals (including microorganisms). For example, bacteria, fungi, insects, and earthworms use fresh organic matter as food. Their digestive process converts fresh organic matter into humus and releases plant nutrients (also called decomposition). The digestive process converts otherwise unavailable nutrients in fresh organic matter to plant usable forms.

FYI

Humus is the remains of decayed animals and plants that have become part of the soil. It is resistant to further degradation.

Organic matter consists of simple compounds (sugars and starches) to very complex organic chemical compounds (long-chain carbohydrates and lignins consisting of many atoms). Living organisms are also considered to be part of soil organic matter.

Organic matter:

- enhances development of soil aggregates
- increases pore space
- increases infiltration and percolation rates in clay soils
- increases water holding capacity of sandy soils
- has high capacity to hold and release nutrients
- contains plant nutrients
- improves ease of cultivation
- promotes biological activity

Table 2 describes terms and values for conveying information about organic matter.

Table 2. Percent organic matter interpretations

Relative Level	Amount - % (based on wt of oven dry soil))
Mineral soil	
Low	< 3
Moderate	3 – 5
High	5 – 10
Very high	10 – 20
Organic soil	> 20

Color

FYI

The surface layer color directly affects a soil's temperature regime (i.e. changes in temperature by depth throughout the year), and this, in turn, affects plant growth.

Organic matter gives darkness to the color of the surface layer. Black surface layers generally have more than 5% organic matter. Progressively lighter colored surface layers have less and less organic matter. However, the amount of organic matter required to darken soil color depends on texture (e.g. more organic matter is required to change the color of a clayey soil than a loamy soil, and more is required for a loamy soil than a sandy soil). This is because finer textured soils have more surface area and require more organic matter to produce a change.

Because color is influenced by soil water content, soil scientists always note the content of water -- dry, moist, or wet -- when describing soil color (quantified through a standard chart). Often, wet soils will contain two or more colors within a layer. When this occurs, the soil layer is described as mottled.

Color affects the capacity of a soil to absorb energy from the sun. A black soil surface warms faster than a gray soil surface. Likewise, a gray soil surface warms quicker than a light tan surface.

Depth of Rooting Zone

Soil depth refers to the amount of soil plants can extend their roots through for support and obtaining water and nutrients. Depth is a measure of the vertical distance from the surface layer to a restrictive layer (e.g. hard bedrock, sand, gravel, and a layer with firm consistence and lack of structure). Depth classes include:

- very shallow (<10")
- shallow (10-20")
- moderately deep (20-40")
- deep (>40")

Bulk Density

FYI

Roots and tubers generally grow better in soils with low bulk density than in soils with high bulk density.

Bulk density is the weight (or mass) of a unit volume of soil. Thus, it is a measure of both the weight of the solid particles and how closely they are packed together. Conversely, it is also a relative measure of pore space. Bulk density varies greatly both within a single soil and among different soils. Because of this variability, soil scientists have not defined terms and values for this property in as detailed a way as they have for many other properties (see Table 3).

Table 3. Examples of typical bulk densities

Layer	Bulk Density* (grams/cubic centimeter)
Typical loamy mineral soil	
Well managed surface layer	0.9 1.2
Compacted surface layer	1.2 - 1.8
Well-managed subsoil	1.3 - 1.6
Compacted subsoil	1.6 - 2.1
Typical sandy surface layer	1.5 - 1.7
Typical mulch surface layer	0.2 - 0.4

***Bulk density is reported on the basis of oven-dry soil. A cubic centimeter of water weighs 1 gram. A cubic foot of water weighs about 62 pounds. A cubic foot of oven-dry soil with a bulk density of 1.5 grams/cubic centimeters would weigh 93 pounds (1.5x62).**

Bulk density directly affects plant growth because it influences the amount of air and water available for plants. Soils with high bulk density have less pore space for air and water than do soils with low bulk density. Bulk density of the surface and subsoil layers can be dramatically influenced by how we manage and manipulate the soil.

Soil Water

What is the most important component that determines the growth of plants in the soil? Many things affect growth, but no growth of plants can occur without water.

Field Capacity and Wilting Point

Field capacity water content occurs when all of the gravitational water (i.e. that water that exists in very large soil pores) has drained. Field capacity is made of tightly held water (water that cannot be removed by plants) and more loosely held, plant-available water. Wilting point describes the amount of water in the soil when plants begin to wilt. At wilting point, the only water remaining in the root zone is tightly held water. Many plants will also wilt when the soil is saturated and no oxygen is available to the roots.

Available Water Capacity

Available water capacity (AWC) is the amount of water soil can hold for plant use. Water available to plants is that between field capacity and wilting point. AWC is reported on a volume basis, such as inches of AWC for some thickness of soil (see Table 4).

Table 4. Available water capacity (inches of water)

AWC	Per 1" of soil	Per 1' of soil
Low	< 0.10	< 1.2
Moderate	0.10 - 0.15	1.2 - 1.8
High	> 0.15	> 1.8

FYI

AWC is one of the most important soil properties affecting plant growth. It determines how soon plants begin to wilt after rainfall or watering.

Soils with low bulk density have higher AWC than do soils with high bulk density, because low bulk density soils have larger pore spaces. Textures with large amounts of silt or very fine sand have the highest AWC. Clayey soils hold the largest amounts of water, however, they have less AWC than do loamy textures because they have many small pore spaces that hold water very tightly. Sandy textures have the lowest AWC because they have very large pores that drain rapidly. Organic matter holds more water than mineral matter. Thus, soils high in organic matter have higher AWC than soils low in organic matter.

Infiltration, Percolation, Drainage, and Runoff

Infiltration and percolation are the rates at which water moves into and through the soil. Infiltration and percolation are described as:

- slow (< 0.4 - 0.6 inches per hour)
- moderate (0.4 - 2.0 inches per hour)
- rapid (> 1.75 inches per hour)

In general, soils on level terrain have more infiltration and percolation than those on sloped terrain. Runoff occurs when water inputs exceed the infiltraiton capacity of the soil. Intense rainfall (o r over-irrigation) enhances runoff rather than infiltration and percolation. A continuous cover of vegetation promotes infiltration and percolation, because it reduces crusting by softening the impact of raindrops and lessens runoff by holding water and giving it more time to soak in.

FYI

The rate of percolation affects an important gardening activity: how soon we can safely till a soil after it rains.

Surface layers consisting of sandy textures or strongly developed aggregates have larger pores and, therefore, more infiltration and percolation than those with clayey texture or no aggregates. Soils that are dry or moist have more infiltration and percolation than wet soils because pores are open in the former and filled in the latter.

Soil drainage refers to the frequency and duration of saturation, and the depth to a saturated layer or water table (or the lack of such a layer). Often, subsoil color reflects the presence or absence of a saturated zone. Well-drained soils have brown or reddish brown subsoils (due to oxidized iron compounds). Poorly drained soils have gray subsoils (due to reduced iron compounds).

Temperature

Soil temperature regime refers to changes in temperature (by depth) throughout the year. A surface layer has much greater fluctuation in temperature than does the next lower layer. This trend continues to a depth of 4 feet at which point the temperature becomes fairly uniform throughout the year. Water requires more energy to warm than the soil mineral fraction (sand, silt, clay). Thus, drier soil warms quicker than a wet surface layer.

Mean annual soil temperature is generally about 1-2° F warmer than mean annual air temperature. However, in the spring, the average daily temperature of the surface soil is lower than the average daily air temperature. This is because more heat is needed to warm soil than to warm air. This trend is reversed in the autumn because soil retains heat longer than air.

The time it takes for soil to warm enough for seeds to germinate and extend their roots is important. Further, we can manage soils in ways that dramatically enhance soil temperature for desired plant growth. Modifying soil temperature is discussed in the next section.

FYI

Root growth and seed germination of many plants in Minnesota ceases when soil temperature cools to about 42° F (often referred to as "biological zero"). Each plant species has its own biological zero (e.g. biological zero may be 75° F for some tropical plants).

MODIFYING SOIL PHYSICAL PROPERTIES

While most soils do not exhibit every ideal physical property, those soils that have physical properties most conducive to plant growth can be considered near ideal. Table 5 describes physical properties of an ideal soil. Minnesota has a wide range of physical soil properties and you will rarely find an "ideal" soil in nature.

After you have gathered information about your soil, compare it to the properties in Table 5. Decide which properties need to be improved and the feasibility of improvement. Methods of improvement include tilling the soil, incorporating organic or mineral matter, modifying drainage, managing water inputs, and mulching.

Table 5. Ideal soil physical properties

Physical Property	Property of an Ideal Soil
Texture	Loamy, preferably loam or silt loam and, in many cases, sandy loam for vegetables
Color	Black surface, brown subsoil
Structure	Well-developed granular or crumb surface, well-developed blocky subsoil
Depth	Deep
Bulk Density	Not compacted
Water	
Infiltration	Moderate or high
Percolation	Moderate
AWC	High
Drainage	Well-drained
Temperature	Warms early

Tillage

Tillage will:

- loosen compacted soil
- increase pore space for improved air exchange between the soil and the atmosphere
- increase rates of infiltration and percolation
- increase AWC
- permit easier expansion and elongation of roots, bulbs, and tubers
- break soil crusts
- kill weeds
- break larger aggregates into finer aggregates (making better contact between the soil and seeds or transplant roots)

To help root growth for several years, till (loosen) compacted soil around perennial plants in an area at least as large as the plant's root zone at maturity. Mix in some organic matter when loosening the soil. You want the soil to have small aggregates for better contact with seeds and transplants, but do this more intensive tillage only in a narrow zone along the rows and around transplants.

FYI

Excessive cultivation encourages decomposition and, thus, loss of organic matter. Conversely, we can easily increase the content of organic matter by adding compost. However, to maintain higher levels of organic matter by this method, compost must be added frequently -- at least every year.

Compaction in lawns can be lessened by using an aerator. Make sure to use an aerator that removes a cylinder of soil as those that only puncture the soil with tines actually cause more compaction. Also, do not mow when the soil is wet and change the direction of mowing by a few degrees each time you mow so that you aren't always walking down the same pathways.

During home construction, heavy excavation equipment compacts a wet soil to a depth of up to two feet. While freezing and thawing may reduce compaction in the upper few inches of soil, compaction below that depth persists for many decades. Also, a lack of adequate compaction may be a problem in a zone as much as 4 feet wide around the foundation. Here, the soil may settle for several years before reaching equilibrium and may settle enough for water to pond next to the foundation. After construction, foot and vehicle traffic also causes compaction on wet soils.

Two properties are improved in the process of soil mixing. First, the soil is loosened -- decreasing bulk density and increasing pore space. This allows more space for air and water. Second, openings are made in the soil surface -- improving water infiltration and decreasing runoff. Such openings promote the exchange of soil air with the atmosphere.

FYI

Excessive tillage can weaken or destroy aggregates, promote crusting, cause loss of organic matter, and enhance germination of weed seeds. Tillage should not take place if the soil is wet enough to adhere to tools or footwear.

Incorporating Organic Matter

Adding organic matter will improve soil structure and reduce compaction. For best results, organic matter (e.g. compost, grass clippings, leaves, manures, sawdust, and straw) should be thoroughly mixed throughout the root zone. Adequate moisture, warm temperature, and ample nutrients enhance the conversion of these materials to humus and plant available nutrients by soil microorganisms. One of the best sources of organic matter that a gardener can add is compost. Two good sources of information on how to make compost in your backyard and use it to improve your garden soil are Extension Bulletin FO 3296 "Composting and Mulching,"and a newly released Extension CD-ROM "Backyard Composting." See the resource section at the end of this chapter for availability.

FYI

It is important not to tread on a garden when soil adheres to footwear or to tread on a lawn when water readily appears in your footprints. These are the main causes of compaction other than those caused by construction.

Incorporating Mineral Matter

If you do decide to add soil (e.g. sandy soil to a clayey soil or a truck load of "black dirt"), be sure to mix it thoroughly with your "native" soil throughout the root zone. If not properly mixed, you may create a restrictive zone between the two layers -- a zone that impedes root growth and water movement. In some clayey soils adding sand can cause them to "set up" similar to concrete.

In many cases, improving the physical properties of your "native" soil by other means would be more cost effective. Adding organic matter improves soil structure while incorporating mineral matter changes soil texture. Organic matter amendments are generally far more effective and economical than incorporating mineral matter.

Modifying Drainage

Under severe conditions, ditches and drain tile are an effective means of lowering the water table or eliminating a saturated zone. Alternatively, constructing a raised bed or mound increases the thickness of soil above the waterlogged zone. Adding organic matter, tilling, or both, increases both pore size and number. Thus, organic matter and tilling, or both will enhance infiltration of water and increase the movement of water through the soil. However, neither one lowers a water table or eliminates a zone saturated with water.

Water Management

Any practice (or natural process) that allows water to leave the yard -- laterally or vertically -- with excess nutrients or soil particles is not environmentally sound. This is because the water contains dissolved nutrients and sediments that can degrade water quality.

Do

- manage the soil so it has a moderate or high infiltration rate
- minimize the amount of water that runs off
- apply only needed nutrients
- use drip hoses for watering trees, shrubs, and flower and vegetable beds

Don't

- apply water when the weather forecast indicates rain in the next few days
- apply more water than is needed by the plants

Consider

- the soil's AWC
- the weather
- whether the plants are showing moisture stress
- depth to root zone (and any restricted layers)

In general, sandy soil needs to be watered more frequently and with lesser amounts per watering than do loamy and clayey soils.

Mulching

Mulching refers to the practice of applying a layer of material to the soil surface. Organic matter makes a good mulch and will:

- suppress weeds
- conserve soil moisture
- reduce soil erosion
- reduce loss of water
- reduce fluctuation of soil temperature
- keep soil temperature higher in the winter or lower in the summer
- promote biological activity, especially microorganisms and earth worms

It is important that the soil is sufficiently warmed for optimum plant growth before applying mulch because organic mulch slows soil warming. For plants that like to have "cool roots," apply the mulch early and for plants that like "hot roots," apply it later.

Organic matter is gradually added to the soil as the mulch decomposes. For annual gardens, mulch can be worked into the soil at the end of the season to further improve the soil. For perennials, it may be beneficial to remove the mulch in the spring to allow the soil to thaw out faster. Different mulches include:

- partially decomposed compost
- shredded leaves
- grass clippings
- pine needles
- wood chips and shredded bark
- sawdust
- straw
- landscape fabric
- newspaper
- cocoa bean hulls
- black or clear plastic
- stone or gravel

Common Myth

"During dry periods, applying 1" of water every 5 to 7 days is adequate."

The amount and timing of watering depends on the kind of soil and plants. For example, for shallow-rooted plants on a coarse-textured soil, applying 1/2" every 3-4 days would be adequate. Applying 1" to such a soil would waste water because some water would move beyond the shallow root zone. Also, because the soil is coarse-texture, not enough water could be held in the root zone to maintain the health of the plants for 5-7 days.

FYI

Leaves, straw, and sawdust have a wide carbon-to-nitrogen ratio. Thus, the amount of nitrogen used by the microorganisms in decomposing them may leave insufficient nitrogen for your plants. This can be avoided by mixing some high-nitrogen fertilizer with such materials.

SOIL BIOLOGICAL PROPERTIES

Living organisms may be divided into two classes: microorganisms --ones that cannot be seen without magnification, and macroorganisms --ones that can be seen without magnification.

Microorganisms

The five kinds of soil microorganisms are, in order of decreasing abundance:

1. bacteria
2. fungi
3. actinomycetes
4. protozoa
5. algae

Soil microorganisms:

- decompose organic matter and release nutrients in available forms
- transform organic matter and assimilate nutrients
- fix nitrogen from the air into biological forms
- reduce nitrate nitrogen to a gas (denitrification)
- oxidize ammonium-N to nitrate-N (nitrification)
- oxidize sulfur to plant available sulfate
- synthesize organic matter by photosynthesis (algae only)

FYI

Up to 30,000,000,000 bacteria may live in one ounce of soil; soil that is well supplied with plant nutrients and organic matter.

Macroorganisms

Three groups of common macroorganisms are listed below along with their roles as consumers of organic matter and or mixers of soil.

Nonarthropods

- earthworms - consumers and mixers
- nematodes - herbivore and carnivore consumers, some are parasitic

Arthropods

- ants - consumers and mixers
- centipedes - carnivorous consumers
- grubs - consumers (of roots)
- millipedes - vegetarian consumers
- mites - vegetarian and carnivorous consumers
- springtails - consumers

Vertebrates

- mice, voles, moles - consumers and mixers
- rabbits, squirrels - consumers
- foxes, badgers, bears - consumers and mixers
- deer - consumers
- birds - consumers

FYI

In any one acre, the upper 6" of a loam soil high in organic matter content may have as many as 7,000 earthworms, 1,000,000,000 nematodes, and 5,000,000 ants.

MODIFYING SOIL BIOLOGICAL PROPERTIES

Managing soils as we describe in this chapter will insure an abundant population of microorganisms. However, if you grow legumes (e.g. beans, peas, clover), be sure your soil has nitrogen fixing bacteria. To determine that, gently remove a mature legume plant from the soil. Look closely at the roots for nodules. Nodules are tan colored, globular shaped, and 0.05 to 0.15 inches in size. If plants have no nodules, apply a culture of nitrogen fixing bacteria to the seeds or to the soil in the bottom of the row at the next planting. A culture of such bacteria can be purchased at a garden store or from seed and plant companies. Table 6 describes biological properties of an ideal soil.

Table 6. Ideal soil biological properties

Biological Properties	Properties of the Ideal Soil
Microorganisms	In numbers and kind sufficient to convert plant debris to humus and available nutrients, fix nitrogen, and help suppress disease organisms
Macroorganisms	In numbers sufficient to assist in conversion of plant debris and mixing and loosening soil

SOIL CHEMICAL PROPERTIES

While most physical properties are not easily altered, chemical properties can be easily altered with amendments such as lime and fertilizer. Sophisticated equipment is often used to measure chemical properties, however, you can make inferences about many chemical properties simply from the way plants grow.

Essential Plant Nutrients

The chemicals or elements needed for plant growth are called essential plant nutrients. Plant nutrients are not plant food -- plants manufacture their own food through photosynthesis. Nutrients can become components of the food manufactured by plants. For example, plants use carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur in building proteins, and use other nutrients as catalysts in life processes.

There are 16 essential nutrients needed for normal plant growth (see Table 7). Four of the essential nutrients -- carbon, hydrogen, oxygen, and nitrogen -- comprise 95% of plant solids. While carbon, hydrogen, and oxygen come from the air and water, nitrogen -- which comprises 78% of the atmosphere -- is unavailable to plants in that form. However, certain bacteria in the soil convert gaseous nitrogen into a form available to plants.The other 12 essential nutrients include boron, calcium, chlorine, copper, iron, manganese, magnesium, molybdenum, phosphorus, potassium, sulfur, and zinc. Plants obtain these 12 elements (along with nitrogen) from the soil.

Nitrogen, phosphorus, and potassium are considered primary macronutrients because plants use more of them than other nutrients. Calcium, magnesium, and sulfur are secondary macronutrients and are in ample supply in many Minnesota soils. Micronutrients are important, but are necessary in smaller amounts.

FYI

In Minnesota soils, nitrogen, phosphorus and potassium may be deficient. With a few exceptions, Minnesota soils have enough of the other nutrients for satisfactory plant growth.

Chemical Form of Plant Nutrients

Nutrients can only be utilized by plants when they are in certain forms (see Table 8). Each of these forms, called, ions, has an electrical charge. Positive ions are called cations and negative ions are called anions. Nutrients in forms other than those listed in Table 8 must be converted to usable forms by chemical or biological processes. For example, rock phosphate and bone meal contain phosphorus, but not in a form available to plants. It must first be converted to one of the orthophosphate ions -- a conversion that occurs very slowly. Likewise, manure, sewage sludge, and compost have compounds containing nitrogen, however, most of the nitrogen in these compounds must be converted to either the nitrate ion or the ammonium ion before it can be utilized by plants.

Table 7. Plant nutrient categories

	Nutrient Elements	
Groups	**Name**	**Chemical Symbol**
Derived from air and water	Carbon	C
	Hydrogen	H
	Oxygen	O
Derived from soil		
Macronutrients		
Primary	Nitrogen	N
	Phosphorus	P
	Potassium	K
Secondary	Calcium	Ca
	Magnesium	Mg
	Sulfur	S
Micronutrients	Boron	B
	Chlorine	Cl
	Copper	Cu
	Iron	Fe
	Manganese	Mn
	Molybdenum	Mo
	Zinc	Zn

Table 8. Macronutrient forms

Nutrient	Ionic Name	Symbol
Primary		
Nitrogen – N	Ammonium	NH_4^+
	Nitrate	NO_3^-
Potassium – K	Potassium	K+
Phosphorus - P	Orthophosphates	$H_2PO_4^-$, HPO_4^{2-}
Secondary		
Calcium – Ca	Calcium	Ca^{2+}
Magnesium – Mg	Magnesium	Mg^{2+}
Sulfur - S	Sulfate	SO_4^{2-}

Soil (pH)

Soil reaction (pH) is the degree of acidity or alkalinity of soils (see Table 9). It is a measure of the concentration of hydrogen ions (H+). Where the amounts of hydrogen and hydroxyl ions (OH-) are equal, the pH is 7. A pH of less than 7 is acid and has more hydrogen than hydroxyl ions. A pH greater than 7 is alkaline and has less hydrogen than hydroxyl ions.

Table 9. Soil pH values

Reaction	pH
Extremely acid	< 4.5
Strongly acid	4.5 - 5.5
Moderately acid	5.6 - 6.0
Slightly acid	6.1 - 6.5
Neutral	6.6 - 7.3
Mildly alkaline	7.4 - 7.8
Moderately alkaline	7.9 - 8.4
Strongly alkaline	> 8.5

FYI

Check for the presence of lime with a weak solution of muriatic (hydrochloric) acid. If lime is present, bubbles of gas will form.

Most garden and landscape plants grow best in soils with a pH range of 5.5 to 7.0, the range where most nutrients have optimum availability (see Figure 3). However, some plants can grow in soils with a pH as low as 3.5 and as high as 10.0. Further, some plants have optimum growth at soil pH values that are more or less than the general optimum range. For example, the optimum range of soil pH for blueberries (an acid-loving plant) is 4.5 to 5.2.

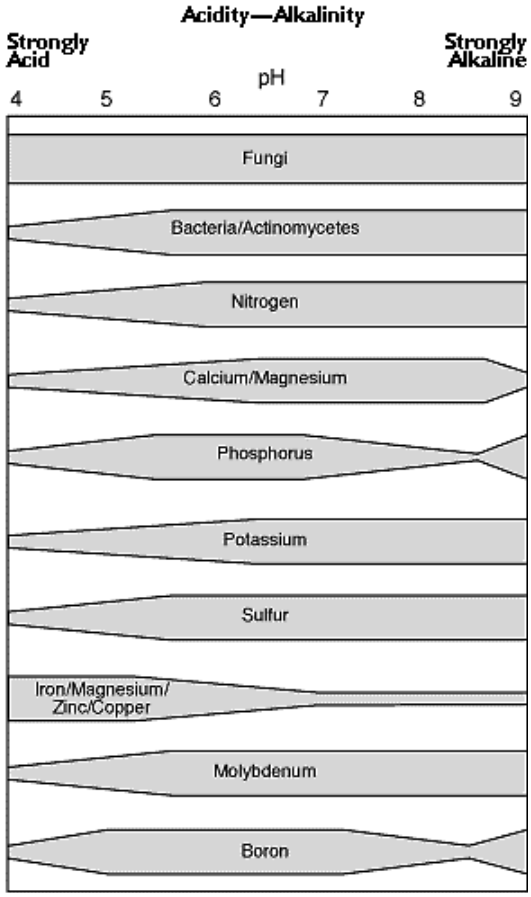


Figure 3. The influence of soil pH on the availability of plant nutrients.

FYI

The scale to measure pH is logarithmic rather than linear. Thus, a soil with a pH of 8.5 is ten times more alkaline than a soil with a pH of 7.5. Conversely, a soil with a pH of 4.5 is 10 times more acid than a soil with a pH of 5.5 and 100 times more acid than a soil with pH of 6.5.

Soil pH affects the solubility of plant-toxic minerals -- manganese and aluminum concentrate at toxic levels in some strongly acid soils. Soil pH also affects microbial activity -- many of the bacteria that fix nitrogen in association with legumes are inhibited as the pH falls below 5.7.

Many of Minnesota's soils have significant amounts of lime in the parent material. Lime causes special problems when trying to acidify the soil for acid-loving plants and, when near the surface, decreases the availability of phosphorus.

How Soils Hold and Release Nutrients

FYI

Because Minnesota's soils have insignificant anion exchange capacity, the nitrate anion is subject to leaching (removal by water percolating through the soil). Phosphate anions, on the other hand, are chemically fixed or precipitated in a nearly insoluble state and, therefore, are not subject to leaching in most soils

Clay minerals, organic matter, and plant nutrients in ionic form have electrical charges (see Table 8). In general, clay minerals and organic matter have slightly negative charges. Thus, cations such as potassium can be held at negatively-charged sites on clay minerals and organic matter (see Figure 4).The amount of positively charged ions that a soil can hold onto is called the "cation exchange capacity" or CEC. The higher the clay and organic matter content, the higher the CEC will be.

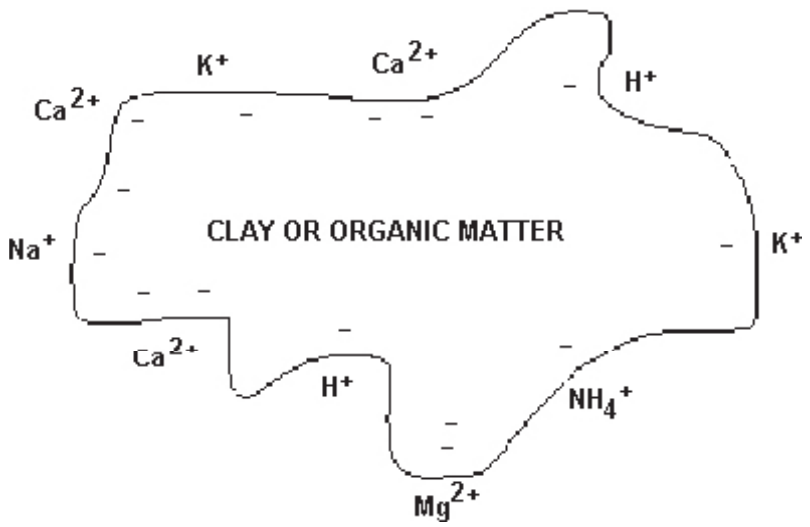


Figure 4. Greatly enlarged very small volume of soil showing ions of primary nutrients in soil water attached to a clay mineral or organic matter particle.

Common Myth

"Moss indicates an acid soil."

Moss commonly indicates a wet or shady condition and/or low fertility.

Plants mainly absorb nutrients from the soil solution, but nutrients on exchange sites are a reserve supply that can replenish the soil solution. When this happens, the charged sites on clay minerals or organic matter are satisfied by other ions. For example, when a potassium ion is absorbed by the root of a plant, the negatively charged site could be satisfied by a hydrogen ion (H+) from water. This process is called ion exchange and, more specifically, cation exchange when a cation is involved and anion exchange when an anion is involved.

The CEC of loamy and clayey soils is sufficient to hold and release more than enough plant nutrients in cation form for vigorous plant growth. Only sandy soils with little or no clay and organic matter have an inadequate capacity to hold sufficient cation nutrients. Soils in Minnesota do not have significant anion exchange capacity.

Nutrient Sources

Nutrients may become available to plants through many sources including:

- ion exchange sites of clay minerals and organic matter
- the weathering of minerals
- decomposition of plant residues and soil organic matter
- chemical transformations by soil bacteria including:
  - nitrogen gas to the ammonium ion within legumes
  - conversion of ammonium to the nitrate ion by free-living bacteria
  - elemental sulfur to the sulfate ion
- fertilizer supplements, both organic and mineral
- N_2 converted to NO_3 by lightning -- about 10 lbs/acre/year in MN

Nutrient Loss

Nutrients can be lost from the soil by:

- flowing away in runoff water
- being carried away on soil particles eroded from the soil surface
- movement of water that contains dissolved minerals through soil (leaching)
- removal of harvested plant products
- gaseous losses of nitrogen

The quality of surface and groundwater resources can be adversely affected by nutrients lost from the soil. Phosphorus and nitrogen in runoff water and eroded sediments can enhance algal blooms in lakes and streams. Also, eroded sediments cause turbidity in lakes and streams which, in turn, reduce biological productivity. Nutrients lost by leaching, especially nitrogen in the nitrate form, contaminate groundwater. Nitrate-N concentrations in drinking water greater than 10 ppm are considered to be a health hazard.

Because Minnesota's soils have insignificant anion exchange capacity, the nitrate anion is subject to leaching (removal by water percolating through the soil). Phosphate anions, on the other hand, are chemically fixed or precipitated in a nearly insoluble state and, therefore, are not subject to leaching in most soils. However, dissolved organically bound phosphorus, and sediment bound phosphorus, are readily subject to being carried away in runoff.

MODIFYING SOIL CHEMICAL PROPERTIES

While most soils do not exhibit every ideal chemical property, those soils that have properties most conducive to plant growth can be considered near ideal. Table 10 describes chemical properties of an ideal soil, provides a comparison of properties common to Minnesota soils, and indicates the range of property values found in Minnesota soils.

Table 10. Ideal Soil Chemical Properties

Chemical Property	Property of the Ideal Soil	Averages in MN Soils	Ranges in MN Soils
Organic matter	High (5-10%)	Moderate	Low to high
Nutrient status	Essential nutrients in amounts sufficient for vigorous plant growth	Adequate	Low to high
Nutrient holding capacity	Sufficient to prevent nutrients from leaching to the groundwater	Adequate	Low to high
pH	In range for nutrients to be in readily available form — moderately acid or neutral (pH 5.5 to 7.0)	Slightly acid	Extremely acid to strongly alkaline

Soil Testing

Any attempt to change soil chemical properties of soil must begin with a soil test. The soil test analysis will provide a basis for adding nutrients and modifying pH, as well as help to avoid adding excessive nutrients.

Soil tests are performed by the University of Minnesota Soil Testing Laboratory as well as other commercial laboratories. Routine soil tests include:

- phosphorus and potassium
- pH
- lime requirement
- organic matter
- texture estimate

Non-routine tests (at an additional cost) include:

- soluble salts
- lead
- micronutrients
- secondary nutrients
- nitrate nitrogen

Usually, it is adequate to test for organic matter, phosphorus, potassium, and lime needs. Analysis for nitrogen is recommended only in Western Minnesota because of its mobility and the unreliability of the test to predict nitrogen needs in eastern Minnesota. A few soils in Minnesota may be deficient in some secondary or micronutrients. Analyses of such nutrients is expensive. Therefore, before requesting analysis for such nutrients, observe your plants closely to determine if they have any symptoms of deficiency (refer to section on "Assessing Nutrient Disorders" on page 36S), or ask your extension educator if soils in your area have been found to be deficient in such nutrients.

Collecting Soil Samples

Proper interpretation of soil test results depends upon collecting a representative sample of the soil. Soil samples can be taken at any time of the year, although spring and fall sampling are usually the most convenient. Separate samples should be collected from areas that differ in soil texture, soil color, the kinds of plants previously grown, and previous applications of fertilizer, organic amendments, and lime.

Samples are most easily collected using a soil tube, soil auger, or a garden trowel or spade. Scrape off all surface vegetation or litter and take the sample to the desired depth. Standardized sampling depths are as follows:

- Sample garden soils and soils to be used for establishing a lawn or turf to a depth of 6 inches
- Sample established turfgrass to a depth of 3 inches
- For trees, shrubs, and perennnial fruits, sample to a 12 inch depth

Soils sampled for lead because of health concerns with young children, should be sampled separately to a depth of 3/4 inch or to the depth to which a child may be exposed.

Each soil sample should be a composite of subsamples collected from randomly selected spots within the chosen area (see Figure 5). Take 5-10 subsamples for relatively small areas (less than 1000 square feet) in home lawns, flower borders, and gardens. Take 10 to 15 subsamples for larger turfgrass areas like industrial grounds and athletic fields. Collect the subsamples in a clean plastic pail, mix the soil thoroughly, and put about one pint of this mixture in a sample bag or box. Sample bags and sample submission forms can be obtained from your country extension office. An example of the Soil Sample Information Sheet is in Appendix 2. Label the sample container and keep a record of the area represented by each sample taken. Samples can be sent directly to the University of Minnesota Soil Testing Laboratory, 135 Crops Research Building, 1902 Dudley Ave., St. Paul, MN 55108, 612-625-310. Addresses of other commercial soil testing laboratories can be obtained from your county extension office or the yellow pages of your phone book.

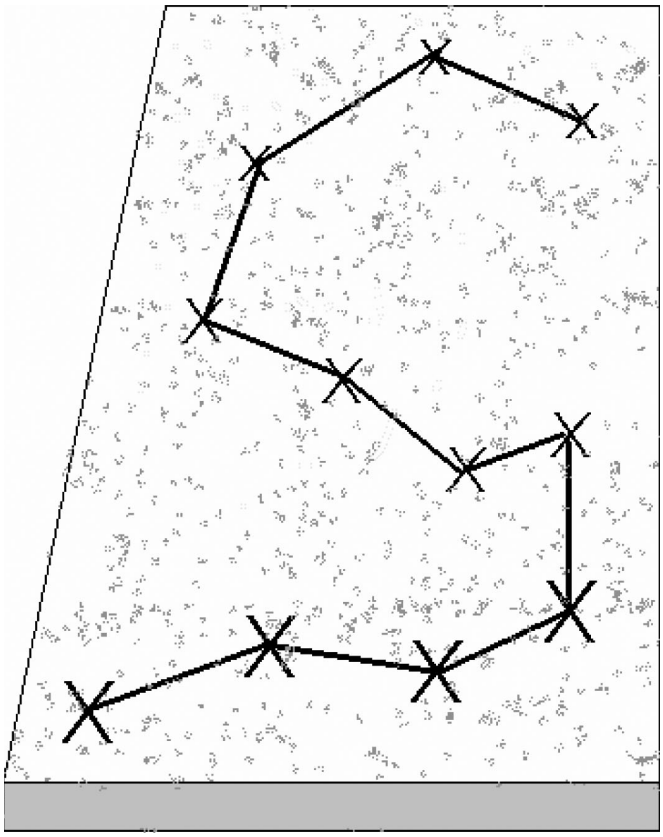


Figure 5. Soil sample collection for a lawn or garden.

Interpreting the Soil Test Report

A soil test report will provide information about pH and lime requirerment, and fertilizer recommendations for nitrogen, phosphorus, and potassium. A soil test value for phosphorus and potassium is an index of the availability of that nutrient to plants in the soil being tested. The University of Minnesota Soil Testing Laboratory reports soil test results as parts per million (ppm) and should be thought of as an index of the relative level.

The probability of response to applied fertilizer can conceptually be determined from relative soil test levels. As shown in Table 11, the higher the soil test level, the lower the probability of response to applied fertilizer. Conversely, a low soil test level would have a high probability of response to applied fertilizer. We will refer to this in more detail when we discuss phosphorus and potassium fertilizer recommendations.

Table 11. Generalized relationship between relative soil test levels and probability of response to applied fertilizer

Relative Soil Test Level	Probability of Response to Applied Fertilizer
Low	> 90%
Medium	60 – 90%
Medium – high	30 – 60%
High	10 – 30%
Very high	< 10%

Changing the pH

The pH of many of Minnesota's soils does not need to be changed for gardens and lawns. Recall that a soil pH in the range of 5.5 to 7.0 is optimum for the availability of plant nutrients. However, some plants grow well in a wider range of pH, and some require a more specific range of pH for good growth (see Table 12).

Table 12. Optimum range of soil pH for some plants

pH	Plants
5.5 – 7.0	Most vegetables, fruits, and landscape plants
5.0 – 6.5	Pin oak
4.8 – 5.3	Potatoes, rhubarb
4.5 – 5.2	Blueberry, cranberry, rhododendron, azalea, blue hydrangea

The amount of liming material required to change soil pH is directly related to the soil's cation exchange capacity (CEC). Soils with low CEC require less material to change pH than do soils with higher CEC (recall that a soil's CEC is directly related to clay and organic matter content).

Buffering capacity determines the amount of liming material needed to change pH and is related to CEC. Soils with high CEC have a high buffering capacity and soils with low CEC have low buffering capacity.

The buffer index is a laboratory measurement that allows making a lime recommendation for a specific soil. At a given pH, soils with a high buffering capacity have a low buffer index and require more lime than soils with low buffering capacity and a high buffer index (see Table 13).

Table 13. Relationship between CEC, pH, buffering capacity, buffer index, and lime needs to raise pH to 6.5

Texture	CEC	pH	Buffering Capacity	Buffer Index	Lime (lb / 1,000 sq ft)
Loamy sand	Low	5.1	Low	6.8	14
Clay loam	Medium	5.1	Medium	6.2	22

Liming (Raising pH)

The University of Minnesota's Soil Testing Laboratory routinely reports soil pH, buffer index, and amount of lime needed to raise pH to 6.5. For soils that are too acid, lime (calcitic and dolomitic) and wood ashes are commonly used for neutralization. Mix the neutralizing material thoroughly with the upper 6 to 12 inches of the soil to maximize its effectiveness.

Lime

Calcitic lime contains calcium carbonate [$Ca(CO_3)_2$]. Dolomitic lime contains both calcium carbonate and dolomite [$MgCa(CO_3)_2$]. Either one is satisfactory but, for sandy soils low in organic matter, dolomitic lime is recommended to add magnesium. Lime is commonly sold as ground agricultural limestone. It varies in how finely it has been ground; finer ground raises pH more rapidly.

Wood ashes

The composition of wood ash varies with tree species and burning conditions. In general, at an equivalent weight, wood ashes can be about ½ as effective as lime in raising pH. Wood ash contains potassium, phosphorus, boron, and very small amounts of other elements. Fresh ashes may damage germinating seedlings or plant roots, therefore, it is important to apply them as a thin layer during the autumn or winter, and mixed in with the soil in the spring.

FYI

Never apply more than 20 pounds of wood ash per 1000 square feet yearly because of potential toxicity. Never apply wood ashes if the pH is above 7.0.

Acidifying Material (lowering pH)

To be effective, all acidifying materials must be mixed thoroughly with the soil throughout the rooting zone. If pH is above 7.5 and lime is present, acidifying large areas may not be cost effective. Monitor the pH after adding acidifying materials to be sure the desired pH has been reached and is being maintained. Acidifying materials include elemental sulfur, iron sulfate, aluminum sulfate, and sphagnum moss peat.

Elemental sulfur

Elemental sulfur is the cheapest material to use for acidifying soil. However, the conversion of sulfur to the sulfate ion by certain soil microorganisms requires 2 to 4 months with soil temperature above 42°F (see Table 14).

Table 14. Sulfur application rates

	Application rates (lb / 100 sq ft)	
Initial pH	Sandy soils	Loamy soils
7.0	2.0	6.0
6.5	1.6	4.8
6.0	1.2	3.6
5.5	0.8	2.4

Iron sulfate

Iron sulfate is expensive, but it lowers pH within a few weeks compared to a few months for elemental sulfur. About 7 times more iron sulfate than elemental sulfur is required to lower a soil's pH.

Aluminum sulfate

Aluminum sulfate is similar to iron sulfate for lowering pH. However, except for blue hydrangeas, we do not recommend using aluminum sulfate. Aluminum becomes soluble and, in turn, toxic for many plants in strongly or more acid soils.

Sphagnum moss peat

Sphagnum moss peat has a pH of 4.0-4.5 and will lower pH for a few years after incorporation. However, it is rather expensive and requires large amounts. For example, 1 to 2 cubic feet should be mixed with the soil in the planting hole for each acid-loving plant (i.e. 1 part peat to 1 part soil by volume).

Ammonium sulfate

Ammonium sulfate is the most acidifying nitrogen fertilizer available. Thus, ammonium sulfate is recommended to supply nitrogen and maintain pH for acid-loving plants. Apply ammonium sulfate based on the nitrogen requirements of the plant.

Fertilizers

Understanding the fertilizer label is essential for proper application of fertilizer. The ratio of N-P_2O_5-K_2O in a fertilizer is called the fertilizer grade. Primary nutrients are always listed on the label as:

- Nitrogen - % of nitrogen
- Phosphorus - % of phosphorus oxide (phosphate or P_2O_5)
- Potassium - % of potassium oxide (potash or K_2O)

Note that nitrogen is expressed as a percent of an element (N), and phosphorus and potassium are expressed as a percent of oxides (P_2O_5 and K_2O). This way of expressing fertilizer content is due to terminology developed in the 1800's. A confusing aspect of this terminology is that elemental nitrogen and oxides of phosphorus and potassium do not actually exist in the fertilizer. They are simply used as a conventional way of comparing nutrient values of one fertilizer to another. For example, a 100 lb. bag of fertilizer labeled 10-10-10 contains 10 lbs. each of N, P_2O_5 and K_2O. A 100 lb. bag of 20-20-20 contains 20 lbs. each of N, P_2O_5 and K_2O or twice the nutrient content of 10-10-10.

Fertilizer labels may also contain the designations W.S.N. (water soluble nitrogen) or W.I.N. (water insoluble nitrogen). Water soluble nitrogen dissolves readily and is in a simple form (e.g. ammonia and nitrate nitrogen). Water insoluble nitrogen does not dissolve readily. Organic forms of W.I.N. must be transformed by soil microorganisms into simple ionic forms before they can be used by plants. Some inorganic forms of W.I.N are slow release nitrogen fertilizers. See Table 15 at the end of this section for a comparison of the advantages and disadvantages of many fertilizers.

FYI

Fertilizer manufacturers are required by law to state the amount of major nutrients as a guaranteed analysis. Look at the label before looking at the brand name.

Organic and Inorganic

There are two types of fertilizer: organic (contains carbon) and inorganic (does not contain carbon). Fertilizers are called organic if the nutrients contained in the product are derived either from the remains of living organisms or from a by-product of them (e.g. blood meal, bone meal, and all manures). Technically, urea is an organic fertilizer because it contains carbon. However, it is a synthetic organic fertilizer because it is manufactured from inorganic materials. Thus, it is not an organic fertilizer and cannot be used for organic crop production.

Complete and Incomplete

A complete fertilizer contains nitrogen, phosphorus, and potassium (e.g. 10-10-10, 16-16-16 or 20-10-5). An incomplete fertilizer has only one or two of the primary nutrients (see Table 15). Incomplete fertilizers are often blended to make complete fertilizers. If a fertilizer has only one primary nutrient, it is called a single carrier fertilizer.

Slow Release

Because plants absorb nutrients throughout their growth, it is important to provide them with a balance of nutrients during that period. The most efficient way to achieve this is to apply a slow release fertilizer. There are three types of slow release fertilizer: slow dissolving, membrane-coated granular, and organic.

FYI

Urea formaldehyde and sulfur-coated urea are generally used as turf fertilizers, whereas resin coated fertilizers are predominately used in container-grown plants and occasionally as a turf fertilizer.

Slow dissolving

Sulfur-coated urea is an example of a slow dissolving fertilizer. Varying the thickness of the sulfur coat controls the rate of release of urea. Release rates increase with an increase in temperature and are not affected by watering. When applied to the surface, sulfur-coated urea releases nitrogen more slowly than when incorporated into the soil. It also supplies the essential element sulfur. Slow dissolving fertilizer generally costs less than other slow release fertilizers. Urea formaldehyde is another example of a slow dissolving fertilizer.

Membrane-coated granular

Fertilizer granules coated with multiple layers of resin membranes swell upon contact with water. This increases the pore size of the resin and allows fertilizer to move into the soil. Release rates depend on coating thickness, temperature, and soil water content. A large release of fertilizer commonly occurs during the first two or three days after application, but periods of release can range from a few days to 6 months or years depending on the coating. Slow release fertilizer need not be applied as frequently as other fertilizers, and larger amounts can be applied without danger of burning. Slow release fertilizers are generally more expensive than other kinds. The real benefit, however, is the frequency of application, which is much lower than with conventional fertilizers.

Table 15. Some common inorganic and synthetic organic fertilizers

Fertilizer	Amounts of primary nutrients (expressed as %)		
	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)
Inorganic			
Ammonium nitrate	33	0	0
Ammonium sulfate	21	0	0
Calcium nitrate	15	0	0
Potassium nitrate	14	0	45
Monoammonium phosphate	11	48	0
Diammonium phosphate	18	46	0
Rock phosphate	0	5	0
Super phosphate	0	20	0
Triple (conc. Super phosphate)	0	46	0
Muriate of potash	0	0	60
Potassium sulfate	0	0	52
Potassium-magnesium sulfate	0	0	22
Organic (synthetic)			
Urea	45	0	0
Ureaformaldehyde	38	0	0

Organic

Some organic fertilizers have relatively high amounts of one of the three primary nutrients, but they either lack the other two primary nutrients or have only small amounts of them. Most are relatively low in all three nutrients and may need to be supplemented with nitrogen, phosphorus, or potassium. Most of the nutrients in organic fertilizers are in chemical forms that are unavailable to plants. Soil microorganisms transform them into plant-available forms, releasing nutrients over a long period. This transformation is only effective when the soil is moist and the soil temperature is warm and, therefore, nutrients may not always be released rapidly enough for vigorous plant growth in the spring. An advantage of organic fertilizers is that they increase organic matter levels in the soil (see Table 16 for the nutrient content of some common organic fertilizers).

Blood meal

Blood meal is a rich source of nitrogen, so rich that it may do harm if used in excess and gardeners must be careful not to exceed the recommended amount suggested on the label. In addition to nitrogen, blood meal supplies certain of the essential trace elements, including iron.

Fish emulsion

Fish emulsion is a partially decomposed blend of finely pulverized fish (it has a strong odor that will dissipate after a day or two). Fish emulsion is relatively high in nitrogen and is a source of several trace elements. Spring applications followed by a deep watering will stimulate an early surge of growth. Too strong a solution of fish emulsion can burn plants (particularly container plants).

Manure

Though a complete fertilizer, manure is low in the amounts of nutrients it can supply. Thus, much higher rates are needed compared to conventional fertilizers. Nutrient content varies among and within sources depending on the animals' diet. Common available manures include horse, cow, pig, chicken, and sheep.

Fresh manure

Fresh manures have the highest amount of nutrients, however, most gardeners prefer to use composted forms of manure because they have less salts and odor. Composted manure also reduces the chance of burning plants and reduces viable weed seeds; fresh manure should not be used where it will contact tender plant roots. Amounts as much as to ½ ton per 1000 square feet may be applied on bare soils before tillage.

FYI

Use caution in applying slow release fertilizers to trees and shrubs. These fertilizers may stimulate growth late in the season. The late season growth may not harden off completely and excessive winter damage may occur.

Sewage sludge

Also termed "biosolids," sewage sludge such as Milorganite is a product of municipal sewage treatment plants. Two forms are commonly available -- activated and composted. Activated sludge has higher concentrations of nutrients (approximately 6-3-0) than composted sludge, and is usually sold in a dry, granular form for use as a general purpose, long lasting, non-burning fertilizer. Composted sludge is used primarily as a soil amendment and has a lower nutrient content (approximately 1-2-0).

Table 16. Approximate nutrient content of organic fertilizers

Amounts of primary nutrients expressed as %			
Type	**Nitrogen (N)**	**Phosphate (P_2O_5)**	**Potash (K_2O)**
Manure (fresh)	----	% Fresh Wt	----
Bat	6.0	9.0	3.0
Cattle	0.6	0.6	0.5
Hog	0.5	0.4	0.5
Horse	0.7	0.3	0.5
Poultry	1.0	0.9	0.5
Rabbit	2.4	1.4	0.6
Sheep	0.9	0.5	0.7
	----	% Dry Wt	----
Alfalfa Hay	2.5	0.5	2.1
Blood meal	13.0	2.0	1.0
Bone meal (steamed)	1.0	15.0	0.0
Yard Waste	1.8	1.3	1.1
Cotton seed meal	7.5	2.5	1.5
Fish emulsion	9.0	7.0	0.0
Lawn clippings	1.2	0.3	2.0
Leaves (sugar maple)	0.7	0.1	0.8
***Sewage sludge (composted)**	1.0	2.0	0.0
***Sewage sludge (activated)**	5.8	3.7	0.8
Sawdust	0.2	0.1	0.2
Straw, grain	0.6	0.2	2.1
Wood ashes	0.0	2.0	6.0

*not allowed for organic crop production

Common Myth

"I don't use any chemicals on my garden. Instead, I use only compost."

In fact, compost consists of a variety of chemicals ranging from complex carbohydrates to simple ions. Use of the word chemical here more accurately refers to manufactured or synthetic chemicals.

FYI

Slow release and organic fertilizers used on fruits and most vegetables may promote excessive vegetative growth and late maturity.

Fertilizers and Herbicides

The major reason for buying a fertilizer combined with a herbicide is convenience -- everything in one application. However, such fertilizers are expensive and they have the disadvantage of poor timing (i.e. the proper time for a fertilizer application often does not coincide with the weed problem).

Special Fertilizers

The three major kinds of special fertilizers are special formulations, special purpose fertilizers, and chelates.

Special formulations

The type or form the fertilizer comes in is called the formulation. Formulations include water soluble powders, slow release pellets, slow release collars or spikes, liquids, tablets, and granular solids. All special formulations must give the amount of nutrients on the label and, in some cases, note how quickly a nutrient is available.

Special purposes

You will find fertilizers packaged for certain uses or types of plants such as Camellia Food, Rhododendron/Azalea Food, or Rose Food. Some of the compounds used in these fertilizers are chosen because they have an acid reaction and, thus, they are beneficial to acid-loving plants where soil is naturally neutral or alkaline. However, consider their cost compared to other methods of acidifying, maintaining acidity, and supplying nutrients.

Chelates

Chelates are molecules that "hold" on to metal ions. Organic compound can act as chelates -- from relatively simple natural chelates (e.g. citrate) to more complex manufactured chemicals. Chelates can hold nutrients and release them in plant-available forms under conditions where the nutrient would otherwise be unavailable. The type of chelate used will depend on the nutrient needed and the soil pH. When a chelate metal is added to the soil, the nutrient held by the chelate will remain available to the plant. Only a few metals, such as iron, benefit from the addition of chelates. Chelates are rather expensive. Their best use is for micronutrients because only small amounts are needed. Chelated micronutrients can also be applied directly to leaves; an application method especially useful for short-term correction of iron deficiency.

FYI

Heavy metals, such as cadmium, are sometimes present in sludge and may accumulate in the soil. Possible negative effects vary, not only with the origin of the sludge, but also with the characteristics of the soil where it is used. To be safe, do not use sewage sludge products to fertilize edible plants. Milorganite has been deemed safe for use on vegetable crops by the USEPA, however, the USDA and MDA do not allow Milorganite or other types of sewage sludge for organic crop production.

Advantages and Disadvantages of Fertilizers

See Table 17 for advantages and disadvantages of different fertilizers.

Table 17. Advantages and disadvantages of different types of fertilizer

Type	Advantages	Disadvantages
Conventional	Fast acting Some are acid forming Low cost	Greater burn potential Solidifies in the bag when wet Nitrogen may leach readily
Slow release	Fewer applications Low burn potential Release rates vary depending on fertilizer characteristics Comparatively slow release rate	Unit cost is high Availability limited Release rate governed by factors other than plant need
Organic	Low burn potential Relatively slow release Contains micronutrients Conditions soil Adds organic matter Some acidify soil	Salt could be a problem with some Bulky, difficult to handle Odor from some Expensive per unit of nutrient Weed seeds a problem with some Heavy metals may be present in sewage sludge
Fertilizers combined with herbicides	Convenient	Expensive Timing of nutrients for plants and herbicide for weeds may not be in synchronization
Specialty fertilizers	Convenient Perform well in special situations	Limited to very special situations Expensive

Fertilizing

The University of Minnesota's Soil Testing Laboratory provides recommendations for phosphate and potash fertilizer applications to vegetable gardens based on soil test levels. Because of the mobility of nitrate, the soil nitrate test is not generally used to make nitrogen fertilizer recommendations for vegetable gardens or landscape plants. Rather, nitrogen recommendations for vegetable gardens are based on soil organic matter level. Because only a limited number of blends are on the market, you may not find one with the ratio of nutrients recommended in the soil test report. In this situation, select the blend with the closest ratio. In general, matching the nitrogen requirement is more important than matching the phosphate or potash requirement (refer to the section on calculating fertilizer applications for more detail). It is important not to over-apply phosphate because of water quality concerns.

Nitrogen

An initial nitrogen (N) application of 0.5 lb. N/1000 sq. ft. (22 lb./acre) is recommended when establishing a new home lawn or commercial turfgrass. An additional 0.5 lb. N/1000 sq. ft. (22 lb./acre) should be applied two weeks after seedling emergence or sodding and watered in.

Nitrogen fertilizer recommendations for established lawns, turfgrass areas, and gardens are based on the soil's organic matter content and the management practices (see Tables 18 and 19).

Table 18. Annual nitrogen recommendations for an established lawn or turfgrass area

	Soil organic matter level [1]		
Maintenance practices	**Low**	**Medium to high**	**Organic soil**
	Amount of nitrogen (N) to apply[2,3] - - - - - - lb. N/1000 sq. ft. - - - - - -		
Regular irrigation			
Clippings removed	4.0	3.0	2.00
Clippings not removed	3.0	2.0	1.00
No irrigation			
Clippings removed	2.0	1.0	0.50
Clippings not removed	1.0	0.5	0.25

[1] Low (< 3.1%), medium to high (3.1 - 19%), organic soil (> 19%)
[2] Multiply by 44 to convert the rates in lb./1000 sq. ft. to lb./acre
[3] Apply no more than 1 lb. quick-release N/1000 sq. ft. in a single application

Table 19. Nitrogen recommendations for vegetable and flower gardens

Soil organic matter level [1]	Amount of nitrogen (N) to apply [2] - - - - - - lb. N/1000 sq. ft. - - - - - -
Low	0.20
Medium to high	0.15
Organic soils	0.10

[1] Low (< 3.1%), medium to high (3.1 - 19%), organic soil (> 19%)
[2] An additional 0.15 lb./1000 sq. ft. may be needed as a sidedress application 3-4 weeks after planting for sweet corn, vine crops, tomatoes, potatoes, and cole crops

FYI

Caution: application of large amounts of nitrogen fertilizers will inhibit development of nodules on legume roots. Excessive nitrogen applications can also leach as nitrate and contaminate ground water.

Nitrogen is gradually released from decomposing organic matter during the growing season, so less fertilizer N is required as soil organic matter levels increase. A well-watered lawn or garden grows more vigorously and requires more N than one that is not watered. Removal of grass clippings also increases N needs. Clippings left on the lawn gradually decompose over a 3-to 4-week period and the nutrients in them are recycled, reducing the need for fertilizer by about 1 lb. N/1000 sq. ft. per year.

Phosphorus

Phosphorus fertilizer (P_2O_5) recommendations for a new lawn or turf are given in Tables 20, and P_2O_5 recommendations for established lawns and turfgrass are presented in Table 21. Recommendations for vegetable and flower gardens are in Table 22.

FYI

Over the years, continuous use of phosphorus-containing fertilizers can build up soil phosphorus to high levels. Overuse of phosphorus fertilizer should be avoided because of possible detrimental effects to surface water quality. If soil test phosphorus is in the very high range, use a fertilizer with a zero or very low phosphorus analysis.

Table 20. Phosphorus recommendations for a new lawn or turfgrass area before seeding or sodding

Phosphorus (P) Soil Test Level - - - - - - ppm - - - - - -		Relative Level	Amount of Phosphate (P_2O_5) to Apply * lb P_2O_5 / 1000 sq ft
Bray-P1	Olsen-P		
0 – 10	0 – 7	Low – medium	5
11 – 25	8 – 18	Medium – high	2
Over 25	Over 18	Very high	0

Table 21. Annual phosphorus recommendations for an established lawn or turfgrass area

Phosphorus (P) Soil Test Level - - - - - - ppm - - - - - -		Relative Level	Amount of Phosphate (P_2O_5) to Apply * lb P_2O_5 / 1000 sq ft
Bray-P1	Olsen-P		
0 – 10	0 – 7	Low – medium	1.0
11 – 25	8 – 18	Medium – high	0.5
Over 25	Over 18	Very high	0.0

Table 22. Phosphorus recommendations for vegetable and flower gardens

Phosphorus (P) Soil Test Level - - - - - - ppm - - - - - -		Relative Level	Amount of Phosphate (P_2O_5) to Apply * lb P_2O_5 / 1000 sq ft
Bray-P1	Olsen-P		
0 – 5	0 – 3	Low	0.4
6 – 11	4 – 7	Medium	0.3
11 - 15	8 – 11	Medium high	0.2
16 – 25	12 – 18	High	0.1
Over 25	Over 18	Very high	0.0

*Multiply by 44 to convert the rates in lb/1000 sq ft to lb/acre

Potassium

Potassium fertilizer (K_2O) recommendations for a new lawn or turf are given in Table 23. K_2O recommendations for established lawn and turfgrass are listed in Table 24. Recommendations for vegetable and flower gardens are in Table 25.

Table 23. Potassium recommendations for a new lawn or turfgrass area before seeding or sodding

Potassium (K) Soil Test Level - - - - - - ppm - - - - - -	Relative Level	Amount of Potash (K_2O) to Apply * lb / 1000 sq ft
0 – 50	Low	6 **
51 - 100	Medium	4 **
101 – 150	High	2
Over 150	Very high	0

*Multiply by 44 to convert the rates in lb/1000 sq ft to lb/acre

**On sandy soils incorporated only 2 lb K20/1000 sq ft prior to seeding or sodding and fertilizer regularly with fertilizer containing potassium after establishment

Table 24. Annual potassium recommendations for an established lawn or turfgrass area

	Maintenance Practices			
	Regular Irrigation		No Irrigation	
Potassium (K) Soil Test Level	Clippings Removed	Clippings Not Removed	Clippings Removed	Clippings Not Removed
- - - - ppm - - - -	Amount of potash (K_2O) to Apply[1, 2, 3] - - - - - - - - - - - - lb / 1000 sq ft - - - - - - - - - - - -			
0 – 50	4	3	3	2.0
51 - 100	3	2	2	1.0
101 – 150	2	1	1	0.5
Over 150	0	0	0	0.0

[1]Multiply by 44 to convert the rates in lb/1000 sq ft to lb/acre

[2]Apply no more than 1 lb K_2O/1000 sq ft in a single application

[3]On sandy soils the recommended rate should de divided into split applications made on a regular basis

Table 25. Potassium recommendations for vegetable and flower gardens

Potassium (K) Soil Test Level - - - - - - ppm - - - - - -	Relative Level	Amount of Potash (K_2O) to Apply * lb / 1000 sq ft
0 – 50	Low	0.4
51 - 100	Medium	0.3
101 – 150	Medium high	0.2
151 - 200	High	0.1
Over 150	Very high	0.0

*Multiply by 44 to convert the rates in lb/1000 sq ft to lb/acre

Potassium will leach through coarse textured soils, so sands, loamy sands, and artificially prepared sandy mixtures such as those used in constructing golf course greens should receive no more than 2 lb. K_2O/1000 sq. ft. (85 lb./acre) prior to seeding or sodding. If the K soil test is low and the recommendation calls for a higher rate, apply the remainder as part of the regular fertilization program after establishment. On sandy mixes and sandy soils, K fertilizer should be surface applied at no more than 1 lb. K_2O per 1000 square feet per application.

Calculating Fertilizer Applications

When you receive your soil test report from the Soil Testing Laboratory, you will notice the recommendations of nutrients to apply in the middle of the page (See sample soil test report in the Appendix 2). All fertilizer recommendations are based on the amount (lbs) of nutrient (N, P_2O_5, and K_2O) to apply per given area. Lawn and turf recommendations are given in pounds per 1,000 sq. ft. and garden, tree, and shrub recommendations in pounds per 100 sq. ft. From this recommendation it is necessary to select an appropriate fertilizer grade and then determine how much of this fertilizer to apply to the garden area.

Fertilizers are sold in many grades. Complete fertilizers, such as 10-10-10 or 5-10-10, contain all three primary nutrients. Single nutrient fertilizers contain only one, but they generally are a high analysis, economical source of that nutrient (e.g., 46-0-0, 0-0-60). Most garden fertilizers are complete fertilizers. They are convenient to use, but it may be difficult to find one that exactly matches the ratio required in a fertilizer recommendation. For complete fertilizers, select one with the closest ratio of N-P_2O_5-K_2O to that recommended. It is most important to accurately match the N requirement when calculating the fertilizer rate and then compromise somewhat if necesary for P_2O_5 and K_2O (See Table 26). Avoid applying excess phosphorus because of potential effects on water quality.

Table 26. Total amounts of various grades of fertilizer to apply based on recommended amounts of actual nitrogen

	Nitrogen Recommendation			
	per 100 sq ft			per 1000 sq ft
Fertilizer Grade	**0.1lb**	**0.15lb**	**0.2lb**	**1.0lb**
	Total amount of fertilizer to apply (lb)			
46-0-0 (urea)	0.22	0.33	0.44	2.2
37-3-3	0.27	0.41	0.54	2.7
36-6-6	0.28	0.42	0.56	2.8
33-0-0 (ammonium nitrate)	0.30	0.45	0.60	3.0
32-4-4, 32-3-10	0.31	0.47	0.62	3.1
30-4-4, 30-0-10	0.33	0.50	0.66	3.3
28-3-3, 28-4-6	0.36	0.54	0.72	3.6
27-7-7, 27-3-3	0.37	0.56	0.74	3.7
25-5-5, 25-3-12*	0.40	0.60	0.80	4.0
24-8-16, 24-0-15	0.42	0.63	0.84	4.2
22-4-4, 22-6-3	0.45	0.68	0.90	4.5
21-0-0 (ammonium sulfate)	0.48	0.72	0.96	4.8
20-20-20, 20-4-8, 20-10-10	0.50	0.75	1.00	5.0
19-19-19	0.53	0.80	1.06	5.3
18-6-12, 18-3-6	0.56	0.84	1.12	5.6
16-8-8, 16-4-8	0.63	0.95	1.26	6.3
15-15-15, 15-5-5	0.67	1.00	1.34	6.7
13-3-9, 13-25-12	0.77	1.16	1.54	7.7
12-12-12, 12-4-4	0.83	1.25	1.66	8.3
10-10-10, 10-20-10, 10-5-5, 10-10-20	1.00	1.50	2.00	10.0
6-12-12, 6-2-0	1.67	2.51	3.34	16.7
5-10-10, 5-10-5	2.00	3.00	4.00	20.0

Calculating fertilizer rates using organic fertilizer sources is often difficult. Their exact nutrient content is frequently unknown, so fertilizer rates can only be approximated using general values. Even though a total nitrogen content of the material is often reported, only a portion of that nitrogen is available to plants the year of application (about 15 to 20% of the organic N, depending on the material). Some types of organic fertilizer can be purchased in bags that are labeled with their fertilizer grade. Fertilizer rates for these products can be calculated in the same manner as for inorganic fertilizers.

Example Fertilizer Calculation

A soil test recommendation calls for 0.1 lb N/100 sq. ft., 0 lb. P_2O_5/100 sq. ft., and 0.1 lb. K2O /100 sq. ft. The area is 40 feet by 10 feet.

Four steps are required to determine how much of a given fertilizer is required for a given area:

Step 1: Measure the area to be fertilized in square feet (feet long x feet wide = square feet)

Example: 40 feet long X 10 feet wide = 400 square feet

Step 2: Select the fertilizer(s) to use based on the soil test by matching the ratio of nutrients recommended to the fertilizer grades available.

Examples: The N-P-K nutrient ratio based on the soil test should be 1-0-1. Ideally, a fertilizer such as a 10- 0-10-, 20-0-20, or 25-0-25 should be selected. At the local garden store, fertilizer bags marked 20-10-10, 27-3-3 and 25-3-12 were available. The one marked 25-3-12 best matches the ratio of 1-0-1 recommended by the soil test.

Step 3: Determine the amount of fertilizer to apply by

Method a. Dividing the recommended amount of the nutrient by the percentage of the nutrient (on a decimal basis) in the fertilizer

$$\frac{\text{lb. nutrient recommended/sq. ft.}}{\text{\% nutrient in fertilizer}} = \text{lb. fertilizer/sq. ft.}$$

Example: (use nitrogen percentage to determine the rate to apply)

$$\frac{\text{0.1 lb. nutrient recommended/100 sq. ft.}}{\text{25\% nutrient in fertilizer (0.25)}} = \text{0.4 lb. fertilizer/100 sq. ft.}$$

Method b. Table 26 simplifies the calculation by providing the total amount of commonly available fertilizers based on their nitrogen content.

Example from Table 26: The nitrogen recommendation calls for 0.1 lb. N/100 sq. ft. and the fertilizer grade selected has a ratio of 25-3-12 (col umn 1). Apply 0.4 lb. (column 2) of this fertilizer per 100 sq. ft.

Step 4: Adjust the total amount of fertilizer to apply for the given lawn or garden area.

$$\frac{\text{lb. fertilizer}}{\text{sq. ft.}} \times \frac{\text{sq. ft.}}{\text{garden or lawn}} = \frac{\text{lb. fertilizer}}{\text{garden or lawn}}$$

Example:

$$\frac{\text{0.4 lb. fert.}}{\text{100 sq. ft.}} \times \frac{\text{400 sq. ft.}}{\text{garden or lawn}} = \frac{\text{1.6 lb. 25-3-12 fert.}}{\text{garden or lawn}}$$

This is equivalent to about 3 cups of a 25-3-12 fertilizer per 400 sq. ft. garden or lawn

FYI

One pound of fertilizer is approximately equal to a volume of 2 cups.

Application Methods

Nutrients can be applied to the soil (e.g. broadcast, banding, sidedressing, or starter solution), or on the plants (e.g. foliar application).

Broadcasting

A recommended rate of fertilizer is spread over the growing area. It can be left on the surface (to be moved downward by water), or it can be tilled into the soil (in the upper few inches). Broadcasting is most appropriate for large gardens or when time or labor is a limitation. It is the safest and easiest method for the home gardener.

Banding

Roots of plants need nutrients, especially phosphorus, to develop vigorously. Banding is an effective way to satisfy those nutrients needs. Tomatoes respond especially well to this method. When fertilizers are broadcast and tilled into soil, much of the phosphorus may be immobilized in the soil, thus, little of it is immediately available to the plant. Nutrients placed in bands are used more effectively by plants than are nutrients that are broadcasted.

FYI

Since phosphorus and potassium in fertilizers are relatively immobile, they should be incorporated into the soil before planting.

Narrow bands of fertilizer are applied in furrows 2 to 3 inches from, and 1 to 2 inches deeper than, the seeds or plants (closer placement may result in burning if the roots). The best technique is to stretch a string where the seed row is to be planted. Then, use the corner of a hoe to dig a furrow 2 inches to the side of the row and 3 inches deep. Spread the fertilizer in the furrow and cover with soil (not much is gained by repeating this on the other side of the string). Then, sow seeds beneath the string.

For widely spaced plants (e.g. tomatoes), fertilizer can be placed in bands 6 inches long for each plant or in a circle around the plant. Place the bands 4 inches from the plant. To place fertilizer below the plant, place the fertilizer at the bottom of the planting hole and mix it with soil. Then, place a layer of soil about 2 inches thick over the fertilized soil and then plant the plant.

Sidedressing

Dry fertilizer is applied as a sidedressing after plants are up. This method is most effective for applying additional nitrogen. Scatter fertilizer on both sides of the row 6 to 8 inches from the plants and till it into the soil. For best results, avoid placing fertilizer too close to roots and follow with a thorough watering.

Starter Solution

Using a starter solution is another way to satisfy nutrient needs, especially for early plant growth. Ratios of 1:2:2 or 1:2:1 are best as higher rates may burn the transplant. You can make a good starter solution, for example, by mixing 2 tablespoons of 5-10-10, 8-16-16, or 10-20-10 in one gallon of water. Apply one cup of this solution when transplants are set in the ground. Transplants, especially tomatoes, eggplant, peppers, or cabbage, respond well to a high phosphorus starter solution.

Foliar Application

Foliar applications are best used when:

- insufficient fertilizer was used before planting
- a quick growth response is desired
- micronutrients such as iron or zinc are immobilized in the soil
- soil is too cold or wet for plants to extract or use the fertilizer applied to the soil

Plants begin to absorb foliar applied nutrients within minutes after application, and most nutrients are completely absorbed within 1 to 2 days. Foliar nutrition can supplement, but not substitute, for soil nutrients at a critical time for the plant. Roots absorb few nutrients from cold soils and, under these conditions, an application of phosphorus in a spray will help establish young plants as well as stimulate growth of perennials. Foliar application is best suited for supplying plants with iron or manganese, especially on soils with pH greater than 7.

Application Timing

The main factors influencing timing and frequency of applying nutrients are the soil, plant, and nutrient type.

Soil

Sandy soils have lower capacity to hold nutrients than do loamy and clayey soils. They are especially vulnerable to losing nitrogen by leaching. Thus, sandy soils require more frequent applications of nitrogen, but in smaller amounts, than do loamy and clayey soils.

Plants

Some plants need more nutrients than others. For example, sweet corn requires more nitrogen than most trees and shrubs. Further, sweet corn may respond well to applications of nitrogen every four to five weeks, whereas most trees and shrubs perform nicely when the proper amount is well-placed once a year.

Nutrients

Proper use of nutrients can control growth rate, form, and character of plants. Nitrogen is the most critical nutrient in this regard. If tomatoes are fertilized heavily with nitrogen into midsummer, the plants will have abundant vines but little or no fruit. Likewise, potatoes fertilized heavily with nitrogen will have abundant and large vines and small tubers.

Remember that a nitrogen application will have its greatest effect for 3 to 4 weeks after application. For example, if nitrogen is applied to tomatoes in the first part of June, no or few flowers will form until early July and fruit will ripen in late August. For this reason it is important to plant crops with similar nutrient needs close together to avoid improper timing of fertilizer applications. Applying nutrients late in the growing season to trees and shrubs usually causes them to produce a flush of new growth. Such plants should instead be moving into dormancy and "hardening off." This delay of dormancy can cause severe cold temperature damage to the new growth in the winter.

FYI

A general rule is that nitrogen is for leafy top growth, phosphorus is for root growth and fruit production, and potassium is for cold hardiness, disease resistance, and general durability. However, a deficiency in any of these nutrients will stunt growth.

ASSESSING NUTRIENT DISORDERS

Another way of assessing nutrient status is to carefully observe the rate of growth and morphology of plants. Plants respond unfavorably to deficiencies of nutrients and to some excesses too. The following list describes general symptoms associated with nutrient conditions. Nutrient deficiencies or toxicities can resemble non-nutritional disorders such as diseases or herbicide damage. Use of soil or tissue analysis, or both, may help confirm the real cause.

Primary Nutrients

Nitrogen (N)

Deficiency: Leaves turn pale green to yellow. Oldest leaves are affected first, but in severe cases the whole plant may be yellow. Growth is usually stunted. Occurs most frequently on sandy soils
Excess: Can occur when high rates of N fertilizer are applied. Results are usually excessive vegetative growth and poor fruit growth.

Phosphorus (P)

Deficiency: Leaves appear reddish-purple. Oldest leaves are affected first. Plant growth is stunted. Common in strongly or extremely acid and alkaline soils or those soils low in native P. Also occurs in cool wet soils in the spring. Plants may grow out of P deficiency as soil warms.
Excess: May induce zinc or iron deficiency.

Potassium (K)

Deficiency: Leaves become gray or tan at or near the margins. Oldest leaves are affected first with characteric symptoms of scorching around the leaf margins. It is most common on sandy soils and soils low in native K.
Excess: Can cause salt burn. Soils with high K levels can induce magnesium deficiency.

Secondary Nutrients

Calcium (Ca)

Deficiency: Growing points of plant may die. Younger leaves are affected. Root tips die and root growth is slow. Tip burn of cabbage, cauliflower, and lettuce and blossom end rot of tomatoes are due to localized Ca deficiency within the plant. Most common on acid and droughty soils.
Excess: Not known to occur in the field.

Magnesium (Mg)

Deficiency: Oldest leaves turn yellow between the veins. In severe cases, younger leaves may be affected and older leaves may drop off. May occur in acid soils, sandy soils, or soils with high levels of potassium.
Excess: Not known to occur in the field.

Sulfur (S)

Deficiency: Symptoms are similar to nitrogen deficiency except that youngest leaves are usually affected first. Most common in sandy soils low in organic matter.
Excess: Not known to occur in the field.

Micronutrients

Boron (B)
Deficiency: Usually occurs on younger parts of plants. Growing points die. Leaves appear distorted. May cause: hollow stem and internal browning in cauliflower and broccoli, cracked stem in celery, internal browning in beets and turnips. Can occur on sandy soils in crops with a high B requirement.
Excess: Can be highly toxic to some plants at low levels. Avoid excess B applications. Toxicity usually occurs on oldest leaves as a scorching of the margins.

Chlorine (Cl)
Deficiency: Rare. Not known to occur in the field.
Excess: Occurs as a marginal scorch of older leaves. Can occur on salt affected soils, near streets where salt is used, or when excessive rates of fertilizer containing Cl are used.

Copper (Cu)
Deficiency: Yellowing or die-back of youngest leaves. Sometimes yellowing between the veins. Most Cu deficiencies occur on organic soils.
Excess: Can occur due to continuous use of copper-containing fungicides. May induced iron chlorosis and cause stunted root systems.

Iron (Fe)
Deficiency: Yellowing between the veins on youngest leaves, veins remain green (often referred to as interveinal chlorosis). Occurs frequently on soils with pH greater than 7.2. Some plant are more susceptible than others. With acid-loving plants (e.g. blueberry, azalea) chlorosis may occur at a pH as low as 5.5-6.0.
Excess: Rare. High levels may induce manganese deficiency.

Manganese (Mn)
Deficiency: Similar to Fe deficiency. Yellowing between the veins of youngest leaves. Usually only the main veins remain green and cause a fishbone-like appearance. In some plants older leaves may develop gray streaks or dots. Occurs mainly in soils with pH greater than 7.2. Can also occur on organic soils with pH greater than 6.0.
Excess: Symptoms are chlorosis and brown spots on leaves. Mn toxicity can occur on soils with pH less than 4.5 or after heat sterilization of greenhouse soils.

Molybdenum
Deficiency: Pale distorted narrow leaves. Causes "whip tail" of cauliflower. Can occur on soils with pH less than 5.0
Excess: Rare.

Zinc (Zn)
Deficiency: Short internodes, may cause rosetting appearance in trees. Younger leaves usually affected first and may show signs of yellowing between the veins. High levels of phosphorus fertilizer may induce Zn deficiency. Can occur on high pH soils or acid sandy soils
Excess: May induce Fe deficiency.

SPECIAL PROBLEMS

Damage by Fertilizer Salts

Many nutrients in fertilizers are in the chemical form of salts (see Table 15), much like our table salt. When a nutrient in salt form is applied to a soil, nearby water begins to move gradually towards the area where it was applied and salt begins to diffuse or move away from the place where applied. This dilutes the fertilizer and distributes it through a much larger area. If tender plant roots are close to the placement of a fertilizer, water is drawn from these roots, as well as from the surrounding soil. The more salt or fertilizer applied, the more water is drawn from nearby roots. As water is drawn from the roots, plant cells begin to dehydrate and collapse. Then the plant roots may burn or dehydrate to a point where they cannot recover. If soil moisture is limited, most of the water drawn towards the salt will come from plant roots and the damage can be severe.

The problem of salts in fertilizers may worsen when fertilizer is applied repeatedly or excessively without sufficient water to leach or wash the old fertilizer salts through the soil. Also, evaporation of water from the soil exacerbates the problem, As the salts in the soil become more concentrated, plants have greater difficulty in absorbing water. Salts may accumulate to such high levels that growth of plants ceases. Excessive applications of organic nutrient sources like manure, compost, and wood ashes can also cause high salt levels. Table 27 gives soluble salt test levels and their effects on plant growth.

Table 27. Soluble salt test values and relative sensitivity levels of plants

Electrical Conductivity* (mmhos / cm)	Salinity Levels	Effect on Plant Growth
0 to 2	Non-saline	None
2.1 to 4	Very slightly saline	Sensitive plants are inhibited
4.1to 8	Moderately saline	Many plants are inhibited
8.1 to 16	Strongly saline	Most cultivated plants inhibited
Over 16	Very strongly saline	Few plants are tolerant

*saturated paste extract

Remedy for container plants

Problems from fertilizer salts is most common in container-grown plants. Salts accumulate on top of the soil container and form a yellow to white crust. A ring of salt deposits may also form around the pot at the soil line or around the drainage hole or accumulate on the outside of clay pots.

The best way to prevent injury from fertilizer salts is to prevent their accumulations by proper watering. When watering, always allow a volume of water equal to at least 1/10 the volume of the container to drain through. Then empty the drip plate to prevent reabsorption of the drained water and its salts by the soil.

As a further safeguard to prevent accumulatioin of fertilizer salts, container-grown plants should be thoroughly leached every 4 to 6 months (leach before fertilizing to avoid loss of fertilizer). Leach by slowly pouring an amount of water equal to about twice the volume of the container. Allow the water to drain completely. Replace any salty crusts with no more than 1/4 inch of the underlying soil before leaching. It is best not to add more soil to the top of the container. If the salt level is extremely high or the container has no drainage, repot the plant with new soil.

Salt levels that cause injury depends on the type of plant and how it is being grown. A plant grown in the home may be injured by salts at a concentration of 200 parts per million (ppm). The same plant growing in a greenhouse where the light and drainge are good will grow with salts 10 times that level, or 2000

ppm. Some nurseries and plant shops leach plants to remove excess salts before the plant is sold. If you are not sure that has been done, leach a newly purchased plant the first time you water it.

Remedy for gardens and lawns

Through rather rare in gardens and lawns, problems with fertilizer salts may occur where excessive amounts of fertilizers have been applied. To remedy over-fertilization, water the lawn with at least 2 inches of water as soon as possible. This will dilute the fertilizer salts by dispersing them throughout several inches of soil. Also, keep the soil moist by frequent watering to prevent further concentration of fertilizer salts.

Two rules should be kept in mind when applying a fertilizer during hot weather when soil moisture is limited. First, do not over-apply nitrogen fertilizers. Second, make sure adequate moisture is present after applying fertilizer high in salts. Fertilizers highest in relative saltiness have the greatest potential to burn plants.

Damage by Road Salts

Damage to plants may occur on areas adjacent to heavily salted roads (e.g as occurs during ice removal). The principles involved with the problem of these salts are the same as those from salts of fertilizers. However, the culprit salts have changed to sodium chloride (table salts) and calcium chloride instead of fertilizer salt.

Remedy

To be certain damage is from road salts, have the soil tested for excess salts. If the problem is excess salts, the main remedy is to water to leach away the salts. A soil pH above 7.8 indicates the presence of excess sodium. An application of about ½ pound of gypsum per 100 square feet will help solve the problem. Gypsum contains calcium and sulfate and the calcium displaces the excess sodium.

Lead in the Soil

Lead in large amounts is potentially toxic to most living organisms including people. Sources of potentially toxic amounts in soil are contamination by lead-based paints and emissions from gasoline-buring engines. Presently, neither of these contaminants is used to any great extent. However, lead is rather immobile in the soil. Thus, concern about lead remains legitimate.

The most serious source of exposure to lead in the soil is through direct ingestion of contaminated soil and dust from contaminated soil. Most plants do not absorb and accumulate enough lead to be a hazard to health. Dust from contaminated soil may accumulate on leaves or fruit, but the danger from that may be greatly reduced by proper washing. If you have concerns about the amount of lead in your soil, have it tested.

RESOURCES

U of MN Extension Service Publications

Master Gardeners receive many of these publications as a part of their training or Core Course. New publications are continually added to the Distribution Center. The most up-to-date listing is available online at http://www.extension.umn.edu. Click on Publications, or search the site for publications of interest. Many of these fact sheets can be read online and are also available from county extension offices. Longer publications or those containing many photographs or illustrations may not be available online. Master Gardeners should order publications through their home county extension office. Public orders may be placed by calling 1-800-876-8636 (outstate) or 612-624-4900 (local).

FO 0636 Fertilizer Urea
MI 0720 Zinc for Crop Production
FO 0723 Boron for Minnesota Soils
FO 0725 Magnesium in Minnesota Soils
FO 0792 Phosphorus for Minnesota Soils
FO 0794 Sulfur for Minnesota Soils
FO 0817 Evaluating Soil Texture for a House Site
BU 1731 Soil Test Interpretations and Fertilizer Management for Lawns, Turf, Gardens, and Landscape Plants
FO 2331 Soils and Landscapes of Minnesota
FO 2543 Lead in the Home Garden & Urban Soil Environments
FS 2923 Preventing Pollution Problems from Lawn and Garden Fertilizers
BU 3115 Soil Compaction—Cause, Effects and Control
FO 3296 Composting and Mulching: A Guide to Managing Organic Yard Wastes
FO 3338 Fertilizing Lawns
FO 3770 Understanding Nitrogen in Soils
FS 3899 Backyard Composting
MI 3986 Clean Water—Pesticide Selection Can Make a Difference
FS 5553 Structures for Backyard Composting
FO 5866 Groundwater Contamination
FO 5867 What Is Groundwater?
BU 5886 Nutrient Management for Commercial Fruit and Vegetable Crops in Minnesota
FO 5956 Lime Needs for Minnesota
FO 6288 Understanding Phosphate Fertilizers

Videos of Minnesota Gardening TV Programs

These are 30-minute videos developed as a series of programs aired in the Twin Cities for the general public. They are available from the University of Minnesota Extension Service Distribution Center: call 612-624-4900 (local) or 1-800-876-8636 (outstate).

VH 3320 Conservation Tillage and Energy Consumption
VH 5657 Minimum Tillage: A Comparison of Methods
VH 6082 Profit with Manure

Composting CD-Rom

Backyard Composting: see www.compost.umn.edu

Minnesota Extension Service Slide Sets

These vary in length and depth. All have a script and/or audio tape. These are also available from the University of Minnesota Extension Service Distribution Center: call 612-624-4900 (local) or 1-800-876-8636 (outstate).

SS 4107 Conservation Tillage
SS 2461 Cross Slope Farming
SS 4149 Dirt, Who Needs It?
SS 1897 Garvin Brook Rural Clean Water Project
SS 4284 Grassed Waterways—Construction & Maintenance
SS 4425 Managing Corn and Soybean Residues to Control Water Erosion
SS 4452 Modern Terraces for Soil Conservation
SS 4600 Soil Erosion by Wind
SS 4669 Washout
SS 4685 What Lime Does and How it Works

Other Resources

Besch, B.B. (editor) 1986. *Soils, Plants and Gardens.* Brooklyn Botanic Garden Record. 79 pp.

Brady, N.C. 1984. *The Nature and Properties of Soils,* 9th edition. Macmillan Pub. Co. 750 pp.

Collins, D.N. 1983. *Turf and Garden Fertilizer Handbook.* The Fertilizer Institute. 126 pp.

Foth, H.D. 1990. *Fundamentals of Soil Science,* 6th edition. John D. Wiley & Sons, 360 pp.

Sinnes, A.C. 1979. *All About Fertilizers, Soils and Water*. Ortho Books. 112 pp. (Out of print)

Tisdale, S.L., W.L. Nelson, J.D. Beaton, and J.L. Havlin. 1993. *Soil Fertility and Fertilizers*, 4th edition. Macmillan Pub. Co. 634 pp.

Soil Survey Staff. Various dates. Soil surveys of Minnesota's Counties. (An individual report for each county). U.S. Gov. Printing Office.

Soil Survey Staff. 1983. Soil associations of Minnesota. U.S.D.A. Soil Cons. Serv. and Agr. Exp. Sta. Univ. Minn. Map at scale of 1:1,000,000 and text on back of map.

Additional Information is in Appendix 2.

chapter 3

fruits

chapter 3

FRUITS FOR THE HOME GARDEN
by Doug Foulk, Extension Educator, Horticulture

INTRODUCTION

Home fruit production provides the gardener with the opportunity to enjoy fresh, flavorful fruit of better quality than those shipped in from California or elsewhere. The University of Minnesota fruit breeding program continues to release cultivars that are delicious and winter hardy for the enjoyment of gardeners in colder climates.

This chapter sets forth some general guidelines for all fruits but deals primarily with tree fruit culture, as this topic is not covered concisely in current Extension publications. Almost any other fruit-related information you might want is available through the University of Minnesota Extension Service. **I highly recommend that you read the following publications:**

FO-1111	Apples for Minnesota and Their Culinary Uses
H200A*	Apple Russeting
P220A*	Apple Scab
P221B*	Black Rot Canker
P222C*	Cedar Apple Rust
P223F*	Fire Blight
P226S*	Sooty Blotch and Flyspeck on Apple and Pear
P244A*	Disease Resistant Apple Varieties
FS-1007-A	Apple Maggot Management in Home Gardens
FO-5625	Strawberries for the Home Garden
E215S*	Strawberry Insect Pests of the Home Garden
FS-1148	Strawberry Diseases
FS-1108	Raspberries for the Home Garden
FS-1152	Raspberry Diseases
E216R*	Raspberry Insect Pests of the Home Garden
FS-3463	Blueberries for the Home Landscape
FS-1122	Currants and Gooseberries in the Home Garden
FO-1125	Growing Stone Fruits in Minnesota
P240C*	Cherry Leaf Spot
P243P*	Plum Pockets
P417B*	Black Knot
FO-1103	Growing Grapes for Home Use
FO-0675	Home Fruit Spray Guide

* = Yard & Garden Brief

These publications may easily be found online at www.extension.umn.edu. Just click on the "Search" button near the top center of the screen and you'll be on your way.

fruits

OBJECTIVES

1. Understand the importance of site selection, soil preparation and proper planting for a successful fruit garden.
2. Understand the importance of and identify successful cultivars and rootstocks of fruits for Minnesota.
3. Understand mulching, pruning, watering, fertilization and other techniques for successful fruit production.
4. Be aware of the major insect and disease problems of fruits for Minnesota.

GUIDELINES FOR PLANNING THE SMALL FRUIT GARDEN

- Locate your fruit planting as close to your home as possible in full sun. Most fruits require a minimum 6 hours of direct sun per day and 8 hours is better. Avoid the north side of buildings and tree root zones.
- In selecting a site, avoid sites that are prone to early or late frost, low wet spots, and exposure to strong prevailing winds.
- Fruits thrive best in a fertile, sandy loam soil high in organic matter, but they will give good returns on the average garden soil under adequate fertilization and good cultural practices.
- Overcrowding frequently results in weak plants and low yields. It also makes insect and disease control more difficult.
- Special attention should be given to the selection of cultivars. They must be adapted to your soil and climatic conditions. If possible with out sacrificing too much yield or quality, select cultivars with the least insect and disease problems.
- Obtain the best nursery stock available. Buy only from reputable nurserymen who guarantee their plants to be true to name, of high quality, and packed and shipped correctly.

When purchasing plants, roots should be moist and have a bright, fresh appearance. Shriveled roots indicate that the plants have been allowed to freeze or dry out in storage or transit. Such plants seldom survive. Plant roots must be kept moist and free from freezing temperatures at all times.

If the plants cannot be set immediately, they should be kept either in cold storage or heeled in. Wrap them in a material that will prevent their drying out, and store them at a temperature just above freezing. Strawberry plants, in small quantities, may be held in the home refrigerator for a few days.

If refrigerated storage is not available, remove the plants from the bundle, and heel them in carefully in a trench of moist soil in a shaded location. Pack the soil firmly around the roots to eliminate all air pockets and to prevent the roots from drying out.

ESTABLISHING AND MAINTAINING THE PLANTING

Nothing causes more disappointment and failure in small fruit plantings than the lack of careful preparation and attention to detail at the time the plantings are established. For best results:

- Prepare the soil properly
- Set the plants carefully
- Create conditions favorable for new growth

If the planting is to be productive and long lived it must have:

- proper fertilization
- no competition from weeds or other plants
- control diseases and insect pests
- proper pruning

GROWING TREE FRUITS

Planning the Planting

Consider the mature size of the tree when designing the planting. Dwarf fruit trees lend themselves admirably to ornamental plantings as well as orchards. They come into bearing earlier than standard size trees, are winter hardy if planted with the graft union about 2 to 3 inches above the soil surface, occupy less space, and can be more easily pruned and sprayed with equipment normally available to the average homeowner. Most nurseries now carry dwarf and semi-dwarf apple trees of several cultivars that should be considered where space is at a premium.

Size of Planting

Space, site, size of family, available time and pollination requirements all determine size of the planting. Cover the range of fruits insofar as family preference, adaptability, and space permit. Never attempt to plant more than you can care for properly.

Tree Spacing

Tree spacing is an important factor, and to a large extent it influences selection of site and cultivars. They can be set farther apart if space allows, but, for best results, should not be set closer than the recommended minimums.

Site Selection

Importance of selecting the best site possible for fruit planting cannot be overemphasized. Good air drainage is essential. Cold air, like water, flows downhill. For this reason, fruit buds on plants set in a low spot are more likely to be killed than when the trees are planted on a slope. Frost pockets, low wet spots, and locations exposed to strong prevailing winds must be avoided. South facing slopes encourage early bud development and can sometimes result in frost damage.

Deep, well-drained soil with a pH of 6.0-7.0 and good fertility should be selected. A fertile, sandy loam or sandy clay loam is suitable for most tree fruits. Adequate drainage is the most important soil characteristic. Proper fertilization and cultural practices may easily improve poor soils. Improving soil with poor internal drainage is difficult and expensive. Fertile soil is desirable, and deep, well-drained soil is vital.

Cultivar Selection

Give special attention to the selection of cultivars for the home garden. They must be adapted to your soil and climatic conditions. If possible without sacrificing too much yield or quality, select cultivars with the fewest insect and disease problems. Several cultivars of the same kind of fruit maturing at different times may be planted to prolong the season. The value of certain cultivars for special uses such as freezing, canning, and preserving should be considered. Some fruit may be purchased in season from commercial growers more economically than you can grow them yourself.

Cross-pollination is necessary for satisfactory fruit set in many tree fruits. Cultivars that are cross fruitful should be selected. To be certain of adequate cross-pollination, plant at least two cultivars of apples.

Apple Rootstocks

Apples, like other tree fruits, will not produce trees with the same characteristics from seed. If you plant a seed from a Red Delicious apple; the fruit would likely be small, unattractive, and of poor quality. Therefore, apple trees are propagated vegetatively by either budding or grafting scion wood of the desired cultivar on a rootstock. The rootstock and scion cultivars both maintain their respective genetic identity but are joined at the graft union and function as a unit.

Traditionally, apple trees have been propagated on rootstocks from apple seeds. More recently, increasing use is being made of vegetatively propagated or

"clonal" rootstocks that have inherent advantages over seedlings. Three major considerations in rootstock selection are:

Size control: Probably the most widely accepted reason for the use of clonal rootstocks is tree size control. By proper selection of rootstock we can determine mature tree size. For example, the same cultivar of apple will produce a 14x16 foot tree on the rootstock cultivar, Malling Merton (MM) 111, down to a dwarf tree of 7x8 feet on a Malling (M)9 rootstock. Intermediate sizes can be attained by other rootstocks such as M 26 and M 7 (Figure 1).

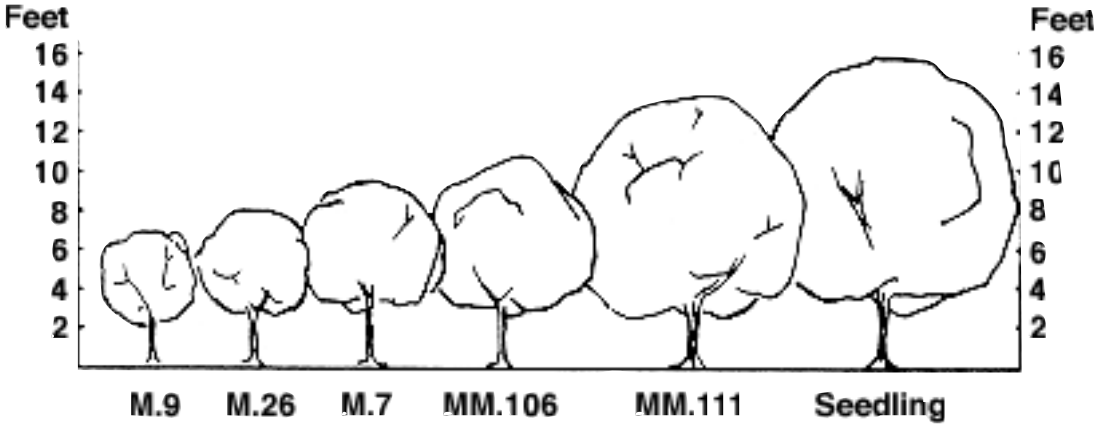


Figure 1: Approximate heights of apple trees grown on various rootstocks.

Unfortunately, many apple trees offered to homeowners are labeled as dwarf trees but the buyer has no idea of how dwarfing the rootstock may be. Types from smallest to largest: M27, M9, Bud 9, M26, M7, MM111, seedling.

Precocity: The earliness at which a tree produces fruit is also directly affected by the rootstock. Trees on seedling rootstocks usually do not begin fruiting until they are 7-10 years old. Trees on M 9 rootstock will often produce crops in 2-3 years. Other rootstocks are intermediate in this regard. Usually, the more dwarfing the rootstock, the earlier the tree will bear fruit.

Stability: A major consideration in selecting apple rootstocks is the degree of anchorage provided. For example, trees on M 9 rootstock are very small but because of brittle roots, must have some type of support. This can consist of a post, a trellis, or other means of holding the tree upright. The semi-dwarfing M 7 rootstock may require support for the first few years but is often grown without support. The more vigorous MM 111 rootstock does not require support and is thus like a seedling rootstock.

Buying Trees

Obtain the best nursery stock available. Buy only from reputable nurseries that guarantee their plants to be true to name, of high quality, and packed and shipped correctly. Beware of bargains. High prices do not necessarily mean high quality, but good, well-grown nursery stock is not cheap.

One-year-old trees are usually preferred. A common mistake made by many homeowners is to select oversized or ready-to-bear nursery trees. Experience has shown that younger trees bear almost as soon, are easier to keep alive, and develop into more healthy, vigorous trees than do the oversized stock. The older trees cost nurseries more to grow and are sold for higher prices, but are usually worth less than younger trees.
When purchasing apple trees on dwarfing rootstock, be sure to specify the rootstock desired.

PLANTING THE ORCHARD

Time of Planting

Spring planting is recommended for Minnesota.

Handling Nursery Stock

Roots of nursery stock should never be allowed to freeze or dry out. When your order arrives, unpack the bundles immediately and inspect the trees. The roots and packing material should be moist. Check to see if the bark is withered. Withered bark indicates the trees have been allowed to dry out in storage or in transit.

If trees cannot be planted immediately, they may be held dormant in the original packing in refrigerated storage for a week or two. If refrigerated storage is not available, trees should be taken out of the bundle and heeled-in carefully in a trench of moist soil in a shaded location. Keeping roots in a container of water for 2 or 3 days until the tree is planted is an excellent idea.

Planting the Trees

Preparation of the soil where fruit trees are to be planted should be as thorough as preparation of the soil for a vegetable garden or ornamental plantings. If the places selected for trees are in a lawn, prepare the site by removing the sod. Loosen the soil by tilling or spading an area three to five times wider in diameter than the width of the root system, and only to the depth of the root system.

Dig a hole in the center of this circle that is one foot larger in diameter than the root ball and is exactly as deep. Maintain undisturbed (not loosened) soil beneath the root ball to prevent the tree from settling. If the tree is containerized and is somewhat pot bound, remove the pot and make a vertical slice up each quarter of the root ball to a depth of about one inch. Cut an X across the bottom of the soil ball as well. Gently loosen some of the roots.

If the tree is bare-root, prune the roots of young trees only where necessary to remove broken and damaged ones or to head back some that are excessively long. Should a tree be so badly scarred or damaged that there is doubt of its survival, it is wise to discard it.
Set the tree so the graft union is 2-3 inches above the soil line. Never set it so deep that the union of the scion and rootstock is below ground level when the hole is filled.

Backfill around the roots with the soil that was removed. Lightly pack or water the soil during this process to eliminate air pockets.

ORCHARD MANAGEMENT

Cultural Practices

Weed control is essential for young fruit trees. Weeds must be eliminated so they will not compete for available moisture and fertilizer. To accomplish this, the use of mulch is recommended. The mulched area should extend a little beyond the spread of the branches.

When trees are planted in rows, the area between the rows may be allowed to grow in sod or used for interplanting with low-growing vegetables or strawberries. There is no objection to this practice in the home orchard, provided ample plant nutrients and moisture are available for proper development of the fruit trees. Under sod culture, frequent close mowing during the growing season is desirable. This reduces competition for necessary moisture and plant nutrients, and also aids in disease and insect control.

Fruit trees, especially those on dwarfing rootstock, are becoming prominent in home landscape designs. Under lawn culture, fruit trees can be given more attention than is usually convenient under other systems of culture. Equipment and materials for watering, pruning, spraying, and other cultural practices are essentially the same as those required for landscape plantings. It is good prac-

tice to apply a mulch or cultivate lightly for the first year or two, or until the tree has become firmly established. Lawn grass, if kept closely clipped, may be allowed to grow around the base of the tree in the third year.

Chemicals for weed control should be used with extreme caution in the home garden. Careless use can result in severe injury to fruit trees and nearby ornamental plantings. See your Extension Educator for the latest recommendations.

Fertilization

As a rule, no fertilizer is recommended or needed at planting time. Shortly after the newly-planted tree becomes established and growth begins, apply ¼ to ½ lb. of a 16 or 20% nitrate fertilizer in a circle around the tree, about 8 to 10" from the trunk. Usually fruit trees show no increased growth or fruitfulness from the use of any nutrient element except nitrogen. The tree requires other elements; however, only in special cases are they deficient in the soil. Deficiencies are more likely to occur on light, sandy soils.

Where a good compost is applied regularly, the use of chemical fertilizer to supplement natural fertility of the soil may not be necessary. Over fertilization with either organic or inorganic materials should be avoided. Excessive vegetative growth will result, usually accompanied by delayed fruiting and possible winter injury.

Where poor growth results after the use of nitrogen only, other elements may be needed. Contact your local Extension Agent for fertilizer recommendations.

Beginning in the year after planting, fertilizer may be applied either after the leaves have fallen or in early spring about 3 or 4 weeks before active growth begins. On light, sandy soils, it is best to delay application until early spring. When trees are grown in a lawn area, delay fertilizing lawn until after trees are dormant to avoid late summer growth.

Apply one ounce of actual nitrogen at fertilization time for each tree of year age, up to 16 ounces. To calculate the amount of fertilizer to apply, divide the actual nitrogen needed by the percentage of nitrogen in the fertilizer. The usual method of application is to scatter fertilizer evenly under the tree, starting about 2' from the trunk and extending to just beyond the tips of the branches.

Terminal growth and general vigor of the individual tree should be observed closely. Where growth the past year was short, increase the amount of fertilizer by 25%. If growth was excessive, reduce the amount or withhold it entirely for one year.

Pruning

The general purpose of pruning fruit trees is to regulate growth, increase yields, improve fruit size and quality, and reduce production costs. Pruning is necessary to shape the trees for convenience of culture and for repair of damage. The methods for pruning fruit trees are designed to produce a strong framework and maximum yield of high quality fruit. Most pruning is done during the dormant season, preferably just before active growth begins in the spring. At this time, pruning wounds heal faster, flower buds can be easily recognized, and injury from low winter temperature is avoided.
Although pruning procedures vary according to the type, age, and cultivar, all newly planted fruit trees should be pruned in the spring before growth starts. This is necessary to stimulate lateral bud development from which to select good scaffold limbs.

Thinning

Apple trees frequently set more fruit than they can mature to a desirable size. By removing excess fruit, a process known as "thinning," this difficulty can be overcome. Thinning not only allows for an increase in size of the remaining fruit on the tree, but also improves fruit color and quality, reduces limb breakage, and promotes general tree vigor. Another benefit from thinning fruits is that it permits more thorough spraying or dusting for effective disease and insect control.

Apples should be thinned as soon as possible after the fruit has set. If full benefits are to be obtained, thinning should be completed within 40 days after full bloom. A distance of 6 to 10" between fruits is recommended. The center apple of a cluster is usually the largest and the best apple to leave.

Rodent Control

Mice and rabbits may cause serious damage to the home fruit planting. They chew off the bark at ground level or below and often completely girdle a tree, causing it to die. Most of this damage takes place during winter. Keep mulch pulled away from the base of the tree, and examine it frequently for the presence of mice.

Tree guards can be used to keep mice and other rodents away from the trunk. Galvanized screen or "hardware cloth" with a ¼" mesh is frequently used. A roll 36" wide may be cut lengthwise, forming two 18" strips. By cutting these strips into pieces 14" long, guards 14 by 18" are obtained. Roll or bend the strip around the trunk of the tree so that the long side is up and down the trunk and the edges overlap. Twist a small wire loosely about the center to prevent the strip from unrolling. Push the lower edges well into the ground. This metal guard will last indefinitely and can be left in place all year.

Tar paper, building paper, sheets of magazines, and aluminum foil can also be used in a similar manner, but must be removed in the early spring to prevent damage to the tree. Perforated plastic guards are also available. Like the metal guards, these can be left in place year round.

Other methods of rodent control have been successful. Ordinary whitewash has given good results in some instances. Some commercial growers use a repellent wash recommended by the USDA, containing equal parts of fish oil, concentrated lime sulfur, and water. All these materials may be applied with a paintbrush to the trunk of the tree from the ground up into the scaffold limbs.

Tree Fruit Problems

For significant insect or disease problems it may be necessary to follow a spray program. Information on the use of chemicals for such a program is available from your county Extension office.
Apple pests and diseases include:

- apple scab
- cedar apple rust
- apple maggot
- codling moth
- plum curculio

To be successful with your spray program, spray at the proper time and do it thoroughly. Leave no portion of the tree unsprayed. To make the job easier and to ensure adequate coverage, thin out excessive growth and remove all dead and weak wood. Cut old trees back to 20' or less, if possible. Train younger trees so they reach a height of no more than 18 feet.

Semidwarf and dwarf trees should be considered when making your planting. Their small size makes the task of spraying easier. This factor should not be overlooked in the selection of cultivars.
Two common problems that may be confused are winter injury and fireblight. The following symptoms can be used to distinguish between the two:

Winter injury (can also take form of sunscald on trunk)
- occurs early in growing season (first warm weather)
- growth wilts and dies shortly after bud-break

Fireblight-a disease caused by a bacterium
- Dieback starts at the tip and works into the tree, resulting in characteristic 'shepherd's crook'

Sanitation

Adopt good sanitation practices. The destruction of harboring places for insects and diseases plays a large part in the control program. Conditions that encourage mice should also be eliminated.

Practices to include in an orchard sanitation program include:

- Collect and burn debris.
- Remove and destroy all dropped fruit.
- Rake and remove fallen leaves.

FREQUENTLY ASKED QUESTIONS

Insects

1. *When and how can I treat apple maggots?*
   Manage apple maggots by trapping and spraying adult flies in July; once they lay eggs in the apple flesh there is no effective management. Trap flies (1/4- inch long with black/white banding on wings and a white spot on body) with sticky red sphere traps, hanging about five in a standard tree. Hang traps by July 1. Trapping is less effective than spraying. Insecticide sprays help manage flies before they lay eggs. Use phosmet (Imidan), diazinon, or carbaryl (Sevin), spraying to cover all surfaces of leaves and fruit. Do not spray before July 1. Timing methods: Hang a trap and spray whenever you have trapped at least 5 flies in one week. Or beginning July 1, spray two days after rainfall or watering of 1/2-inch or more (less effective than trap test). Or, spray regularly every 10-14 days beginning July 1 (most effective but uses most insecticide). Do not pick apples sooner than the time indicated on the insecticide label. Maggots overwinter in cocoons in the ground. Pick up fallen apples and bury them at least a foot deep (or make cider, cook or feed to livestock); encourage neighbors with apple trees to do the same. (Apple Maggot Management in Home Gardens, FS-1007)

Diseases

2. *How can I prevent my apples from becoming scabby?*
   Controlling apple scab includes both cultural and chemical practices. Cultural control includes sanitation (removing infected leaves and apples), and annual pruning to increase airflow and reduce moisture. Chemical control is required during wet seasons, but may not be required during dry seasons if good cultural practices are followed. (Yard and Garden Brief: Apple Scab. For detailed directions on fungicide use, see Home Fruit Spray Guide, FO-0675.)

3. *What are the black growths on my cherry tree branches? Will they kill my tree?*
   Questions to ask: What do the growths look like? Are they on the stem or branch? One side of the branch or all around it?
   Black growths on cherry trees are usually black knot. This fungus readily infects many species of Prunus, including chokecherries, plums, peaches and apricots. Usually it occurs on branches, but may also occur on the main stem. Initial infections appear as swellings, while older infections appear as cracked, hardened, black knots. If infection reaches main stem it may eventually cause the tree to die. Control measures include pruning out infected branches and applying a dormant application of lime sulfur or Bordeaux mixture to the tree. Branches should be pruned at least six inches below the swelling or knot in late winter. Also, prune new infections developing during the growing season. Pruning alone may be effective in some cases. (Yard and Garden Brief: Black Knot)

4. *My plums are swollen and enlarged. What caused them to become deformed? Can I prevent this in the future?*
   Plum fruit that appears hollow, enlarged and swollen is probably infected by a fungus, known as plum pockets. This disease causes flesh to be thick and

spongy. Control measures include sanitation (removal of infected fruit and branches), maintaining tree vigor, and possibly use of a fungicide such as Bordeaux mixture in early spring prior to bud break. However, the problem usually does not require fungicide control. (Yard and Garden Brief: Plum Pockets)

5. *My raspberry plants have spots on the canes and don't produce fruit. How can I get rid of the spots and get more raspberries?*
   Questions to ask: Ask details about appearance. If necessary ask for a sample. Several diseases on raspberries infect canes. Since they look similar it's difficult to determine which disease is present and which fungicide should be applied. Common management strategies include rouging of diseased plants, removing and destroying old canes after harvest, thinning new canes in a row to two per foot, or six plants per hill, carefully cultivating to avoid root damage, planting in well-drained soil, and using fungicides during the growing season. Prune plants only when dry weather is expected for three days. Possibly apply a dormant spray of line-sulfur or Bordeaux mixture. (Raspberry Diseases, FS-1152)

6. *What are the orange, gooey structures on my cedar tree? Will they kill my tree? How do I get rid of them?*
   Questions to ask: When did structures begin to appear? Do you see any other brown, woody structures on the tree? What were weather conditions like when the growths appeared? Are there any apple trees in the area? The fungus causing this disease is cedar apple rust, which occurs on both cedar and apple trees, and requires both hosts to survive and reproduce. The orange gelatinous structures growing on the cedar branches are known as telial horns. The brown woody structures, from which horns appear, as known as galls. These orange structures are composed of fungal material and appear in spring during wet periods. Galls typically do not damage the cedar and may be pruned out. Older, nonactive galls will be brown, shriveled and woody. The disease can cause problems on apple trees and may require chemical control to prevent infection. See publications for details. (Yard and Garden Brief: Cedar-Apple Rust; and Home Spray Fruit Guide, FO-0675)

General

7. *Where can I get/how can I grow hardy peaches?*
   Peaches aren't hardy enough for Minnesota winters. (Growing Stone Fruits in Minnesota Home Gardens, FO-1125)

8. *Why do my blackberries survive the winter but don't make berries?*
   Blackberries aren't hardy here. The canes will survive our winters but the flower buds will not, so they won't produce any fruit.

9. *What's the best apple to grow in Minnesota?*
   Some favorites include: Honeycrisp, which stores for up to 10 months in the refrigerator; Fireside, Sweet Sixteen, Haralson, Prairie Spry, Liberty and Freedom. Look for disease-resistant trees. (Apples for Minnesota and Their Culinary Uses, FS-1104; Yard and Garden Brief: Disease Resistant Apple Varieties)

10. *Do you need more than one tree to get fruit when growing apples, plums and apricots?*
    Yes. Use two varieties in each planting to serve as a source of pollen for the other variety. Cross-pollination is possible only when varieties bloom at about the same time. When purchasing trees, be sure to ask what variety would be a good pollinator. (Growing Stone Fruits in Minnesota Home Gardens, FO-1125)

11. *What do I need to do to grow blueberries?*
    Plants grow best in a sunny location. They'll tolerate partial shade, but will produce less fruit. Plants require highly acidic soil (pH of 4.0 to 5.0) that is well drained, loose and high in organic matter. If you have highly alkaline soil you may not be able to grow them. (If you don't know the pH of your soil, you can have soil analyzed at the University of Minnesota Soil Testing

Facility.) For northern gardens, recommended cultivars are Northblue, Northcountry, Northsky and St. Cloud.
Plant more than one variety for pollination. Prepare soil and plant young bushes in late April or early May, three to four feet apart, in a large hole to encompass all roots, and water thoroughly. Mulch on top. For the first two years, remove flowers in spring to encourage vegetative growth for healthy plants. Fertilize as needed. (Blueberries for Home Landscapes, FS-3463)

12. *When do I cut back my raspberries?*
It depends on the type of raspberry you have. Summer-bearing red and yellow raspberries: After the last harvest, cut all canes that have produced fruit to ground level and remove them. Fall-bearing raspberries: If you want only a fall crop, cut all canes off at the base before growth begins in spring. If you want summer and fall crops, thin canes as described for summer-bear ing raspberries. (Raspberries for the Home Garden, FS-1108)
13. *Can I grow cherries in Minnesota? Which ones work here?*
Tart cherries and Nanking cherries grow here. They are self-fruitful so no pollinator is needed. Tart cherry varieties for Zone 4 are Mesabi, a semi-dwarf; and Meteor and North Star, both dwarf varieties. (Growing Stone Fruits in Minnesota Home Gardens, FO-1125)

RESOURCES

University of Minnesota Extension Service Publications

Master Gardeners receive many of these publications as a part of their training or Core Course. New publications are continually added to the Distribution Center. The most up-to-date listing is available online at http://www.extension.umn.edu. Click on Publications, or search the site for publications of interest. Many of these fact sheets can be read online and are also available from county extension offices. Longer publications or those containing many photographs or illustrations may not be available online. Master Gardeners should order publications through their home county extension office. Public orders may be placed by calling:
1-800-876-8636 (outstate) or 612-624-4900 (local).

BU 0532	Grafting & Budding Fruit Trees
FO 0432	Growing Apples and Pears in Minnesota
FO 1103	Growing Grapes for Home Use
FS 1007	Apple Maggot Management in Home Gardens
FO 1111	Apples for Minnesota
FO 5625	Strawberries for the Home Garden
FS 1104	Fruits for Minnesota
FS 1108	Raspberries for the Home Garden
FS 1122	Currants and Gooseberries in the Home Garden
FS 1125	Growing Stone Fruits in Minnesota
FS 1133	Minnesota's Wild & Edible Fruits
FS 1148	Strawberry Diseases
FS 1152	Raspberry Diseases
FS 3463	Blueberries for the Home Landscape
MI 0574	Common Fruit Insects
FO 0675	Home Fruit Spray Guide

Yard & Garden Briefs

Apple Russeting
Apple Scab
Black Rot Canker
Cedar-Apple Rust
Cherry Shot Hole
Fireblight
Garden Huckleberry
Insect Pests of Cultivated Strawberries
Leaf Spot and Leaf Scorch of Strawberry
Nectria Canker
Postharvest Diseases of Fruits and Vegetables
Raspberry Insect Pests
Sap and Fungus Beetles
Sooty Blotch and Flyspeck on Apple Fruits
Sooty Mold
Thinning Fruit Trees

chapter 4

vegetables

chapter 4

VEGETABLES

by Beth Jarvis, Interim Extension Educator

INTRODUCTION

Vegetable gardening is very fulfilling. The rewards of producing a successful garden include saving money in the family food budget, enjoying foods picked at their flavor peak, growing unique or unusual vegetables, and controlling pesticides used.

This chapter is a comprehensive overview of planning, planting and care of the vegetable garden. Several different planting styles, such as small space and wide row, are also discussed. Growing tips for specific vegetable families are included. Commonly encountered problems are also listed.

LEARNING OBJECTIVES

Learning objectives of this section for Master Gardeners are to:

1. Understand the importance of site selection, soil preparation and proper planting for a successful vegetable garden.
2. Understand the importance of and identify successful varieties and cultivars of vegetables for Minnesota.
3. Understand crop rotation, mulching, pruning, watering, fertilization, and other techniques for successful food production.
4. Be aware of the major insect and disease problems of vegetables for Minnesota.

PLANNING GUIDELINES

When planning your garden, it is important to ask a few basic questions:

- Who will be doing the work?
- What do you and your family like to eat?
- How do you plan to use the produce from your garden?
- How much space is available?

Be realistic about the amount of free time you have available. If you have limited time or this is your first garden, think small. There's nothing more discouraging than facing a large mid-summer garden overrun with weeds. It's better to have a small garden that's well tended than a large weed patch. You can usually expand the garden space next year if you have the time.

Limit a first garden to family favorites. There's no point in raising a lot of something your family will not eat. Consider the potential yield of what you plant. Two zucchini plants can feed an entire neighborhood.

Will you be freezing, canning, or drying extra produce? A bountiful crop of tomatoes can quickly turn into a headache if the supply outstrips your family and friends' ability to consume them. Consider donating extra produce to a local food shelf.

A small garden space, intensively planted, can yield an amazing quantity of food. Lettuce and parsley can be incorporated into flower gardens as edging plants. Tomatoes and cucumbers can also be grown in large containers. Many vining crops can be trained to grow on trellises, reducing the amount of space needed.

Some Additional Planning Hints

Plan the garden on paper first. Draw a map showing arrangement and spacing of crops. If you wish to keep the garden growing all season, you may need a spring, summer, and fall garden plan.

Plan the garden and order seeds by January or February. Some plants may be started indoors as early as mid-February.

In your plan, place tall and trellised crops on the north side of the garden so they won't shade the shorter vegetables.

Group plants by length of growing period. Plant spring crops together so that later crops can be planted in these areas when the early crops mature. Long season, space hogging crops such as squash can be planted near early crops that will have been harvested by the time the later season crops spread out. Consider length of harvest as well as time to maturity. Place perennial crops to the side of the garden where they will not be disturbed by annual tillage.

LOCATING THE GARDEN

Vegetables grow best in a level area with loose, well-drained soil, and at least six hours of sun (8-10 hours is ideal).

Use contour rows or terraces on sloped or hillside sites to avoid erosion. South-facing slopes are warmer and less subject to damaging frosts.

Avoid placing the garden in low spots, at the base of a hill, or at the foot of a slope bordered by a solid fence. Such areas are slow to warm up in the spring and frost settles in these places since cold air naturally drains into low areas. If there is a creek nearby, the water table may be very high or the area subject to flooding.

Avoid windy locations; if you must plant in a windy spot, build or grow a wind-break.

Locate near a good and easily accessible supply of water.

Choose a spot near your home so it is convenient to work in the garden or to harvest.

Avoid planting near trees and shrubs; they compete for nutrients and water, and may cause excessive shading.

Sites too near buildings may result in plants not receiving enough sunlight. Observe shading patterns through the growing season if possible before starting the garden. If you have a shaded area you wish to use anyway, plant it in shade-tolerant crops. Increase effective light if needed by providing reflective surfaces around plants.

Try not to plant related vegetables in exactly the same location in the garden more often than once in three years. Rotation prevents the buildup of insects and disease. Use old plans as guides for rotating crops.

Avoid locations near busy roads. Airborne pollutants from automobile exhaust can contaminate vegetables, especially leafy types.

Avoid locating the garden on a site where buildings with lead paint have stood; soil lead may be present in toxic amounts. If you are unsure about your chosen location, have the soil tested for lead content.

SOIL PREPARATION

The ideal vegetable garden soil is deep, friable, well drained, and has high organic matter content. Proper soil preparation provides the basis for good seed germination and subsequent growth of garden crops. Careful use of various soil amendments such as compost or peat can improve garden soil and provide the best possible starting ground for your crops.

SEEDS

Seed purchased from a dependable seed company will provide a good start. Keep notes about the seeds you purchase—their germination qualities, vigor of plants, and tendencies toward insects and disease. From this information you can determine whether one seed company is not meeting your needs, or whether the varieties you have chosen are unsuitable for your area or gardening style. For example, if powdery mildew is a big problem on squash family plants in your area, the next year you may want to look for mildew-resistant varieties.

Saving Seed

There are certain considerations that should be kept in mind when saving seed. Hybrid varieties are not likely to be the same as the parent plants; therefore, only open-pollinated varieties should be used for home seed production. Some seed dealers have responded to the increasing interest in seed-saving by clearly marking open-pollinated varieties in their catalogs.

Another consideration in saving seed is the possibility of carrying seed-borne diseases into the next year's crop. Many commercially grown seeds are grown in dry areas unsuitable to fungal, viral and bacterial diseases which may be present in your region. Take care to control diseases which can be carried in seed.

And finally, if you've ever saved squash seed during a season in which you had more than one type of squash planted, you have probably seen the weird results that may be obtained from cross-pollination! Saving seeds from cross-pollinated crops is not generally recommended for the novice because of problems with selection, requirements for hand pollination and isolation, biennial habits, and genetic variability.

Some common self-pollinated plants from which seed may be saved include lettuce, beans and peas, herbs, and tomatoes. For all kinds of saved seeds, be sure to mark the storage containers clearly with permanent (preferably waterproof) ink, indicating the variety and date saved.

Seeds will remain viable for some time if properly stored. To test for germination, sprout seeds between moist paper towels; if germination is low, either discard the seed or plant enough extra to give the desirable number of plants.

Viability of vegetable seeds

Average Number of Years Seeds May be Saved

Vegetable	Years	Vegetable	Years
Asparagus	3	Leek	1
Bean	3	Lettuce	5
Beet	4	Muskmelon	5
Broccoli	5	Mustard	4
Brussels sprouts	5	Okra	2
Cabbage	5	Onion	1
Carrot	3	Parsley	2
Cauliflower	5	Parsnip	1
Celery	5	Pea	3
Chinese cabbage	5	Pepper	4
Collard	5	Pumpkin	4
Corn	5	Radish	5
Cress, water	5	Rutabaga	5
Cucumber	5	Spinach	5
Eggplant	5	Squash	5
Endive	5	Sweet corn	1
Kale	5	Tomato	4
Kohlrabi	5	Turnip	5
Watermelon	5		

Depth of Planting

As a general rule, vegetable and flower seeds should be covered about 4-5 times their lateral diameter or width (not their length). There are exceptions, however; read the packet directions. Some seeds require light for germination and should not be covered at all. These instructions apply to seeds planted both inside and out.

Starting Seed Outdoors

Many seeds may be sown directly in the garden. Seedlings can emerge quite easily from a sandy or organic soil. If garden soil is heavy with a high silt and/or clay content, however, the seeds should be covered only 2-3 times their diameter. In such soils it may be helpful to apply a band of sand, fine compost, or vermiculite 4 inches wide and 1/4 inch thick over the row after seeds are planted. This will help retain soil moisture and reduce crusting, making it easier for seedlings to push through the soil surface.

Soil temperature has an effect on the speed of seed germination. Some such as onions, lettuce, and spinach benefit from cool temperatures; others such as sweet corn and cucumber will rot before they have a chance to sprout if planted too early.

Row Planting

Sow seed thinly; it may help to mix very small seed with coarse sand to distribute the seeds more evenly. Draw soil over the seed, removing stones and large clods. Firming soil over seeds improves uptake of soil moisture, hastening germination. Water the seeds in to improve soil/seed contact. When plants have grown to 4-6” tall, thin according to seed packet instructions to provide adequate room for growth.

Broadcast Planting

Many crops may be sown in wide rows or beds instead of in long, single rows. Crops such as spinach, beans, peas, beets, lettuce, and carrots are especially suited to this type of culture. Seed should be sown evenly over the area, then raked in with a rake or three-pronged hand cultivator. Firm soil over the seeds. Thin young plants to allow room for growth.

Hill Planting

Larger vegetables such as melons, squash, corn, and cucumbers may be planted in hills. Soil is mounded to a foot or so in diameter, at the recommended spacing. Plant 4-6 seeds per hill, firming the soil well. Thin the seedlings to 3-5 plants per hill.

TRANSPLANTS

Most gardeners use transplants to give long season plants a chance to grow to maturity under their preferred weather conditions, or just to lengthen the harvest. Others start their own transplants for a larger choice in varieties and the control of plant production from seed to harvest.

Annuals

Transplants of annual vegetables and flowers should be stocky, healthy, free from disease, and have good roots. They should not be too small or too mature (tomatoes will transplant all right with fruits already on them, but many other plants will drop flowers or fruit after transplanting). Be sure plants have been hardened-off so that they will easily adapt to environmental change. Successful transplanting is achieved by interrupting plant growth as little as possible. This is one of the advantages of using peat pots or peat pellets, which do not have to be removed when transplanting. When transplanting peat pots, remember to tear the rim off the peat pot down to the soil line in the pot. Exposed portions of peat pots dry out in the wind and wick water from the rest of the pot.

Transplant on a shady day, in late afternoon, or in early evening to prevent wilting. It helps to water the plants several hours before transplanting.

Dig a hole large enough to hold the roots of the plants. Set the plants slightly deeper than previously planted and at recommended intervals. Tomatoes are an exception to the rule of how deep to plant; they will develop roots all along the stems, and you can plant deep enough to leave only two or three sets of leaves exposed. Press soil firmly around the roots of transplants.
Remember to use cutworm collars made from juice cans opened at both ends, strips of paper, or even aluminum foil on transplants susceptible to cutworm damage.
For a few days after transplanting, protect the plants from wind and sun by placing newspaper or cardboard on their south sides, or by covering with baskets or flower pots. Water the plants once or twice during the next week if there is insufficient rain.

Perennials

When buying small fruit plants and perennial crowns such as asparagus, order early or buy from reliable local outlets. Discount department stores often allow plants to dry up, so watch for this, especially if you are buying sale plants. Select varieties that will do well in your growing conditions. For perennial plants it will pay to do some research to find out what the major disease and insect pests are and buy resistant varieties. Dormant bareroot plants and one- or two-year-old crowns are preferred. Look for roots that are full, slightly moist, and have color. Roots that are dry brown or soggy black are indicative of poor storage and will probably not give good results. Check crowns for signs of viable buds. Inspect plants for signs of insects or disease. If you receive plants by mail which are not satisfactory, do not hesitate to write to the dealer.

Once you have the plants, keep the roots moist (but not soaking wet) by misting occasionally, and do not allow them to freeze or be exposed to high temperatures. If it is necessary to keep the crowns for more than a few days, place in cold storage (not freezing) or else heel in a trench of moist soil in a shaded location. Pack soil firmly against roots to eliminate any air pockets.

Transplant crowns according to directions, digging holes large enough to give the roots plenty of room to spread. Remove any roots which are discolored or dried out. Once transplanted, shade the plants if necessary and water when needed. Extra care at the beginning of their growth will result in productive, healthy plants.

CARE OF THE GARDEN

Watering

Irrigation practices, when properly used, can benefit the garden by:

1. Aiding in seed emergence.
2. Reducing soil crusting.
3. Improving germination and plant stand.
4. Reducing wilting and checking of growth in transplants.
5. Increasing fruit size of tomato, cucumber, and melon.
6. Preventing premature ripening of peas, beans, and sweet corn.
7. Maintaining uniform growth.
8. Improving the quality and yields of most crops.

A healthy plant is composed of 75-90 percent water, which is used for the plant's vital functions, including photosynthesis, support (rigidity), and transportation of nutrients and sugars to various parts of the plant. During the first two weeks of growth, plants are becoming established and must have water to build their root systems.

While growing, vegetable crops need about an inch of water per week in the form of rainwater, irrigation water, or both from April to September. Keep a rain gauge near the garden and supplement rainfall with irrigation water if needed. There are ways to reduce the amount of water you have to add. (See below.)

During dry periods, one thorough watering of 1-2 inches of moisture each week is usually enough for most soils. Soil should be wetted to a depth of 5-6 inches each time you water and not watered again until the top few inches begin to dry out. Average garden soil will store about 2-4 inches of water per foot of depth.

Critical watering periods for selected vegetables are:

Asparagus	Spear production, fern development
Broccoli, Cabbage, Cauliflower	Head development
Beans, Peas	Pod filling
Carrot	Seed emergence, root development
Corn	Silking, tasseling, ear development
Cucumber	Flowering, fruit development
Eggplant, Tomato	Flowering, fruiting
Lettuce	Head development; moisture should be constant
Melons	Flowering, fruit development

Fertilization

The amount of fertilizer to apply to a garden depends on the natural fertility of the soil, the amount of organic matter present, the type of fertilizer used, and the crop being grown. The best way to determine fertilizer needs is to have the soil tested. Soil testing is available through your local extension educator, through private labs, and with soil test kits which can be purchased from garden shops and catalogs.

INTENSIVE GARDENING METHODS

The purpose of an intensively grown garden is to harvest the most produce possible from a given space. Intensive gardening is not just for those with limited garden space; rather, an intensive garden concentrates work efforts to create an ideal plant environment, giving better yields with less labor.

A good intensive garden requires early, thorough planning to make the best use of time and space in the garden. Interrelationships of plants must be considered before planting, including nutrient needs, shade tolerance, above- and below-ground growth patterns, and preferred growing season. Using the techniques described below, anyone can develop a high-yielding intensive garden.

The Raised Bed

The raised bed or growing bed is the basic unit of an intensive garden. A system of beds allows the gardener to concentrate soil preparation in small areas, resulting in effective use of soil amendments and creating an ideal environment for vegetable growth.

Beds are generally 3-4' wide and as long as desired. The gardener works from either side of the bed, reducing the incidence of compaction caused by walking on the soil.

Soil preparation is the key to successful intensive gardening. Humus-rich soil will hold extra nutrients, and existing elements that are "locked up" in the soil are released by the actions of earthworms, microorganisms, and acids present in a life-filled soil, making them available for plant use.
If your soil is not deep, double-dig the beds for best results. Remove the top twelve inches of soil from the bed. Insert a spade or spading fork into the next 10-12" of soil and wiggle the handle back and forth to break up compacted layers. Do this every 6-8" in the bed. Mix the top soil with a generous amount of compost or manure, and return the mixture to the bed. It should be somewhat fluffy and may be raised slightly. To create a true raised bed, take topsoil from the neighboring pathways and mix it in as well.

Space plants at equal distances from each other on all sides, so that leaves will touch at maturity. This saves space, and the close plantings reduce moisture loss from surrounding soil.

Vertical Gardening

The use of trellises, nets, strings, cages, or poles to support growing plants makes vertical gardening possible.

Vining and sprawling plants such as cucumbers, tomatoes, melons, and pole beans are obvious candidates for this type of gardening. Some plants entwine themselves onto the support, while others may need to be tied.

Vertical planting will cast a shadow, so beware of shading sun-loving crops, or take advantage of the shade by planting shade-tolerant crops near the vertical ones.

Plants grown vertically take up much less space on the ground, and though the yield per plant may be (but is not always) less, the yield per square foot of garden space is much greater.

Because vertically growing plants are more exposed, they dry out faster and may need to be watered more frequently than if they were allowed to spread over the ground. This fast drying is also an advantage to those plants susceptible to fungus diseases.

A higher rate of fertilization may be needed, and soil should be deep and well-drained to allow roots to extend vertically rather than compete with others at a shallow level.

Interplanting

Interplanting is the growing of two or more types of vegetables in the same space at the same time.

Proper planning is essential to obtain high production and increased quality of the crops planted. To successfully plan an interplanted garden the following factors must be taken into account for each plant:

- length of the plant's growth period
- its growth pattern (tall, short, below- or above-ground)
- possible negative effects on other plants
- preferred season
- light, nutrient, and moisture requirements

Interplanting can be accomplished by alternating rows within a bed (plant a row of peppers next to a row of onions), by mixing plants within a row, or by distributing various species throughout the bed.

Long season (slow maturing) and short season (quick maturing) plants like carrots and radishes, respectively, can be planted at the same time. The radishes are harvested before they begin to crowd the carrots.

An example of combining growth patterns is planting smaller plants close to larger plants, radishes at the base of beans or broccoli.

Shade tolerant species like lettuce, spinach, and celery may be planted in the shadow of taller crops.

Heavy feeders, such as cabbage family crops, should be interplanted with less gluttonous plants such as lettuce and spinach.

Interplanting can help keep insect and disease problems under control. Pests are usually fairly crop-specific; that is, they prefer vegetables of one type or family. Mixing families of plants helps to break up large expanses of the pest-preferred crop, helping to contain early pest damage within a small area, thus giving the gardener a little more time to deal with the problem.

Succession and Relay Planting

Succession planting is an excellent way to make the most of an intensive garden. To obtain a succession of crops, plant something new in spots vacated by spent plants. Corn after peas is a type of succession.

Planting a spring, summer, and fall garden is another form of succession planting. Cool season crops (broccoli, lettuce, peas) are followed by warm season crops (beans, tomatoes, peppers), and where possible, these may be followed by more cool-season plants. Succession planting may be successful in USDA zone 4 but it may be difficult in cooler areas.

Relaying is another common practice, consisting of overlapping plantings of one type of crop. The new planting is made before the old one is removed. For instance, sweet corn may be planted at two-week intervals for a continuous harvest. This requires some care, though; crops planted very early are likely to get a slower start because of low temperatures. In the case of corn, it can be disastrous to have two varieties pollinating at the same time, as the quality of the kernels may be affected. Give early planted corn extra time to get started, for best results. Another way to achieve the same result is to plant various varieties of the same vegetable at the same time; for example, you can plant an early-, a mid-, and a late-season corn to extend the harvest.

Starting seeds indoors for transplanting is an important strategy for intensive gardening. To get the most from the garden plot, a new crop should be ready to take the place of the crop being removed. Several weeks may be gained by having 6" transplants ready to go into vacated areas. Don't forget to recondition the soil for the new plants.

GROWING VEGETABLES IN CONTAINERS

If you don't have space for a vegetable garden, or if your present site is too small, consider raising fresh, nutritious, homegrown vegetables in containers. A window sill, patio, balcony, or doorstep can provide sufficient space for a productive container garden.

Problems with soil-borne diseases, nematodes, or poor soil can also be overcome by switching to container gardening.

Grow vegetables that take up little space such as carrots, radishes, and lettuce or crops that bear fruits over a period of time such as tomatoes and peppers for best use of space and containers.

Dwarf or miniature varieties often mature and bear fruit early, but most do not produce as well overall as standard varieties.

The amount of sunlight that your container garden spot receives may determine which crops can be grown. Generally, root crops and leaf crops can tolerate partial shade, but vegetables grown for their fruits usually need at least six hours of full, direct sunlight each day and perform better with 8-10 hours. Available light can be increased somewhat by providing reflective materials around the plants, for example, aluminum foil, white-painted surfaces, marble chips.

Container gardening lends itself to attractive plantscaping. A dull patio area can be brightened by the addition of baskets of cascading tomatoes or a colorful herb mix. Planter boxes with trellises can be used to create a cool shady place on an apartment balcony.

Protect plants from very high heat caused by light reflection from pavement. Move them to a cool spot or shade them during the hottest part of the day. Plants should be moved to a sheltered location during severe rain, hail, or wind storms and for protection from fall frosts.

Be sure the pots you are using are large enough so that the soil will hold moisture that lasts two days between waterings.

WAYS TO EXTEND THE GROWING SEASON

To get the most out of a garden, you can extend the growing season by sheltering plants from cold weather both in early spring and during the fall.

Cold Frames and Hot Beds

In early spring a cold frame is useful for hardening-off seedlings that were started indoors or in a greenhouse. This hardening-off period is important, as seedlings can suffer serious setbacks if they are moved directly from the warmth and protection of the house to the garden.

The cold frame provides a transition period for gradual adjustment to the outdoor weather.

It is also possible to start cool-weather crops in the cold frame and either transplant them to the garden or grow them to maturity in the frame.

Cold frames have no outside energy requirements, relying on the sun for their source of heat.

The ideal location for a cold frame is a southern or southeastern exposure with a slight slope to insure good drainage and maximum solar absorption.

A sheltered spot with a wall or hedge to the north will provide protection against winter winds.

Sinking the frame into the ground somewhat will also provide protection, using the earth for insulation.

To simplify use of the frame, consider a walkway to the front, adequate space behind the frame to remove the sash, and perhaps weights to make raising and lowering of glass sashes easier.

Spring and summer uses of the cold frame center around plant propagation. Young seedlings of hardy and half-hardy annuals can be started in a frame many weeks before they can be started in the open.

The soil in a portion of the bed can be replaced with sand or peat moss or other medium suitable for rooting cuttings and for starting sweet potato slips.

Growing frames can be built from a variety of materials with wood and cinder block being the most common. If you use wood, choose wood that will resist decay, such as a good grade of cypress, or use pressure-treated wood. Never use creosote-treated wood or wood treated with pentachlorophenol, since these substances are harmful to growing plants. Wood frames are not difficult to build. Kits may also be purchased and easily assembled; some kits even contain automatic ventilation equipment.

There is no standard size for a cold frame. The dimensions of the frame will depend on amount of available space, desired crops, size of available window sash, and permanency of the structure. Do not make the structure too wide for weeding and harvesting; 4 to 5 feet is about as wide as is convenient to reach across. The sash of the frame should be sloped to the south to allow maximum exposure to the sun's rays.

Ventilation is most critical in the late winter, early spring, and early fall on clear, sunny days when temperatures rise above 45ºF. The sash should be raised partially to prevent the buildup of extreme temperatures inside the frame. Lower or replace the sash each day early enough to conserve some heat for the evening.

Avoid damage from summer's extreme heat and intensive sunlight by shading with lath sashes or old bamboo window blinds. Watering should be done early in the day so that plants dry before dark to help reduce disease problems.

Hot Beds

Hot beds are heated by soil heating cables, steam-carrying pipes, or fresh, strawy manure buried beneath the rooting zones of the plants. Heat is collected by all these frames when the sun's rays penetrate the sash made of clear plastic, glass, or fiberglass.

To convert your cold frame to a hotbed:

1. Dig out area 8-9" deep.
2. Lay down thermostatically controlled electric cable in 6-8" long loops, evenly spacing cable but never crossing another loop.
3. Cover with 2" of sand or soil.
4. Lay out hardware cloth to protect cable.
5. Cover with 4-6" of good soil.

Cloches and Row Covers

The cloche (pronounced klosh) includes many types of portable structures which shelter plants from drying winds and cold air and provide a greenhouse-like atmosphere for seeds and small plants in order to get an early start on the season, or to extend the fall garden as long as possible.

Cloches are set out over individual plants or made into tunnels for whole rows.

They trap solar radiation and moisture evaporating from the soil and plants. The hotkap and cut-off plastic jug are simple forms. Water filled tubes, such as Wall O'Waters, protect plants from unexpected freezes because freezing water gives off heat.

More elaborate ones are fiberglass tunnels, special plastic cloches, or row covers with slits in them to allow some aeration, and panes of glass connected by specially designed hinges to form a tent.

Cloches are generally lightweight, portable, and reusable.

It is preferable to have a design which can be closed completely at night to prevent frost damage and opened or completely removed during the day for good air circulation.

Cloches should be anchored or heavy enough that they don't blow away.

Greenhouses

There is an almost overwhelming selection of greenhouses on the market, and plans for building even more types are available. If you intend to purchase or build a greenhouse, it is wise to investigate the alternatives thoroughly, preferably visiting as many operating home greenhouses as possible.

COMMON VEGETABLE QUESTIONS

Beans

Q: My beans look healthy but aren't forming pods. Why?
A: Blossoms may drop during hot, windy conditions.

Cabbage

Q: Why doesn't Chinese cabbage head in the spring?
A: Seed head forms quickly in warm weather once plant has been chilled.

Corn

Q: How long does it take from silk to harvest for sweet corn?
A: About 20 days.

Q: Why didn't the ears of my sweet corn fill out to the tip?
A: Dry weather during silking and pollination.
Planting too close
Poor fertility (especially potassium deficiency)
Poor pollination

Cucumber

Q: Why did cucumber vines suddenly wilt and die?
A: Probably bacterial wilt. Control beetles.

Q: Why aren't my cucumbers setting fruit?
A: First flowers are all male.
Cold temperatures and/or rainy weather prevent bee pollination.
Insecticides kill bees.
Gynoceious hybrids need a pollinator.

Leeks

Q: Why did leeks rot at roots?
A: Maggots. Treat with diazinon in spring.

Lettuce

Q: Why is lettuce bitter?
A: Bitterness occurs in hot weather when seedstalk forms. Some bitterness will disappear after a couple days in the refrigerator.

Melons

Q: What is the difference between cantaloupe and muskmelon?
A: True cantaloupe is not grown in the U.S. Cantaloupes are round netted types of muskmelons grown in the southwest U.S. Muskmelons are ridged.

Q: Why are muskmelons poor flavored?
A: Poor fertility (lack of potassium).
Cool temperatures.
Wet conditions.
Loss of leaves by disease.
Harvesting before maturity.

Q: How can I tell if my watermelons are ripe?
A: Tendrils near stem turn brown, skin resists puncture by thumbnail, ground spot turns yellow (more reliable than "thumping")

Onions

Q: Should onion tops be broken over?
A: No. May be immature.
Rot easier.
Use short-season varieties.

Peas

Q: Should peas be inoculated with nitrogen-fixing bacteria before planting?
A: On new ground there may be yield benefits. In established gardens, probably not.

Peppers

Q: Why aren't my peppers setting fruit?
A: Hot, dry winds; night temps over 70º or below 50ºF; excess N fertilizer

Vine Crops

Q: Will my pumpkins and squash cross-pollinate?
A: Certain types can cross-pollinate but taste, shape, and color are not affected in the first growing season. Offspring will show effects of cross.

Tomatoes

Q: What causes tomato leaves to roll up?
A: Physiological leaf roll is most common on trained and pruned tomatoes. Symptoms are most prominent on leaves near the plant's base.

Q: Why do tomatoes crack?
A: Some varieties are more susceptible to cracking.
Severe pruning.
Uneven soil moisture supply.

Q: What causes my tomatoes to rot on the bottom?
A: Blossom-end rot is associated with a calcium deficiency, fluctuations in moisture, heavy applications of nitrogen fertilizer and root pruning. It can be minimized by maintaining a uniform supply of moisture through irrigation and mulches, avoiding root pruning by cultivating no closer than 1 foot from the plants and incorporating fertilizers high in superphosphates and low in nitrogen prior to planting.

Q: What causes grayish-white spots that look dry and papery on my tomatoes?
A: Sunscald is common on green fruit on the side facing the sun, usually due to a loss of leaves that protects the fruits. Control disease problems that may cause foliage loss and cover exposed fruits during growth to lessen chances of sunscald.

Q: Why are some of my tomatoes puckered and swollen with distorted growth?
A: Catface is a condition thought to develop when there are abnormal conditions during flowering such as extreme heat, drought, low temperatures, or herbicide contact.

Q: The leaves and stems on my tomato plants are distorted and misshapen. What causes this?
A: Tomatoes are very sensitive to injury from 2, 4-D herbicide and other hormone-type weed control chemicals through drift or a contaminated sprayer. The plant will outgrow damage when exposed to small amounts of chemical but may have a delayed harvest. Plants do not recover from severe damage.

OTHER VEGETABLE QUESTIONS

Cabbage Crops

Q: How large should the central head of broccoli grow before cutting?
A: 4-6 inches

Q: What causes small plants, poor heading, and early flowering of broccoli?
A: High temperatures.
Anything that interrupts growth—extended chilling of young plants, extremely early planting, severe drought, delayed transplanting, low boron levels.

Q: Why do brussels sprouts remain loose tufts of leaves instead of developing into firm heads?
A: Development during hot weather. May help to top the plant at 24-36 inches to direct energy to developing sprouts.

Q: What can be done to prevent cabbage heads from splitting?
A: Cut roots on one side of plant. Twist head to one side.

Q: What causes cabbage to develop seedstalks rather than solid heads?
A: Exposure to low temp 35-45ºF for extended periods when stems are pencil size or larger causes bolting.

Q: What is flowering cabbage?
A: Non-heading form similar to kale.

Q: Why do butterflies fly around my cabbage?
A: Adults of cabbage worms looking to lay eggs.

Q: What causes large lumpy swellings of my cabbage roots?
A: Clubroot which has no cure.

Q: What causes leaves in the head of cauliflower?
A: Caused when cauliflower matures during hot weather.

Q: Why does late cauliflower fail to make satisfactory heads?
A: Doesn't become well established in hot, dry conditions. Give late plants ample space.

Q: Is purple cauliflower grown the same way as regular cauliflower?
A: Actually is type of broccoli. Doesn't need blanching. Turns green when cooked.

Q: What causes browning of cauliflower curds?
A: Downy mildew, exposure to sunlight

Q: When is the best time to harvest kohlrabi?
A: 2-3 inches in diameter.

Root Crops

Q: What causes beets to develop tops but not roots?
A: Overcrowding because of improper thinning.

Q: What causes corky internal black spots in beet roots?
A: Boron deficiency. More common at pH 6.8 or higher.

Q: What varieties of beets are best for greens?
A: Crosby Green Top, Early Wonder, Lutz Green Leaf

Q: What causes the bitter green top on carrot roots?
A: Sunburning. Pull soil up on row. Cut off green part and rest is okay.

Q: Why do carrots develop a fork or twist in them?
A: Forks—poor soil preparation, stones, close cultivation
Twisting—seeded too thickly, inadequate thinning
Q: What causes carrots to get hairy roots, be poor color, and have a bitter flavor?
A: Aster yellows disease

Q: When should Jerusalem artichokes be harvested?
A: Anytime from late September until growth begins in spring.

Q: What are the best storage conditions for Jerusalem artichoke?
A: Near freezing, high humidity. Plants lose moisture rapidly.

Q: Do parsnips need to freeze before they are edible?
A: Frosts convert starch to sugar so they are sweeter, but they are edible earlier.

Q: Why shouldn't I plant my leftover potatoes as seed?
A: Buildup of virus and other diseases. Use certified seed.

Q: How can I prevent scabby potatoes?
A: Resistant varieties, crop rotation.
Never lime soil for potato production.
Avoid high pH soil.

Q: Why do my potatoes have hollow centers?
A: Grown too quickly—keep even moisture supply and avoid fluctuations.

Q: My potatoes formed little green "tomatoes" on their stems. Are they edible?
A: No, these seed balls contain true seeds of potato and are not edible.

Q: What causes green skin on potatoes?
A: Exposure to light. Areas contain bitter alkaloids.

Q: Why do the chips I make from my potatoes turn so dark brown?
A: High sugar content. Depends on storage and variety. Store at 70ºF for 2-3 days before chipping.

Q: Why do sweet potatoes grow long and stringy?
A: Too much rain or poorly drained soil prevent proper root formation. Prefer hot dry weather.

Q: What makes sweet potatoes crack and split?
A: Too much moisture just before harvest.

Q: Are sweet potatoes ruined if they were frosted before digging?
A: No but should be harvested immediately. Length of storage may be reduced.

Q: Why do radishes crack and split?
A: Overmature, excess moisture. Harvest when young, 19-29 days.

Q: Why don't my radishes form good roots?
A: Planted too thick, weather too hot for spring varieties, or too much shade.

Q: Why are my radishes so "hot"?
A: Have been growing too long.

Q: What causes the little brown tunnels in radishes?
A: Root maggots. Diazinon controls.

Q: Is it best to harvest salsify in the spring?
A: Like parsnips, root get sweeter with frost. If mulched, can harvest until April.

Q: Why do rutabagas get tough and bitter tasting?
A: Matured during hot weather. Sow late June for fall crop.

Q: When is the best time to plant turnips?
A: Grow either as spring or fall crop. Spring—plant as early as possible; Fall—plant in late July

CULTURE OF SELECTED VEGETABLE CROPS

Asparagus

Asparagus is a perennial vegetable which will live from 12-15 years or longer. During the spring harvest period, the spears develop daily from underground crowns.

Start asparagus either from seed or from one- to two-year-old crowns. Starting plants from seed requires an extra year before harvest. Seed may be started in peat pots; they are slow to germinate. Seedlings may be transplanted in June. Crowns are usually shipped and set out in April or May.

Choose a site with good drainage and full sun. The tall ferns of asparagus may shade other plants, so plan accordingly. Prepare the bed as early as possible and enrich it with additions of manure, compost, bone or blood meal, leaf mold, or wood ashes, or a combination of several of these. (Note, wood ash will raise the pH of your soil and may not be advisable.)

Dig a trench 12-18" deep, with 4-5' between trenches. The same method may be used in wide-bed plantings, with plants staggered in three rows. Mix the topsoil that has been removed with organic matter and spread about two inches of the mixture in the bottom of the trench or bed. Set the plants 15-18" apart, mounding the soil slightly under each plant so that the crown is slightly above the roots. Crowns should be of a grayish-brown color, plump and healthy-looking. Remove any rotted roots before planting. Spread the roots out over the mound of soil and cover the crown with 2-3" of soil. Firm well. As the plants grow, continue to add soil over the crowns (about 2" every two weeks) until the trench is filled. Water if rainfall is inadequate.

Weed the bed each spring before the first shoots come up to avoid accidentally breaking off spears. During the production period, it is best to pull rather than hoe weeds if possible.

Asparagus shoots or spears should not be harvested the first season after crowns are set. Harvest lightly for 3-4 weeks the second year. The fleshy root system needs to develop and store food reserves to produce growth during subsequent seasons. Plants harvested too heavily too soon often become weak and spindly and the crowns may never recover. An extra year is added to the above schedule for asparagus started from seed; i.e., do not harvest at all the first TWO seasons, and harvest lightly the third. When the asparagus plants are in their fourth season, they may be harvested for 8-10 weeks per year.

Harvest spears daily during the 6-8 week harvest period. The 6-8" spears are best, and should be snapped off just below the soil surface. If the asparagus is allowed to get much taller, the bases of the spears will be tough and will have to be cut; cutting too deeply can injure the crown buds which produce the next spears. Blanched asparagus is a gourmet item; to blanch (whiten) the spears, mound soil around them or otherwise exclude light from them so that chlorophyll is not formed in the stalks. When harvest is over, allow the spears to grow. Some gardeners prefer to support the growing foliage with stakes and strings to keep them tidy.

In all asparagus plantings, cut the foliage down to 2" stubs after frost when the foliage yellows, before the red berries fall off. A 4-6" mulch of compost, manure, leaves, or other material added at this time will help control weeds and add organic matter and nutrients.

Common Problems

DISEASES: rust (use resistant varieties)
INSECTS: asparagus beetles, cutworms
CULTURAL: weak, spindly plants and/or too few spears (too early or too heavy a harvest); crown rot or poor production (inadequately prepared, heavy soil)

Beans

Bush snap beans are the most popular because of their early maturity and because trellising is not required. Varieties include standard green, yellow wax, and purple-pod types. Though wax beans are yellow and waxy in appearance, their flavor is only subtly different from that of regular green snap beans. The purple pod beans are different in appearance while growing, but the pods turn green when cooked. Flat-pod green snap beans such as Roma or Romano are somewhat different in flavor and texture than the round-pod ones, and are preferred by many gardeners. These are available in both bush and pole types.

First plantings of bush beans should be made after danger of frost is past in the spring and soil is warmed. Seeds planted in cold soils germinate slowly and are susceptible to rotting. Also, seedling growth may be slow in cool temperatures. Plant several crops of bush beans 2-3 weeks apart, until mid-July for a continuous harvest. Snap beans should be kept picked to keep plants producing heavily.

Half-runner beans have a growth habit between that of bush and pole beans, producing beans usually used as snap beans. Though they have runners about 3 feet long, half-runners are generally grown like bush beans. Trellising, however, may increase production of these already heavy yielders.

Pole type beans come in many varieties, generally bearing over a longer period than bush types. They require trellising, and for that reason generally yield more in the same amount of space. Pole beans are natural climbers but will not interweave themselves through horizontal wires. Interplanting pole beans with corn is often recommended, but practices vary. Beans should be planted late enough to allow some growth and development of the corn first.

Scarlet runner beans are a type of pole bean that is quite ornamental as well as productive and delicious. The vines grow rapidly, producing beautiful red flowers and beans, which may be harvested as snap beans when young and as green shell beans later. Beans are ready to pick in 75-85 days and several pounds are produced per plant. The value of scarlet runner beans is mainly ornamental, though—the lush 6-15 foot vines can be used to cover arbors, trellises, or fences. An added feature is that the flowers are attractive to hummingbirds.
The yard-long or asparagus bean is related to black-eyed peas and has similar flavor, but the entire pod may be eaten. On trellised vines, pods may be produced which are 1-1/2 to 2 feet long. Asparagus beans need warm temperatures and a long growing season to do well.

Common Problems

DISEASES: mosaic (use resistant varieties); anthracnose; bacterial blight (use disease-free western-grown seed); seed rot (do not plant in cold moist soils); root and stem rots
INSECTS: Mexican bean beetles and larvae, corn earworm, mites
CULTURAL: Large plants with few beans (excess nitrogen); blossom drop (excessive heat, dry winds)

Cole Crops

It is best not to plant cabbage family crops—broccoli, cabbage, cauliflower, brussels sprouts—in the same spot year after year, since diseases and insect pests will build up. Rotate crops within your garden.

Broccoli

There are two types of broccoli, heading and sprouting. Most garden broccoli is of the heading type which is closely related to cauliflower and forms a large central head. When this is removed, side branches will form throughout the summer. Sprouting or Italian broccoli forms many florets or small heads but these do not produce a solid head.

To raise broccoli, buy transplants locally or produce your own and set out mid-April to early May. Set plants 18 inches apart in rows 30 inches apart. Sprouting broccoli is sown directly into the garden in spring. Follow packet directions. Broccoli has a relatively shallow, fibrous rooting system. Cultivate carefully or, even better, mulch.

The heads of broccoli are really flower buds. These must be harvested before the flowers open or show yellow. Mature heads measure 3-6” across. Lateral heads that develop later are smaller.

Common Problems

DISEASES: clubroot, yellows or fusarium wilt, blackleg, and blackrot
INSECTS: cabbage root fly maggots, cutworms, cabbage worms, cabbage looper worms, flea beetles, aphids
CULTURAL: poor heading (buttoning), and early flowers (interrupted growth due to chilling, extremely early planting, or drying out; or high temperatures).

Brussels Sprouts

Brussels sprouts are grown for harvest in the fall because cool weather during maturity is essential for good flavor and quality. Brussels sprouts are tall (sometimes 2-3’) erect biennials that are grown as annuals. The sprouts develop in the leaf axils and mature along the stalk. The lowest sprouts mature first and should be harvested when firm, 1½ to 2 inches in diameter. Lowest leaves may be removed to permit sprouts to mature.

Common Problems

DISEASES: clubroot, yellows or fusarium wilt, and black rot
INSECTS: cabbage root fly maggots, cutworms, cabbage worm, cabbage looper worms, flea beetles, aphids
CULTURAL: sprouts have loose tufts of leaves instead of firm heads (sprouts developed during hot weather, crop failures can also be due to water stress)

Cabbage

Buy locally-grown transplants or produce your own. Start cabbage seeds in growing structures 4-6 weeks before the first date when plants can be set out or sow a few seeds in the cold-frame or garden every month in order to have cabbage plants thereafter. It takes about three weeks to get plants ready from seed-

ing to set during the summer months.

Plant spacing affects head size. Close spacing (12 inches apart in the row) produces small heads. Average spacing is 15-18 inches apart in rows 30 inches apart. Cabbage is harvested when it reaches adequate size, depending on variety and growing conditions. Firm heads are preferred, especially for storage. Heads can be left on the plant in the garden for about two weeks in the summer, three to four weeks in the fall. If the first head is removed and the plant left in the ground, a second crop of smaller heads will develop.

Common Problems

DISEASES: clubroot, yellows or fusarium wilt, blackleg, black rot
INSECTS: cabbage root fly maggots, cutworms, imported cabbage worms, cabbage looper worms, flea beetles, aphids
CULTURAL: head cracking or splitting (excessive water uptake and growth near maturity, root prune with spade or trowel or twist stalk to break some roots and reduce water uptake)

Cauliflower

Spring seedlings should be transplanted after danger of frost is past. Many gardeners experience buttoning of cauliflower heads in the spring. This is a failure of the cauliflower head to gain in size after it reaches about 1" or less in diameter usually due to transplant or heat stress during the head formation period.

Cauliflower should be blanched when the curd flower head is about 2-3". Three to four large outer leaves are pulled up over the curd and fastened with a rubber band, or are broken over the top of the cauliflower and tucked in on the other side of the curd. Normal blanching time is 5-15 days depending on the air temperature. Self-blanching types which have leaves that grow up over the head may eliminate the need for this practice. If weather is warm during the blanching period, tie the leaves loosely to allow air circulation. Harvest while the curd is still firm. If it gets too mature, it will become grainy or ricey.

Common Problems

DISEASES: club root, yellows or fusarium wilt, blackleg, black rot
INSECTS: cabbage root fly maggots, cutworms, cabbage worms, cabbage looper worms, flea beetles, aphids
CULTURAL: poor heading (interrupted growth due to chilling from extremely early planting, or drying out, or high temperatures)

Corn

Sweet corn varieties differ significantly in time to maturity and in quality; yellow, white, bi-color, standard, and extra-sweet varieties are available. Most varieties planted are hybrids which have been bred for greater vigor and higher yields. A continuous harvest can be planned by planting early-, mid-, and late-season varieties, or by making successive plantings of the same variety every two weeks or when the last planting has 3-4 leaves (corn sown in early spring will take longer because of cool temperatures).

Pollination is a very important consideration in planting sweet corn. Because corn is wind-pollinated, block plantings of at least 3-4 short rows will be pollinated more successfully than one or two long rows. Good pollination is essential for full kernel development.

Most of the various types of corn will cross-pollinate readily. To maintain desirable characteristics and high quality, extra-sweet and standard sweet corn should be isolated from each other. A distance of 400 yards or planting so that maturity dates are one month apart is necessary to insure this isolation. Sweet corn plantings must be isolated from field corn and popcorn or ornamental corn as well. White and yellow types will also cross-pollinate, but the results are not as drastic. The newly developed *extra- or super-sweet types* convert sugar into starch more slowly than standard varieties and will retain their sweetness longer than usual

after harvest. Super-sweet varieties may be less creamy than standard varieties due to genetic differences. This characteristic decreases the quality of frozen or canned super-sweet corn, though newer cultivars of extra-sweets show improvement.

Some gardeners are interested in growing *baby corn* such as that found in salad bars and gourmet sections of the grocery store. Baby corn is immature corn, and many varieties are suitable, but Candystick, with its 1/4" diameter cob at maturity, is a good one to try, especially since its dwarf habit means that it takes up less space in the garden. Harvesting at the right time is tricky; silks will have been produced, but ears are not filled out. Experimentation is the best way to determine when to harvest baby corn.

It is not necessary to remove suckers or side shoots that form on sweet corn. With adequate fertility these suckers may increase yield, and removing them has been shown in some cases to actually decrease yield.

Normally, sweet corn is ready for harvest about 20 to 30 days after the first silks appear. Pick corn that is to be stored for a day or two in the cool temperatures of early morning to prevent the ears from building up an excess of field heat, which causes a more rapid conversion of sugars to starch. Of course the best time to pick is just before eating the corn; country cooks say to have the pot of water coming to a boil as you are picking the corn, husking it on the way from the garden to the house! This is an exaggeration, but with standard varieties, sugar conversion is rather rapid. Field heat can be removed from ears picked when temperatures are high by plunging the ears in cold water or putting them on ice for a short time. Then store in the refrigerator until ready to use. Extra-sweet varieties will also benefit from this treatment, but they are not as finicky.

Common Problems

DISEASES: smut (remove infected part, select a different variety next year, avoid injury to developing plants); stunt (transmitted by leafhoppers)
INSECTS: corn earworm, European corn borer, flea beetles
CULTURAL: Poor kernel development—failure to fill out to the tip (dry weather during silking states, planting too close, poor fertility—especially potassium deficiency—too few rows in block resulting in poor pollination). Lodging—falling over (too much nitrogen or wind damage when the soil is wet).
OTHER: birds eating seed, raccoons eating mature ears of corn, gardener's impatience (picking too soon)

Cucumbers

Varieties include both the slicer or fresh salad type and the pickle type (which can also be used fresh) and dwarf-vined or bush varieties. New varieties of cucumber are being released which are advertised as all-female, or gynoecious types. On a normal cucumber plant the first 10-20 flowers are male, and for every female flower, which will produce the fruit, 10-20 male flowers are produced. Some of the new varieties produce plants which have only female flowers, while others have a greater proportion of female to male flowers. These plants tend to bear fruit earlier, with a more concentrated set and better yields.

Parthenocarpic cucumbers are all female and are seedless because the fruit is produced without being pollinated. If this type of cuke is planted near others, pollination will occur and seeds will form. This type is usually grown in greenhouses.

Burpless cucumbers are long and slender with a tender skin. Through plant breeding the bitterness associated with the burp has been removed. Other causes of bitterness in cucumbers include temperature variation of more than twenty degrees and storage of cucumbers near other ripening vegetables.

Most varieties of cucumber vines spread from row to row. Training on a trellis or fence along the edge of the garden will correct this and also lift the fruit off

the soil. If trellised, plant four to five seeds per foot in rows spaced 30 inches apart. Untrellised rows may need to be spaced 4-6' apart. When plants are 4-5" high, thin so they are 9-12" apart. It may be better to plant a second crop around July 1, which will have fewer disease problems, than to try to continue harvesting an early planting until frost.

There are many excellent bush varieties of cucumber now available. Most of these produce well for the limited amount of space and may be a desirable alternative in a small garden if trellising is not possible.

In order for the flower to develop into a fruit, pollen must be carried by bees from male flowers, on the same plant or on different plants, to the female flower, the one with the tiny swollen pickle. Gynoecious cucumber flowers are pollinated by male flowers from other plants, the seeds of which are usually included in the seed packet. Poor cucumber set is common during rainy weather when bees are inactive. If pesticides are necessary, use them after sundown to avoid harming the bees.

Plants respond to mulching with soil-warming black plastic in the spring for earlier harvest. Organic materials are useful in the summer to return moisture and keep the fruit clean in non-trellised plantings.

Working in the vines when leaves are wet may help spread diseases. Wait until after morning dew or rain evaporates. Trellising gets leaves up off the ground so that they dry off faster. Also, if the vines are trellised, the gardener is less likely to step on the vines and there is no need to move the vines for weeding or other purposes, reducing the risk of damage. If vines are not trellised, avoid destroying blossoms or kinking vines by gently rolling the vines away rather than lifting them when searching for harvestable fruit. Try to select resistant varieties when possible.

Common Problems

DISEASES: bacterial wilt (spread by cucumber beetles), mosaic, leaf spot, anthracnose, scab, powdery and downy mildews
INSECTS: cucumber beetles, aphids, flea beetles
CULTURAL: misshapen cucumbers (low fertility or poor pollination/insect damage), failure to set fruit (too few bees for adequate pollination, no pollinating plants for gynoecious hybrids, changes in temperature)

Eggplant

The standard eggplant produces egg shaped glossy purple black fruit 6-9" long. The long, slender, Japanese eggplant has a thinner skin and more delicate flavor. Both standard and miniature eggplants can be grown successfully in containers; but standards yield a better crop. White, ornamental varieties are available and edible yet are poor eating quality.

Warm to hot weather throughout the season is necessary for good production. Seeds germinate quickly at 70-90ºF; and plants should be grown for 8-9 weeks before setting them out. Cold temperatures will stop plant and root growth reducing plant vigor and yields. Using hot caps or cloches protects plants from cold conditions.

Though eggplants do well in hot weather; they must have well-drained soil and do not thrive in very humid areas. When plants are about 6" high, nip back the growing tip to encourage branching. Pick fruits when immature, about two-thirds maximum size. Mature fruit should not be left on the plant as this will reduce overall productivity.

Because of the eggplant's susceptibility to verticillium wilt, rotate

plantings with other crops on the same garden soil.

Common Problems

DISEASES: verticillium wilt
INSECTS: flea beetles, aphids, lace bugs, Colorado potato beetle, red spider mites

Lettuce

Lettuce, a cool-season vegetable crop, is one of the easiest to grow. Lettuce withstands light frost; however, sunlight and high summer temperatures usually cause seed stalk formation (bolting) and bitter flavor. Slow-bolting or heat-resistant varieties are available and are recommended for extending the lettuce-growing season. There are several types of lettuce commonly grown in gardens:

Iceberg is the lettuce most widely available as a fresh market type. It has a tightly compacted head with crisp, light green leaves. Many gardeners find this type difficult to grow because it requires a long season and some of the most advertised varieties are not heat-resistant and tend to go to seed as soon as temperatures go up. Select a slow-bolting variety and start seed indoors in late winter or late summer for best results. Transplant in early spring or fall to take advantage of cool weather and mulch well to keep soil temperatures from fluctuating and to hold moisture in.

Butterhead, or Bibb lettuce, is a loose-heading type with dark green leaves that are somewhat thicker than those of iceberg lettuce. Butterheads develop a light yellow, buttery appearance and are very attractive in salads. A miniature variety of butterhead, Tom Thumb, is very easy to grow, requiring a short growing time. One head of this lettuce is about right for one or two servings, so this is one lettuce to plant in succession, about two weeks apart. It may be started indoors for an even longer season. Bibb lettuce will develop bitterness readily if temperatures get too high.

Romaine, or Cos, is relatively easy to grow, forming upright heads with rather wavy, attractive leaves.

Loose-leaf types of lettuce are grown by most gardeners and have either green or reddish leaves. This type is fast-growing, long-lasting lettuce used for salads, sandwiches, and in wilted lettuce salads. Leaf lettuce basically needs only to be planted and harvested.

Sow in rows, 10-20 seeds per foot, in rows 8-12” apart. Thin individual plants 4-8” apart, depending on variety. Leaf lettuce also grows very successfully in a wide bed arrangement; seedlings are thinned to 4-8” on all sides. Cos and head types should be sown or transplanted 12-18” apart. Allow 30” between rows.

Cultivate carefully as lettuce is shallow-rooted. Use frequent, light waterings to encourage rapid growth, but do not over water, as this may cause disease of roots or leaves. Overhead watering should always be done in the morning to give plants time to dry off. As mentioned above, mulches are helpful in maintaining soil moisture and keeping leaves off the ground.

Lettuce planted in very early spring should be given full sun so that the soil will warm enough for rapid growth. For long-season lettuces, plant so that crops such as sweet corn, staked tomatoes, pole beans or deciduous trees will shade the lettuce during the hottest part of the day when temperatures are over 70ºF. Interplanting is a space-saving practice. Some lettuces, like Tom Thumb and leaf lettuces, are attractive in flower borders.

Lettuce is best planted in succession, or using different varieties that mature at different times.

Common Problems

DISEASES: stem, leaf, and root rots
INSECTS: aphids, root aphids
CULTURAL: tip burn (irregular moisture or lack of calcium); bolting; bitterness due to high temperature or lack of moisture; leaf rots due to soil and/or water on leaves

Melons

Muskmelons and watermelons are warm season crops requiring a long growing season of 80 to 100 days from seed to fruit. New bush varieties which take less space are available for small gardens.

Melons can be produced from transplants or planted directly. Those grown from transplants can be harvested as much as two weeks earlier than melons grown directly from seed, since the gardener must wait until danger of frost is past to plant. Plant or transplant muskmelon in rows five feet apart with hills spaced every 2-3 feet, two or three plants per hill. Watermelon hills should be 6-8 feet apart, and rows 7-10' apart if a path is desired between rows. Seed should be sown ½ -1" deep after danger of frost has passed and soil is warmed.

Muskmelons and watermelons are well suited for growing on black plastic mulch. The black plastic absorbs heat readily, allowing the soil to warm quickly. It also keeps the soil moisture level from fluctuating greatly and is effective in controlling weeds.

Male and female flowers are separated on the same plant. Bees must carry pollen from flower to flower to insure good fruit. Use insecticides late in the evening to prevent killing bees.

Melon plants can be trained in rows for easy harvesting. Growing on a trellis allows closer spacing (rows three feet apart), but each trellised melon must be supported by a sling made of a material which dries quickly to prevent rot. Old nylon stockings, cheesecloth, and other net-like materials make good fruit slings. Very large watermelons probably should not be trellised at all, since the weight of the fruit, even if supported, would likely damage the vine. Fruit in contact with the soil can be damaged by insects on the bottom. Place a board or a couple inches of light mulching material, such as sawdust or straw, beneath each fruit when it is nearly full-sized.

Common Problems

DISEASES: bacterial wilt (spread by cucumber beetles), fusarium wilt, leaf spot, powdery and downy mildews, alternaria blight.
INSECTS: cucumber beetles, squash vine borer, squash bug
CULTURAL: poor flavor and lack of sweetness (poor fertility, low potassium, magnesium, or boron); cool temperatures; wet weather; poorly adapted variety; loss of leaves from disease; picking melons unripe; poor pollination (wet, cool weather, lack of bee pollinators, planting too close resulting in excessive vegetative growth); split fruit (heavy rain when melons are ripening).

Onions

Onions are often grouped according to taste. The two main types of onions are strong flavored (American) and mild (often called European). Each has three distinct colors, yellow, white, and red. In general, the American onion produces bulbs of smaller size, denser texture, stronger flavor, and better keeping quality than European types. Globe varieties tend to keep longer in storage.

Onion varieties also differ in the number of hours of daylight required to make a bulb. If the seed catalog lists the onion as long day, it sets bulbs when it receives 15-16 hours of daylight. For green or bunching onions, use sets, seeds, or trans-

plants in spring.

For bulb production, plant sets in early spring. Set 1-2” apart and 1-2” deep in the row. Thin to four inches apart and eat the thinned plants as green onions. Avoid sets more than an inch in diameter because they are likely to produce seed stalks. Too early planting and exposure to cold temperatures also causes seed stalk development. Some people have best bulb production using seedlings or transplants rather than sets.

Bulbs compete poorly with weeds due to shallow root systems. Shallow cultivation is necessary; do not hill up soil on onions as this can encourage stem rot. Insure ample moisture especially after bulbs begin enlarging.

Onions should be harvested when about two-thirds of the tops have fallen over. Careful handling to avoid bruising helps control storage rots. Onions may be pulled and left in the field for several days to dry then cured in a well-ventilated attic or porch for one to two weeks out of direct sun. Tops may be left on or cut off, but leave at least one inch of the top when storing. Thorough curing will increase storage life.

Common Problems

DISEASES: neck or stem rot, bulb rot
INSECTS: thrips, onion root maggots
CULTURAL: bulb rot (bruising, insufficient drying); split or double bulb (dry soil during bulb formation); very small bulb (too late planting or too dry soil).

Peppers

Although types of peppers belong in one of six groups, most are classified according to their degree of hot or mild flavor. The mild peppers include bell, banana, pimento and sweet cherry while the hot peppers include the cayenne, jalapeno, and tabasco.

Bell peppers are commonly harvested when green but will turn red or yellow when fully ripe. About 200 varieties are available. Banana peppers are long and tapering and harvested when yellow, orange or red. Another sweet pepper, pimento, has conical, 2-3” wide by 4” long, thick walled fruit. Most pimentos are used when red and fully ripe. Cherry peppers vary in size and flavor. Usually they are harvested orange to deep red. Slim, pointed, slightly twisted fruits characterize the hot cayenne pepper group. These can be harvested when either green or red and include varieties such as anaheim, cayenne, serrano, and jalapeno. Celestial peppers are cone shaped, $^3/_4$” to 2” long, and very hot. They vary in color from yellow to red to purple making them an attractive plant to grow. Slender, 1-3”, pointed tabasco peppers taste extremely hot and include such varieties as chili piquin and small red chili.

Peppers generally have a long growing season and suffer slow growth during cool periods. Therefore, after the soil has thoroughly warmed in the spring, set out 6- to 8-week-old transplants to get a head start toward harvest. Practice good cultivation and provide adequate moisture. Mulching can help to conserve water and reduce weeds.

Hot peppers are usually allowed to fully ripen and change colors (except for jalapenos) and have smaller, longer, thinner, more tapering fruits than sweet peppers. Yields are smaller.

Common Problems

DISEASES: tobacco mosaic virus, anthracnose
INSECTS: aphids, flea beetles, cutworms, European corn borer
CULTURAL: blossom end rot (moisture irregularities or calcium deficiency); blossom drop (when night temperatures go above 75ºF, or when a full crop of fruit set is excessive).

Potatoes

Both white-skinned and red-skinned potatoes can be grown as an early crop for new potatoes and as a late crop for storage. Choose an early maturing variety and a medium-to-late maturing variety. Plant potatoes from mid-April to early May, depending on your location. Hard frosts and freezes may set back growth. Potatoes prefer cool springs and moisture throughout the growing season.

Avoid a garden site in a turned-under lawn as grub worms may damage developing tubers unless soil insecticides are used. A soil pH of 6.0 to 6.5 is most desirable; however, scab disease will be less when the pH is between 5.0 to 5.2. In addition to the base application of fertilizer, add about one-fourth pound of 10-20-10 fertilizer for each 75 foot row. Work this into the furrow and mix with the soil before planting.

Purchase certified seed stock that has been inspected for diseases that lower yields. Saving your own seed potatoes is generally not worthwhile because viruses and diseases often show up the next year. Seed potatoes should be firm and unsprouted. Wilted and sprouted potatoes usually have lost vigor from being too warm in storage. Seed pieces for planting should be cut to about 1-1/2 to 2 ounces. Potatoes about six ounces in size will cut into four pieces nicely. Each seed piece should have at least one good bud or eye. Plant potatoes in furrows cut-side down, 3-5” deep. Later crops should be planted 5-6” deep.

Pull a ridge of soil over each row when planting. Drag a board or hoe across the ridges just before the sprouts break through to eliminate weeds. Later cultivation should be shallow and far enough from the rows to make certain that no roots are damaged. Potatoes should be hilled, by pulling soil up around the plants, whenever 4” or more of foliage has emerged. This forces stem elongation and tubers to form from the stems. Stop hilling when potatoes bloom as bloom signals the end of tuber production.

When the tops have grown too large to allow cultivation, a finishing cultivation, sometimes called laying by or hilling up is given. Laying by throws soil over the potatoes to prevent exposure of the potatoes to sun which can cause greening or scalding. Green portions on potatoes taste bitter and contain an alkaloid. Cut off and discard green areas before using.

The release of the new true seed potatoes is an interesting development. The major advantage of growing potatoes from seed is the decreased chance of disease. For the home garden, growing from seed pieces is generally less time consuming and will give better yields. With time, true seed potatoes may be bred for higher yields, but at present, good quality stock potatoes yield the best crop.

Common Problems

DISEASES: early blight, scab, late blight, tuber rots, virus complex, fusarium, verticillium and bacterial wilts.
INSECTS: Colorado potato beetles, flea beetles, leafhoppers
CULTURAL: green skin (sun exposure), hollow heart (alternate wet and dry conditions), black walnut wilt (too close to a black walnut tree).

Squash

Summer squash grows on nonvining bushes. There are many varieties having different fruit shapes and colors. The three main types include the yellow straightneck or crookneck; the white saucer-shaped scallop or patty pan; and the oblong green, grey, or gold zucchini.

Soil containing plenty of well-rotted compost or manure is ideal, although good crops may be grown in average soils which have been adequately fertilized. For extra early fruit, plant seeds in peat pots in greenhouses or hotbeds and transplant about three weeks later after danger of frost. Older plants that have hardened off and stopped growth will not transplant well and should be discarded.

Squashes are warm season plants and do not do well until soil and air temperatures are above 60ºF.
Seed or transplants can be planted through black plastic. Cover seed with one inch of soil.

Squash plants have separate male and female flowers on the same plant. Pollen must be transferred from the male flowers to the female by bees. Use insecticides late in the evening to prevent killing bees.

Common Problems

DISEASES: powdery and downy mildews, blossom blight, bacterial wilt
INSECTS: cucumber beetles, squash vine borers
CULTURAL: blossom end rot (irregular moisture or calcium deficiency) flower drop (may occur normally when female flowers form before male flowers or during periods of heavy fruit set)

Tomatoes

Tomatoes are valuable garden plants in that they require relatively little space for large production. Each tomato plant, properly cared for, yields 10 to 15 pounds or more of fruit.

Choose varieties with disease resistance bred in for best results. Fusarium and verticillium wilt are common diseases that can destroy a whole tomato crop. Many varieties are resistant to these two diseases—look for VF after the cultivar name, indicating resistance to the wilts. VFN means the plants are resistant to verticillium, fusarium, and nematodes; VFNT adds tobacco mosaic virus resistance to the list.

There are several major types of tomatoes that can be chosen according to need:

Midget, patio, or dwarf tomato varieties have very compact vines best grown in hanging baskets or other containers. The tomatoes produced may be the cherry type (1” diameter or less) or larger fruit. These plants are usually short-lived, producing their crop quickly and for a short period.

Cherry tomatoes have small, cherry-sized (or a little larger) fruits often used in salads. Plants of cherry tomatoes range from dwarf (Tiny Tim) to seven-footers (Sweet 100). One standard cherry tomato plant is usually sufficient for a family, since they generally produce abundantly.

Compact or determinate tomato plants may include cultivars of the first two categories. Determinate refers to the plant habit of growing to a certain size, setting fruit, and then declining.

Indeterminate tomato plants are the opposite of the determinate types. The vines continue to grow until frost or disease kills them. These are the standard, all-summer tomatoes that most people like to grow. They require support of some kind for best results, since otherwise the fruit would be in contact with the soil and thus susceptible to rot.

Beefsteak type tomatoes are large-fruited types, producing a tomato slice that easily covers a sandwich, the whole fruit weighing as much as two pounds or more. These are usually late to ripen, so plant some standard-sized or early tomatoes for longest harvest.

Paste tomatoes have small pear-shaped fruits with very meaty interiors and few seeds. They are less juicy than standard tomatoes and are without a central core. Paste tomatoes are a favorite for canning since they don’t have to be cut up and they are very meaty.

Some tomatoes are orange, yellow, pink, or striped, and usually the only way to get these is by growing your own from seed.

Winter storage tomatoes are a relatively new item for gardeners. The plants are set out later in the season than most tomatoes and fruits are harvested partially ripe. If properly stored, they will stay fresh for twelve weeks or more. While the flavor does not equal that of summer vine-ripened tomatoes, many people prefer them to grocery store tomatoes in winter.

Tomato plants may be started indoors from seed or transplants may be purchased. If starting your own plants, use a light soil mix and give the plants plenty of light. Tall, spindly transplants are usually caused by low light levels in the home. Unless you have a sunny, south-facing window, supplemental light will be necessary. The seed are sown 6-8 weeks before the last frost date in your area. A few weeks before transplanting time, harden-off indoor-grown plants by exposing them to an increasing number of hours outdoors each day. Bring plants in if there is danger of frost. A few varieties of tomato (the sub-arctics) are bred to grow well in low spring temperatures; however, these are rarely available in the usual markets and ordinarily must be grown from seed.

When you are ready to put home-grown or purchased plants into the ground, select stocky transplants about 6-10" tall. Set tomato transplants in the ground covering the stems so that only two or three sets of true leaves are exposed. Horizontal planting of tomato plants is an effective way to make plants stronger, especially leggy ones. Roots will form along the buried portion of the stem, giving better growth and less chance of plant injury from a too-weak stem. Do not remove the containers if they are peat or paper pots, but open or tear off one side to allow roots to get a good start. If non-biodegradable containers are used, knock the plants out of the pots before transplanting, and loosen the roots somewhat. Press the soil firmly around the transplant so that a slight depression is formed for holding water. Pour approximately one pint of starter solution (2 tbsp. 5-10-10 or 5-10-5 fertilizer per gallon of water, or dilute fish emulsion) around each plant to wash the soil around the roots.

If plants are to be staked or trellised, space them 24" apart in rows 3' apart. Though it requires more initial work, staking makes caring for tomatoes easier than letting them sprawl. Since they are off the ground, fruit rots are reduced, spraying is easier and may be required less often, and harvesting is much less work. Use wooden stakes 6' long and 1-1/2 or 2 inches wide. Drive them one foot into the soil about 4-6" from the plant soon after transplanting. Attach heavy twine or strips of cloth to the stakes every 10". As the plants grow, pull the stems toward the stakes and tie loosely.

Prune staked tomatoes to either one or two main stems. At the junction of each leaf and the first main stem a new shoot will develop. If plants are trained to two stems, choose one of these shoots, normally at the first or second leaf-stem junction, for the second main stem. Remove all other shoots, called suckers, weekly to keep the plant to these two main stems. Pinch shoots off with your fingers. Tomato plants may also be set along a fence or trellis and tied and pruned in a manner similar to that used with stakes.

Growing tomatoes in wire cages allows the tomato plant to grow in its natural manner, but keeps the fruit and leaves off the ground, offering the advantages of staking as well. Using wire cages requires a large initial expenditure and a large storage area, but many gardeners feel that the freedom from pruning and staking is worth it. The cages, if heavy- duty, will last many years. Be sure to get fencing with at least 6" spacing between wires so that you can get your hand inside to harvest the tomatoes. If tomato plants in wire cages are pruned at all, once is enough; prune to three or four main stems.

Wire-cage tomatoes develop a heavy foliage cover, reducing sunscald on fruits and giving more leeway when bottom leaves become blighted and have to be removed. Many staked plants are nearly naked by late summer. Caged plants are less prone to the spread of disease from plant handling, since they do not have open wounds and must be handled less frequently than staked plants. However, it helps to space the plants somewhat further apart (three feet is good) to allow good air circulation between plants; humidity is higher because of the foliage density, and diseases such as late blight spread rapidly in humid situations. If well-nourished and cared for, caged tomatoes can produce exceptional harvests and make up for the extra space with high production. This type of culture is

especially suited to indeterminate varieties.

Common Problems

DISEASES: early blight, septoria leafspot, verticillium and fusarium wilts, late blight, tobacco mosaic virus, bacterial spot
INSECTS: flea beetle, Colorado potato beetle, aphids, mites, whiteflies, cutworms
OTHER PESTS: nematodes
CULTURAL: blossom-end rot (irregular soil moisture or calcium deficiency); poor color, yellow spots, or large whitish-grey spots (sun scald from lack of foliage cover); leaf roll (physiological condition often found in pruned tomatoes); fruit cracking (irregular soil moisture); black walnut wilt (roots of tomato plants near a black walnut tree).

RESOURCES

University of Minnesota Extension Service Publications

Master Gardeners receive many of these publications as a part of their training or Core Course. New publications are continually added to the Distribution Center. The most up-to-date listing is available online at http://www.extension.umn.edu. Click on Publications, or search the site for publications of interest. Many of these fact sheets can be read online and are also available from county extension offices. Longer publications or those containing many photographs or illustrations may not be available online. Master Gardeners should order publications through their home county extension office. Public orders may be placed by calling
1-800-876-8636 (outstate) or 612-624-4900 (local).

FS 0431	Growing Vine Crops
FS 0434	Growing Salad Vegetable Crops
FS 0435	Growing Carrots & Other Root Vegetables
FS 0436	Growing Cole Crops
FS 1155	Parasitic Diseases of Tomato and Their Control
FS 1156	Nonparasitic Disorders of Tomatoes
FS 1160	Verticillium Wilt of Potatoes
FS 1167	Damping Off of Seedlings
FS 1168	Tomato-Tobacco Mosaic Virus
FS 1169	Diseases of Cole Crops
FS 1172	Diseases of Cucurbits
FS 1422	Planting the Vegetable Garden
FS 1424	Harvesting and Storing Garden Vegetables
FS 1427	Controlling Disease in the Home Vegetable Garden
FO 1861	Growing Asparagus in Minnesota
FO 1862	Growing Broccoli & Cauliflower in Minnesota
MR 2121	Production of Naked Seeded Pumpkin: A Food Crop for the Family Farm
FO 2412	Disease Resistant Vegetable Varieties
FO 2543	Lead in the Home Garden & Urban Environment
MI 6645	Vegetable Gardening in the Midwest

Videos of Minnesota Gardening TV Programs

These are 30-minute videos developed as a series of programs aired in the Twin Cities for the general public. They are available from the University of Minnesota Extension Service Distribution Center: call 612-624-4900 (local) or 1-800-876-8636 (outstate).

VH 5981	Starting Seeds
VH 5991	Herbs
VH 5992	Vegetables
VH 6007	New Annuals and Vegetables
VH 6015	Season Extenders
VH 6017	Tomatoes
VH 6032	Planting From Seeds
VH 6242	Reducing Pesticide Use
VH 6245	Sweet, Sweet Corn

VH 6255 Cool-Season Vegetables
VH 6264 Growing and Using Herbs
VH 6457 Growing, Harvesting and Using Peppers
VH 6470 Cold Frames, Hot Beds
VH 6478 Growing Healthy Tomatoes
VH 6480 Storing Garden Produce

University of Minnesota Extension Service Slide Sets

These vary in length and depth. All have a script and/or audio tape. These are also available from the University of Minnesota Extension Service Distribution Center: call 612-624-4900 (local) or 1-800-876-8636 (outstate).

SS 2318 Growing Cucurbits
SS 2319 Growing Tomatoes
SS 2518 Yard Waste Management, "You Can Make a Difference!": An Environmental Issue for the 1990s
SS 4007 Advanced Vegetable Gardening
SS 4040 Basic Vegetable Gardening
SS 4306 Herbs in Minnesota Gardens
SS 4314 Home Vegetable Gardening
SS 4347 How to Start a Garden
SS 4504 Planning and Planting a Vegetable Garden
SS 5630 All America Selections in Flowers and Vegetables
SS 6405 Get Your 5-A-Day from the Garden

Yard and Garden Briefs

Anthracnose and Rust of Garden Beans
Bacterial Diseases of Garden Beans
Common Smut
Garlic
Gardening in Raised Beds
Growing Asparagus
Growing Basil
Growing Chives & Dill
Growing Herbs
Growing Luffa Gourds
Growing Parsley
Horseradish
Late Blight of Potato and Tomato
Pea Diseases
Peppers
Physalis
Planting Vegetables in Midsummer for Fall Harvest
Potatoes
Preserving Gourds for Lasting Color
Raising Leeks in Minnesota Gardens
Sap & Fungus Beetles
Saving Vegetable Seeds: Tomatoes, Peppers, Peas & Beans
Season Extenders for Minnesota Gardens (Coldframes/Cloches)
Septoria Leaf Spot
Slugs
Squash Vine Borer Management in Home Gardens
Starting Seeds Indoors
Trellises and Cages
Using Dog & Cat Manure on Home Gardens

Books

Abraham, George. *The Green Thumb Book of Vegetable Gardening*, Prentice-Hall, Englewood Cliffs, NJ.
All About Vegetables, Ortho Books, Chevron Chemical Co., San Francisco, CA.
Carr, Anna. *Rodale's Color Handbook of Garden Insects*, Rodale Press, Emmaus, PA.
Hill, Lewis. *Cold-Climate Gardening*, Storey Communications, Inc. Pownal, VT.
Knott, J.E. *Handbook for Vegetable Growers*, John Wiley and Sons, Inc., New York, NY.

Taylor's Guide to Vegetables and Herbs, Chanticleer Press, Inc., New York, NY.

Vegetable Gardening for Illinois, University of Illinois, Circular 1150, Urbana, IL.

Vegetables, The American Horticultural Society, The Franklin Library, Franklin Center, PA.

Westcott, Cynthia. *The Gardener's Bug Book*, Doubleday & Company, Garden City, NY.

Additional information is found in appendix 3.

chapter 5

entomology

chapter 5

entomology

ENTOMOLOGY

by Jeffrey Hahn, Professor and Assistant Extension Entomologist

INTRODUCTION

This chapter will introduce you to insects. We will discuss insects' role in the environment, insect anatomy, insect life cycle, integrated pest management, and how to diagnose insect problems.

LEARNING OBJECTIVES

Learning objectives of this section for Master Gardeners are to:

1. Understand insects' role in the environment.
2. Recognize insect body parts.
3. Understand insect life cycles.
4. Become familiar with the major groups of insects
5. Learn the philosophy of Integrated Pest Management.
6. Recognize insect damage on plants.
7. Appreciate insects.

INTRODUCTION TO INSECTS

"If all mankind were to disappear tomorrow, the world would regenerate back to the rich state of equilibrium that existed 10,000 years ago. If insects were to vanish, the terrestrial environment would collapse into chaos."
-- Edward O. Wilson, Entomologist and Pulitzer Prize winning author quoted in Omni, September, 1990.

Insects are the most numerous and successful animals on earth. Entomologists have identified about 90,000 different species living in North America and about one million different species in the world. Taxonomists estimate that there may be as many as two to five million species in the world (some estimate as many as thirty million species); most of these unidentified species are probably living in the tropics. In a typical backyard, there are as many as 1,000 different species of insects at any given time.

Insects have existed on earth for about 350 million years (compared to about 2 million years for humans). Insects occupy virtually all types of habitats except for oceans. Insects use many resources as food and can be divided into three general groups: herbivores, i.e. feeding on plants, carnivores, i.e. feeding on insects and other animals, and saprivores, i.e. feeding on dead or decaying plant or animal material. Insects' adaptability plus their relatively small size and high reproductive potential has allowed insects to be very successful organisms on this planet.

Insects' Relationships To Humans and the Environment

The vast majority of insects are harmless or beneficial to people. Insects that are not directly helpful to people are still beneficial to the environment and help maintain the balance of nature. It has been estimated that the beneficial activities of insects are worth approximately $20 billion in the United States.

Pollination is a very important insect activity that benefits humans as well as the environment. About 80% of all flowering plants in temperate zones are pollinated by insects. Bees are the most important group of pollinating insects. Flies, butterflies and moths, and beetles also pollinate plants. Many plants, including many fruits and vegetables, are dependent on insects for pollination.

Insect products Insects also provide us with many useful products. Honey bees are important for producing honey, beeswax (used in cosmetics, candles, waxes, and polishes), and royal jelly (used in health foods and face creams). Other insect products used by humans include silk, shellac, and dyes.

Natural Control Insects are important as biological control agents. They feed on other organisms, especially insects, helping to keep general populations from becoming too abundant. Insects, in particular, are so prolific that even harmless species would become pests if they reproduced without natural enemies to limit their numbers. Insects are particularly considered beneficial when they attack other organisms, especially insects, thought by humans to be pests (e.g. ladybird beetles eating aphids). Insects are also important as biological control agents of weeds, such as purple loosestrife.

There are two general types of biological control agents that attack other insects, predators and parasitoids. Predators capture and devour insects (called prey), killing them in a relatively short amount of time. Predators eat all or most of the preys' body. Predators are usually larger or stronger and eat many individual prey.

Parasitoids (also known as parasites) lay their eggs on or in the bodies of other insects (called the host). All life stages can be parasitized, although a specific parasitoid will always parasitize the same stage of a host. After they hatch, parasitoids feed for a relatively long time, consuming all or most of the host's tissues, eventually killing the host. The host is usually larger than the parasitoid. A parasitoid attacks only one individual host, although many parasitoids can attack an individual host.

Decomposers and Recyclers Insects perform a valuable service as scavengers. They help break down organic material by eating dead animals, dead and dying plants, and dung. These activities help remove unwanted material from the environment and hasten the breakdown of organic material so it can be returned to the soil.

Aerators Insects living and tunneling in the ground help improve the physical condition of the soil and enrich it. Insects help aerate the soil which improves water and oxygen movement. Insect droppings and their dead bodies serve as fertilizer.

Food Source Insects are an important source of nutrition for animals. Many mammals, birds, reptiles, amphibians, and fish feed on insects. Some of these animals, rely exclusively on insects for their diet. Humans also consume insects as an important part of their food source. In many cultures throughout the world insects, including grasshoppers, termites, beetle grubs, and caterpillars are routinely eaten.

Medicine and Research Insects also are useful in medicine. For example, bee venom has been used in the treatment of arthritis and live maggots are used to treat some cases of non-healing wounds (called maggot therapy). Some scientists use insects in their research. Fruit flies are commonly used in genetic experiments. Manduca caterpillars are used at the University of Minnesota in experiments to better understand the insect nervous system. This may lead to a

better understanding of the human nervous system. Insects can also be nuisances especially if a large number is present.

Forensic Entomology Insects are useful any time they are used to help solve crimes or settle legal disputes. They may be used in a variety of urban issues, e.g. to help detect abuse of children or elderly people. Insects may also be involved in stored product cases dealing with contamination. Most people are familiar with forensic entomology when insects are used to help solve murder cases or accidental deaths. This is done by collecting insects found on dead bodies and identifying them. Because different insects are present during different stages of body decomposition, the insect fauna at any given time can help establish how long the body has been dead. This information can be critical when trying solve the mystery of a death.

Human Culture Insects are part of our everyday lives. They can be found in books, poetry, cartoons, music, movies, arts and crafts, jewelry, and nicknames. They are in our history, our folklore, our myths, and even in our everyday language.

Beauty and Wonder Finally, insects are appreciated for their beauty and their interesting lives and behaviors. Additionally, they are often used in art and literature and many other aspects of our culture.

Insects as Pests Only about 2% - 5% of insect species are considered to be pests. Losses due to these insects have been estimated in the United States to be about $5 billion. Insect pests are especially important because they destroy or spread disease to crops and other valued plants, destroy wood products, clothing and fabrics, and stored foods. They also attack humans and animals by biting, stinging, or spreading diseases. Insects can also be nuisances, especially when large numbers are present.

Metamorphosis: Insect Development

Insects hatch from *eggs.* Most insects are oviparous, i.e. they lay eggs. Eggs are generally oval and elongate, although there can be much variation. Eggs can be laid singly or in clusters. Many insects surround their eggs in some sort of protective material. A few insects, e.g. aphids, are viviparous, i.e. eggs develop inside the mother and she gives birth to live young.

Immature insects must shed their skeletons (outer shells) in order to grow because the exoskeleton does not expand. This process is called *molting.* The stage of the insect between molts is called an *instar* (e.g. an insect that has molted once would be a second instar). Insects often have four or five instars, although this varies with different insect species.

A distinctive feature of insects in the phenomenon called *metamorphosis.* Metamorphosis is defined as a change in form during development. Sometimes this change is gradual but many times it is very dramatic. Insect development is generally divided into two different types, simple or gradual metamorphosis and complete metamorphosis.

The life stages of simple metamorphosis are *egg, nymph,* and *adult.* The immature nymphs look similar to the adults except nymphs are smaller, lack wings and are sexually immature. Their wings develop externally (on the outside of their bodies). The last instar nymph molts into an adult. Nymphs and adults often live in the same habitat, eating the same food.

The life stages for complete metamorphosis are *egg, larva, pupa,* and *adult.* Larvae look very different from adults, usually feeding on different types of food, and living in different habitats. Last instar larvae molt into a pupa or resting stage. In the pupal stage, the insect does not feed and usually does not move. Inside the pupa, the insect changes form through tissue breakdown, tissue reorganization, and the development of new structures, such as wings, legs, antennae and mouthparts from masses of specialized cells. Wings develop internally (inside the body). The insect eventually molts one last time with the adult insect emerging from the pupa.

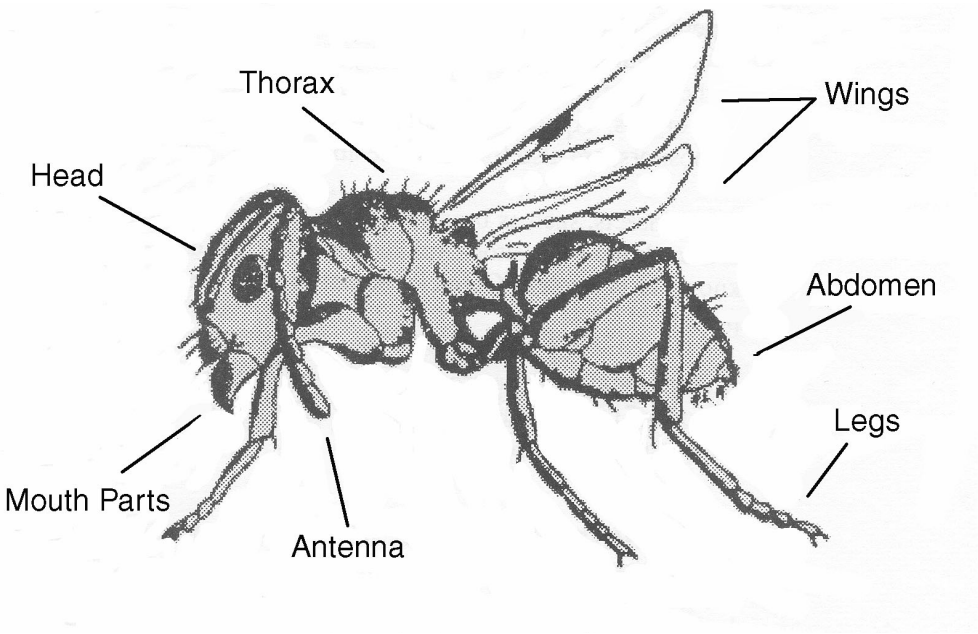
Many insects take one year to complete their life cycle. They are said to have one *generation* a year. A generation is the time it takes an insect to develop from a particular stage to a descendant in the same stage (e.g. from an adult to the next adult stage). Other insects may have more than one generation in a year. Others may require more than a year to finish one generation.

Anatomy: Insect Form and Structure

Insects (and their relatives, including spiders, mites, centipedes, millipedes, sowbugs etc.) possess a hard external integument known as an *exoskeleton*. This differs from the internal skeleton, or endoskeleton, that humans and other vertebrate animals possess. The insect exoskeleton is important for protection from the outside environment, prevention of water loss (i.e. drying out), for attachment of muscles, and support of internal organs.

Insects possess three major body parts: *head, thorax,* and *abdomen.*

Several important features are found on the *head.* The *antennae* are prominent and distinctive. One pair is nearly always found on the adult's head (there are only a few exceptions where insects lack antennae, e.g. some scale insects). Antennae are usually found between or in front of the eyes. Antennae are segmented, vary in form and complexity, and are sometimes referred to as feelers or horns. Antennae are used by insects for many types of sensing, including smelling, hearing, tasting, and feeling. Antennae can be an important feature to identify some insects.



Compound eyes are made up of varying numbers of facets. Each facet sees a small part of what the insect is viewing. Together, they comprise what the insect sees. The size of the compound eye (i.e. how many facets it has) varies. It can be a few as several facets as in some subterranean ants and as many as 50,000 facets in the large eyes of dragonflies.

Insect *mouthparts* are described as being mandibulate, i.e. possessing mandibles, although there is much variation. Mouthparts can be generally divided up into two types: chewing mouthparts, i.e. mandibles (jaws) are prominent, or *sucking* mouthparts, i.e. the mouthparts are modified into beak-like or tube-like mouthparts. While they differ considerably in appearance, the same basic parts are found in both types. Mouthparts are often very important in identifying insects to order (i.e. beetles, true bugs, flies etc.). Immature insects may have the same mouthparts as adults or they may have very different mouthparts.

The second major body part is the *thorax.* It is divided into three sections, *prothorax, mesothorax,* and *metathorax*. There is a pair of legs on each thoracic segment, a total of six (a few adult insects possess no legs). Legs, like so many other insects parts, vary much in form and function. Legs are used for running and walking, jumping, grasping, swimming, and digging. The type of leg and the number of segments the legs are composed of can be important in identifying insects.

The *wings* are also attached to the thorax. Most insects have four wings, attached to the second and third thoracic segments (mesothorax and metathorax). Flies have only two wings (attached to the mesothorax). A few insects lack wings altogether. There are a variety of modifications of insect wings, including hardened wings (e.g. beetles), leathery wings (e.g. grasshoppers, crickets, and katydids), hemelytrous wings which are half leathery and half membranous (e.g. true bugs). Wings are important to identify insects to order.

The *abdomen* generally possesses eleven segments and usually lacks appendages. The abdomen is relatively simple in structure compared to the head and thorax. Some insects possess a pair of appendages on the last segment of the abdomen known as *cerci.* Cerci vary in form and usually function as sensory organs. Appendages for mating and laying eggs, including *claspers* and *ovipositors,* are also found on the abdomen.

Some insects, such as bees and wasps, possess a *stinger* on the abdomen which is a modified ovipositor. Aphids possess a pair of appendages on the abdomen known as *cornicles.* Cornicles secrete a fluid used by aphids for defensive purposes.

Butterfly and moth caterpillars and sawfly larvae possess fleshy false legs on the bottom of the abdomen known as *prolegs.* When they turn into adult insects, these prolegs are lost.

Insect Classification

Living organisms are classified by scientists into broad groups that share similar characters which are in turn classified into smaller and more specific groups, each sharing a certain set of traits. These taxonomic divisions are listed to give a sense of how insects are organized with respect to other animals and to each other.

Kingdom	e.g. Animalia
Phylum	Arthropoda
Class	Insecta
Order	Coleoptera
Family	Coccinellidae
Genus	Hippodamia
Species	convergens *

* (Also known by the common name, convergent lady beetle.)

There are 32 orders of insects (this number may vary depending on which authority you are reading). Most of the insects you are likely to see belong to one of seven common orders. You can recognize these orders from the following descriptions.

Orthoptera are the crickets, grasshoppers, and katydids (older classifications also include mantids, cockroaches, and walkingsticks in this order). The Orthoptera have an incomplete life cycle with nymphs resembling adults. Both adults and nymphs have chewing mouthparts. Orthoptera usually have four wings which are folded behind their back. Their first pair is somewhat thickened or leathery. Orthoptera are typically plant feeders.

Hemiptera are the true bugs. They have an incomplete life cycle. Nymphs resemble adults. True bugs have piercing-sucking mouthparts. Some are slender and needle-like while others are more stout and beak-like. True bugs have four wings folded behind their back. Their first pair of wings are referred to as being

hemelytrous, i.e. the first part of the wings (the area closest to the head) is thickened or leathery while the second section is membranous (fly-like). The second pair of wings are membranous. Most Hemiptera are plant feeders, although some are predaceous.

Homoptera includes aphids, leafhoppers, psyllids, scales, and cicadas. These insects have an incomplete life cycle. Nymphs generally look similar to adults, although they often are small and hard to see. Homoptera have piercing-sucking mouthparts. They usually possess four wings (some Homoptera lack wings). All four wings are membranous or the first pair of wings are thickened or leathery. Homoptera are herbivorous.

Coleoptera are the beetles, the most abundant group of insects. They develop through complete metamorphosis. Larvae usually possess legs and have a definite head with chewing mouthparts. Their general appearance is grub-like or worm-like. Adults also have chewing mouthparts. Beetle adults have four wings, the first pair is hardened while the second pair is membranous (fly-like). Habits for both larvae and adults vary, including herbivorous, predaceous, and saprophagous.

Diptera are the true flies. Diptera have complete development. Fly larvae are maggots or worm-like in form. They are usually legless (although a few possess legs). They generally possess chewing mouthparts but lack a conspicuous head. Their habits are variable, although only a few are herbivorous. Adult flies have two clear, membranous wings and generally have sucking mouthparts, ranging from sponging-sucking (e.g. house fly) to siphoning-sucking (e.g. bee fly) to piercing-sucking (e.g. mosquito). Adult flies feed on liquids or liquified foods from many different sources but are rarely plant feeders.

Lepidoptera are the butterflies and moths. They develop by complete metamorphosis. The larvae are caterpillars. In addition to 3 pairs of true legs on the thorax, there are also 2 - 5 pairs of prolegs (false legs) found on the ventral, posterior end of the abdomen. Lepidoptera larvae have chewing mouthparts and are plant feeders. Adults have 4 membranous wings, usually covered with scales. They use siphoning mouthparts to feed on plant nectar and other liquids.

Hymenoptera are the sawflies, wasps, bees and ants. They develop by complete metamorphosis. Larvae are caterpillar-like (sawflies) or grub or worm-like (wasps, bees, ants). Hymenoptera larvae may have legs and 6 - 10 pairs of prolegs (sawflies) or are legless (wasps, bees, ants). Hymenoptera larvae may have a definite head and chewing mouthparts (sawflies) or the head and mouthparts may be inconspicuous (wasps, bees, ands). They can be herbivorous (sawflies), predaceous (wasps and ants) or pollen feeders (bees). Adults have 4 clear, membranous wings. They have chewing mouthparts and feed on a variety of food sources, including nectar and pollen.

INTEGRATED PEST MANAGEMENT (IPM)

What is a pest? A pest can be defined as any organism (in this case insects) that interferes with the necessities and enjoyment of our lives. This includes insects that are damaging as well as annoying. However, keep in mind that labeling an organism as a pest is from the human point of view. There are no insects that are inherently 'bad'. An insect's status as a pest can change depending on where it is found, what it is feeding on, and how many are present.

There are many reasons why insects may be managed in yards, gardens, and in and around homes.

Plant Health Insect feeding can severely injure plants, reduce their vigor, and even cause death. Injury or loss of plants can reduce property values, create hazardous situations (trees or limbs falling on homes or power lines), decrease a secondary supply of food, and lessen our enjoyment of gardening. In some cases, the feeding may be of secondary importance when insects vector diseases which can devastate plants.

Plant Appearance Insect feeding may have little or no impact on plant health, although it may affect the attractiveness of the plants. Management of these pests helps preserve the appearance of the plants. How much aesthetic injury is tolerated is subjective and a matter of personal preference.

Public health Some insects can potentially injure people through bites (e.g. fleas, bed bugs), stings, (e.g. wasps, bees), transmission of disease, or as a source of allergies (e.g. cockroaches, lady-beetles).

Property Damage Insects can damage property, including pests that damage structures and other objects made of wood; insects that consume and/or contaminate food products; insects that destroy wool and other types of fabrics; and insects that damage paper products.

Nuisances Some pests do not present any harm to people or property but are managed because they are a nuisance by being annoying, disagreeable, unpleasant, or simply found in places where they are not wanted. The number of insects that people consider a nuisance can differ -- some people can tolerate more insects than others.

The traditional strategy for dealing with pest problems is termed pest control. Pest control is reactive, tactics are planned and executed only after problems are discovered. Tactics to avoid or minimize pest problems are not used. Cultural, physical, and biological tactics have little or no role. Pest control tolerates little or no damage and usually attempts eradication. Perhaps, most importantly, control is dependent on the application of pesticides, often employing routine pesticide applications. Because of this emphasis and reliance on pesticides, pest control is undesirable.

Integrated pest management (IPM) has many definitions. One offered here is 'a sustainable approach to reduce pests to a tolerable level by using the best balance of cultural, physical, biological, and chemical methods while minimizing health, environmental, and economic risks'. Although there are many definitions, they generally share similar key ideas.

IPM is a decision-making process. The best combination of pest management tools are used based on the specific pest problem that is present. This allows IPM to be flexible and to change tactics when it is necessary. IPM is proactive, tactics are often planned before problems occur. Monitoring for pests is a key step, to help detect pests before they become severe. It is important to identify pests that are discovered and to understand their biology. Integrated pest management emphasizes tactics that manage the environment to reduce or avoid pest problems. IPM uses the best balance of methods, not relying on a single tactic. Pesticides are considered but as a last option. They are applied judiciously using the least toxic chemical that is effective.

Although IPM is preferred, it is not always easy. It can be challenging to be familiar with the large number of pest problems and plants that are present in a particular environment. Pest management can be time consuming and labor intensive when monitoring and inspecting for pests. Although pest management advocates the tolerance of some damage, the public may insist on little or no injury

A pest is an animal or plant that is detrimental or annoying to people or property. It typically is an organism that is out of place. For example we like lady beetles in our garden but generally don't appreciate them when they are in our homes. However, what we call a pest can be subjective. Calling something a pest is a label we assign to living creatures. Animals and plants are not inherently pests, they all play a role in the environment.

There are a number of reasons to manage insect pests. We may do so because they threaten the health and appearance of plants we value. They may also threaten human health as well damage our property. Sometimes they are pests just from their mere presence.

The lowest number of insects that cause injury whether it is aesthetic, economic or health-related is called *injury* level. The point when management is required to keep pest numbers below the injury level is called *action threshold.* Thresholds can vary according to what particular pest is involved, the potential damage it can cause, where the pest is found, and the attitudes of people. An insect that is a health concern generally would have a lower threshold, i.e. the presence of a smaller number of pests that are acceptable before management would be implemented. A pest that is a aesthetic or nuisance problem would probably have a higher threshold. IPM strives to reduce (not to eradicate) pest numbers below the level when injury may occur. It is possible when dealing with pests in structures to have a threshold of zero.

There are six steps in an IPM program:

1. Planning ahead considers factors that keeps plants healthy, e.g. planting in proper sites, reducing the attractiveness of plants to pests, modifying the environment to reduce pests, reducing the attractiveness of a building or its surrounding environment to keep pests out of homes. Planning ahead also considers key plants and key pests to better anticipate pest problems.

2. *Detection* You can detect pests by one or more of the following: visual examination for insects and symptoms of their feeding, the use of traps, calendar dates (i.e. the average appearance of a pest is at a certain time of the year), plant phenology (i.e. the time an insect is expected to appear corresponds with the first appearance of a specific plant event, e.g. flowering), and computer forecasting programs. Use evidence of feeding, calendar dates, plant phenology and computer forecasting as guides and rely on sightings of pests to determine the presence of pests.

3. *Identification* Identifying a pest helps you understand its biology, life cycle, and habits. This information tells you the type of damage the insect can cause and how severe it can potentially become. Knowing what insects have been found also helps us understand when the pests are most vulnerable to management tactics. Identification is very important to avoid treating nonpest insects. Two different pests that appear similar may actually require different management tactics. Always know what insect is present before implementing IPM.

4. Establish action thresholds. Before selecting your management tactics, determine how many insects can be tolerated. Consider the actual amount of damage that has occurred and what the potential for injury is. Sometimes there may be an established threshold when dealing with a particular insect pest in a specific situation. Other times the threshold may be more subjective. Keep in mind that the action threshold for a particular pest problem may have already been reached.

5. Determine which *combination of methods* will be most effective. Types of methods includes cultural, such as resistant plant varieties and weed control, mechanical, such as screens and physical removal, biological, such as conserving natural enemies, and lastly pesticidal. Taking no action is a valid option. When pesticides are used, apply them judiciously using the least toxic pesticide that is effective. The management methods that are used may be influenced by cost and time.

6. The final step is to *evaluate the results* and determine if follow-up action is necessary. Continue to plan and monitor for insects even if additional management steps are not taken. IPM is an ongoing process

DIAGNOSING INSECT PROBLEMS

There is no secret to diagnosing pest problems. It takes practice and experience. The more you do it, the better you will get at it. Part of the learning process is knowing what questions to ask. In general, the following questions will help you receive basic information that will aid you in making a diagnosis.

What kind of plant is it?
Are property owners seeing damage? (if so, describe it)
When was damage first seen?
Are insects present? (describe them)
When were insects first seen?
Where are insects seen?
How many insects are seen?
Ask lots of questions.

It is usually best to ask opened ended questions. For example, ask 'how long is the insect', not 'is the insect an inch long'. You will usually get a more accurate answer when property owners have to think about what they are seeing and tell you in their own words.

Everyone gets questions they can not immediately diagnose. It is okay to say you don't know but offer to find out how to answer their question. There are a number of resources that you can turn to in order help to determine the problem. First, there are publications (fact sheets and Yard and Garden briefs) that discuss many of the problems that you are likely to encounter. There are also many books, that either you may own or that may be in your extension office.

If you have access to the internet, check out the Yard and Garden Line newsletter (http://www3.extension.umn.edu/projects/yardandgarden/). It is produced the 1st and the 15th of every month from April through September (monthly during the winter). It discusses current pests and issues and may help you diagnose problems you encounter. All previous articles are archived for easy access. While at the Yard and Garden home page, also check the Insect Journal. There is information about insects that are currently common, picture galleries, and publications and other resources.

Of course, you can always contact me when you have insect questions. You can e-mail (hahnx002@umn.edu) or call (612-624-4977). In cases when you need an insect or a damaged plant sample examined, first consider e-mailing an digital image. In many instances, that is enough to identify the problem. When that is not sufficient or when a digital camera is not available, master gardeners can send a sample to me. There is a $5.00 charge for samples. Ideally, the client requesting the identification should pay this fee.

Insect Damage to Plants

It is important to recognize plant damage caused by insects when diagnosing plant problems. When insects are present, ask yourself what is the real problem with the plant and are the insects that are present capable of causing the observed symptoms. The answer may not always be 'yes'. On the other hand, insect damage may be present but the responsible pests may not be seen. Then you have to rely on the symptoms of the plant to identify the problem. Diagnosing plant damage can be challenging, especially as some disease and abiotic problems can look similar to insect injury. The following is a description of common types of insect damage found on plants.

Damage from chewing insects

Leaves are very commonly affected by chewing insects. Many insects (e.g. butterfly and moth larvae, sawfly larvae, and beetle adults and larvae) chew holes or entire sections of leaves. The tissue around the areas that are chewed typically stay green. In a few cases, insects feed on the leave tissue between major veins (e.g. cakerworms and Japanese beetles). This is referred to as *skeletonizing.*

Some insects feed on one layer of leaf tissue, leaving the veins (e.g. some sawfly larvae, some caterpillars). This type of injury is called *windowpane feeding*. This often gives the leaves a transparent or lacey appearance. The tissue is green at first but later turns brown. This type of damage is random through the plant

Other insects (e.g. sawfly larvae, fly larvae) feed literally inside the leaves between the two leaf surfaces. They are called *leafminers.* There are two types, serpentine leafminers when the insect forms a trail through the leaves as it feeds and blotch leafminers, when the insects feed within a particular area of the leaves. The damaged tissue appears whitish or an off colored green at first but later turns brown. Leafminer damage is random through the plant.

Some chewing insects (e.g. flatheaded borers, bark beetle larvae, clearwinged borer larvae) feed in the phloem layer of woody plants, in the trunk, branches, or shoots. This insect feeding is more difficult to diagnose because insects are rarely seen. It is also challenging because symptoms can look similar to disease or abiotic problems. Borers gain entrance to the plant either by inserting eggs into the plant tissues with the sharp ovipositor of the parent insect or by chewing their way in after they hatch from eggs laid on the surface of the plant. In either case, the hole they enter is almost always minute and not seen. The tunneling of the larvae underneath the bark girdles the plant, interrupting the flow of food and water. This results in dieback starting at the ends of the branches and progressing down. After they complete their life cycle, they chew through the wood, creating an exit hole. The size and shape of the exit holes will vary according to the type of borer involved and can be useful in identifying the pest. Borers that attack evergreen shoots can cause stunted growth that can die back.

Borers can be placed into one of two groups. *Primary borers* are insects that can successfully attack and reproduce in healthy woody plants. *Secondary borers* only survive in stressed, unhealthy trees and shrubs.

Chewing insects may attack the stems of herbaceous plants. They may feed externally (e.g. cutworms) cutting plants off. Others (some moth caterpillars) bore into the stems of herbaceous plants. Symptoms of stems borers include discoloration and/or wilting of the plant and eventually dieback of the plant. Similar to this injury, some insects (e.g. some fly maggots) feed on roots and other underground plant tissue. Injury also includes discoloration, wilting, and dieback. Pull up plants to examine the roots for chewing damage to verify insects.

Other plant parts that can be injured by chewing insects include flowers (e.g. rose chafers), fruits (e.g. codling moth larva), and vegetables (corn earworm). External evidence of chewing is usually visible.

Damage from sucking insects

These insects insert needle-like mouthparts into plant tissue and feed on plant sap. Common insects that feed this way are aphids, scales, whiteflies, leafhoppers, plant bugs, and lace bugs. Sucking insects feed on all plant parts, especially leaves and stems. While these insects are usually exposed on a plant, they are often small and may not be noticed.

In some case, plants infested with these insects may not exhibit any symptoms. Piercing-sucking feeding on leaves often leaves a speckled, pinprick-like discoloration on the upper surface of foliage (e.g. spider mites, plant bugs, lace bugs). Piercing-sucking insects can also curl, stunt, or distort leaves (e.g. woolly aphids, some plant bugs). Feeding on stems or branches can result in wilting and/or yellowing and browning (e.g. aphids, scale). Some insects can cause fruit to be misshappened (e.g. lygus bug) due to their feeding.

Damage from gall insects

Galls are abnormal or deformed plant growths due to insect or mite feeding. Although the gall is made up entirely of plant tissue, insect feeding influences the form and shape it takes as it grows. Common insects and mites that induce plant galls are cynipid wasps, psyllids, adelgids, gall midges, and eriophyid mites. Leaves, twigs, buds, stems, flowers, petioles, and roots can be affected. Despite the appearance of galls, they normally have little impact on plant health.

Damage from oviposition (laying eggs)

Insects sometimes damage plants when they oviposit eggs into plant tissue. Oviposition can injure and even kill branches (e.g. cicadas). Oviposition can deform fruit and cause premature fruit drop (plum curculio).

Answering Household Insect Questions

People contacting master gardeners through the Yard and Garden Line will not only be asking questions about insects in their yards and gardens but also about insects in their homes. Although master gardeners are not expected to answer all household insects questions, there are some topics that you should be familiar with and prepared to discuss with clients including pantry insects, wasps, spiders, and accidental invaders (e.g. lady beetles). If you are asked a household insect question that you are not familiar, refer the client to a publication on the subject. If there is a master gardener in your county that has taken the Home Insect Control (HIC) class, refer household insect questions to them.

Publications (Fact Sheets and Yard and Garden Briefs)

Fruit Insects
Apple Maggot Management in Home Gardens
Fruit Insects, Common
Home Fruit Spray Guide
Raspberry Insect Pests
Strawberry Insect Pests of the Home Garden

Vegetable Insects
Asparagus Beetles in the Home Garden
Caterpillar Pests of Cole Crops in Home Gardens
Colorado Potato Beetles in Home Gardens
Red Turnip Beetles in the Home Garden
Sap and Fungus Beetles
Squash Bugs in Home Gardens
Squash Vine Borer Management in Home Gardens

Flower Insects
False Japanese Beetles
Fourlined Plant Bugs
Iris Borer
Rose Chafer
Roses, Insect Pests of
Slugs

Houseplant Insects
Houseplant Insect Control

Tree and Shrub Insects
Aphids on Trees and Shrubs
Birch Leafminers
Bronze Birch Borer and Its Management, The
Cankerworms
Forest Tent Caterpillars
Fungus Killed Flies
Galls, Insect and Mite
Galls, Insect and Mite, in the Landscape
Gypsy Moth: A Threat to Minnesota
Honeysuckle Witches Broom Aphid
Insecticide Suggestions to Manage Tree and Shrub Insects in the Landscape
Japanese Beetle Management in Minnesota
Lace Bugs
Leaf Beetles in Urban Landscapes
Maple Petiole Borer

Native Elm Bark Beetle Control
Plant Bugs, Ash and Honeylocust
Roses, Insect Pests of
Sawflies of Trees and Shrubs
Scale Insects of Trees and Shrubs
Spring and Fall Cankerworms
Woolly Aphids on Deciduous Trees and Shrubs

Lawn/Turf Insects
Lawn and Turf Insects, Controlling
Nightcrawlers

Household Insects
Ants
Carpet Beetles and Clothes Moths
Cockroaches
Crickets
Earwigs, Controlling (Online version not available.)
Flies, Fall Nuisance
Flies, Summer Filth
Foreign Grain Beetles
Ground Beetles
Horsehair Worms
Lady Beetles, Multicolored Asian
Larder Beetles
Masked Hunter
Mites, Clover
Mites in Homes, Bird and Rodent
Osage Oranges
Environmentally Responsible Methods of Pest Control In and Around Homes
Powderpost Beetles
Pseudoscorpions
Psocids
Sowbugs, Millipedes, and Centipedes in the Home
Silverfish and Firebrats
Spiders In and Around Homes, Common
Spiders, Potentially Dangerous
Springtails
Stored Foods, Insect Pests of
Weevils, Home Invading
Wood Borers, Bark Beetles, and Seed Insects in Homes

Biting or Stinging Insects
Bed bugs
Black Flies
Fleas
Head Lice Management in Schools and Homes
Minnesota Ticks and Their Control
Scabies and Chiggers on Humans, Control of
Wasp and Bee Control

For the most current urban entomology publications, see the listing at the following url: http://www.extension.umn.edu/projects/yardandgarden/EntWeb/publications 1.html.

To find additional entomology references see the listings at the following url: http://www.extension.umn.edu/projects/yardandgarden/EntWeb/Otherresources.html

chapter

6

Pathology

chapter 6

Pathology

PLANT PATHOLOGY

by Janna L. Beckerman, Ph. D., Extension Plant Pathologist and Assistant Professor

INTRODUCTION

The purpose of this chapter is to introduce the Master Gardener to plant pathology and develop a basic understanding of the discipline and become a practitioner of the field. To accomplish this, the microbiology of disease causing organisms is discussed, with a focus on common yard and garden diseases. This basic understanding of plant pathology is then coupled with an investigative approach to develop an accurate diagnostic process. Only with an accurate diagnosis can proper disease management be undertaken.

LEARNING OBJECTIVES

The objectives of this section are to:

1. Develop a basic understanding of plant pathology, including the common agents of plant disease.
2. Develop key skills necessary for accurate diagnosis.
3. Understand management practices available after diagnosis.

WHAT IS PLANT PATHOLOGY?

All living organisms are subject to disease, including plants. This tends to surprise people, most of whom give little thought to plant disease. For most people, the only questions they might ask a plant pathologist are: "What is wrong with my plant?" quickly followed by: "That's interesting. Now what can I do to get rid of it?" These two simple questions can be reduced to two words: Diagnosis and Management. Question number one deals with DIAGNOSIS. Question number two deals with the MANAGEMENT of the problem. However, before one is able to diagnose and manage the disease, an understanding of the problem needs to be established.

What is Disease?

Plant disease has numerous definitions. For our purpose, plant disease can be defined as: *An abnormal condition that impairs functioning and can be recognized by symptoms and signs.*

Symptoms: Changes in the appearance, growth or development of the plant in response to biotic or abiotic factors. Some common symptoms include chlorosis (yellowing), necrosis (dead tissue), cankers, blight, anthracnose, and ringspots. This will be discussed in greater detail later in the chapter.

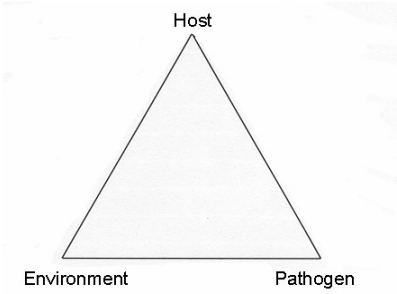
Signs: The disease-causing agent. Mycelia and fungal fruiting bodies, cysts and bacterial ooze are signs. Remember: Viral signs can only be seen with the aid of an electron microscope!

The Effect of Disease on Plants

It is the symptoms and signs that demonstrate the disruption of normal plant function that results in a loss of structure, appearance or economic value of a given plant. There are several types of infections that actually benefit the plant, e.g., nitrogen-fixing bacteria form nodules on the roots of certain legumes or the mycorrhiza-forming fungi that improve nutrient uptake to the infected plant. These associations benefit the plant. Disease, on the other hand, occurs when an organism "takes something away" from a plant, or prevents a plant from achieving its genetic potential.

The Plant Disease Triangle

How exactly does disease happen? The disease triangle easily models what is happening when we observe plant disease in progress. The disease triangle shows that any disease requires a host, a pathogen and the environment. It is important to remember that all three factors are necessary for the development of disease. If any one of these factors is missing, disease will not occur.



Environment: Where the plant is located and the weather conditions affecting it. Some environmental conditions favor certain pathogens over others.

Pathogen: The disease-causing agent.
Common disease causing agents include:
- Fungi
- Bacteria
- Viruses
- Nematodes
- Phanerogams (plant pathogenic plants).

Host: The susceptible plant that can develop disease.

Plants can be resistant, tolerant, susceptible or immune.

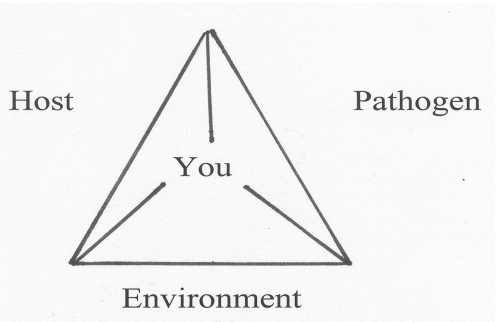
Resistance: Usually specially bred cultivars chosen and propagated due to their ability to prevent the spread of disease through an infected plant.
Example: *Malus* cv. 'David' is resistant to cedar-apple rust.

Tolerance: Often used when resistance is not available, tolerance enables a plant to complete the necessary life processes (flowering, fruit production or maintain appearance) even though infection occurs.
Example: *Malus* cv. 'Cortland' is tolerant to cedar-apple rust.

Susceptible: All plant are susceptible to some disease. This is a compatible interaction between the host and the pathogen, and may result in plant death.
Example: *Malus* cv. 'Golden Delicious' is very susceptible to cedar-apple rust.

Immune: A nonhost for a given disease
Example: Oak is immune to cedar-apple rust.

The Disease Tetrahedron



As a gardener, you have choices not available to the farmer. This is why we've included you in this process. Now, there may not be much you can do about the weather, but there are things you can do about your choice of plants, where you plant them, how you plant them and how you care for them. All of these decisions affect what diseases you get, the likelihood that you get them and how you may go about managing them…or not.

Disease Development

The infection process involves 6 steps: Inoculation, Penetration, Infection, Invasion, Reproduction and Dissemination.

Inoculation: Pathogen meets hosts. It refers to the initial contact between host and pathogen. In the case of fungal spores, bacteria and the seeds of parasitic plants, it also involves attachment to the host. It may also refer to germination of the pathogen. In the case of some pathogens, like rust fungi, certain topographical cues trigger the development of structures necessary for penetration. Without those cues, the pathogen fails to infect and dies.

Penetration: Penetration is the entrance of the pathogen into the plant. Penetration by plant pathogenic organisms can occur in several ways. These include:

Penetration through natural openings, such as the stomates or lenticels.
Penetration through wounds such as frost cracks, sunscald
Direct penetration through intact plant surfaced
Insect Vectored

Infection: growth by the pathogen, usually at the expense of the host. This involves multiple steps, and although a very dynamic time in both the life of the host and the pathogen, NO SYMPTOMS ARE VISIBLE.

Invasion: The pathogen has established itself and is spreading throughout the plant. Symptoms are developing and are visible. Pathogens may begin to reproduce, which may be observable through the development of signs.

Reproduction: In the case of microbes, reproduction may be sexual or asexual. Asexual reproduction often produces secondary inoculum that increases disease severity. Sexual reproduction results in the shuffling (recombination) of genes. For many fungi, the propagule that resulted from sexual reproduction is often the overwintering stage.

Dissemination: Closely linked to inoculation, pathogens are disseminated via the wind, rain, insects, soil and people.

Plant Defense

Like any living creature, plants are subject to infection by microbes. Plants differ from animals in three ways. First, plants can't "run away," and must contend with whatever they encounter. That said, plants are able to "escape" or avoid disease, but not in the way we usually think of escape. Second, plants do NOT have an immune system. Plants have evolved elaborate structural and chemical defenses, but they do not produce antibodies or white blood cells to fight disease. Third, plants can suffer enormous destruction without survival becoming an issue. Loss of roots, leaves, branches or even stem tissue does not necessarily result in death.

At this point, you may wonder how any plant survives, let alone reproduces and/or looks pleasing. The potential for disease and pathogens are everywhere. However, just as pathogens have evolved elaborate mechanisms to infect, plants have evolved equally elaborate mechanism to defend themselves.

Structural Defense:

Plants have numerous features that prevent pathogens from attacking and invading. The most obvious plant defense mechanism, needles or thorns, prevents or discourages all but the hungriest herbivores from eating some plants. The cuticle, a waxy structure on the leaf, can be too thick to allow infection to occur. Below the cuticle, the cell wall may form a similar function, and impede the spread of a pathogen to the extent that other defense responses act in concert to compartmentalize the pathogen, thereby preventing further spread. Thick hairs may keep pathogens from ever coming in contact with the leaf surface. Natural openings, such as lenticels, stomates or floral organs may prevent infection due to timing, which a breeder may exploit to allow the host to escape infection.

Chemical Defense:

Some plants produce chemicals that prevent disease. Young sorghum seedlings are virtually disease resistant because of high levels of cyanide (in the form of hydrocyanic acid) that is present after germination. Plants contain thousands of chemicals that can slow or stop the growth of pathogens. Some of these are being produced all the time; others are induced upon wounding or infection. These induced chemicals may be toxic to the pathogen, or may be necessary to detoxify something that the pathogen produces.

Combination Defense:

Some structural barriers are produced as a response to infection. When injured cells die, tannins, lignins, and resins (to name but a few) are produced and form a barrier. Most of the time, these barriers prevent the disease from spreading. However, with wilt pathogens, it is the formation of barriers, called tyloses, which block water flow in the xylem and cause wilting to occur.

The Causal Agents of Plant Disease

Plant disease may be caused by biotic (living organisms) or abiotic (non-living) agents. To translate this into "human terms," we think of biotic agents as "germs" and abiotic agents as "accidents." Skinning our knees is an accident. A cold, caused by "germs" may be viral or bacterial.

Abiotic Factors:

Abiotic agents of plant disease injure but do not infect, healthy, living plants. For this reason, they are often referred to as "disorders." Because they aren't alive, they do not "spread," like biotic agents of plant disease. Some abiotic agents of plant disease and the damage that they cause are:

Abiotic Factor	Result
Moisture	
High	Flooding-lack of oxygen, root rot
Low	Drought-dieback, opportunistic pathogens
Temperature	
High	Sunscald
Low	Frost damage
Light	
High	"sun"scald, pigmentation
Low	chlorosis, etiolation
Wind	
Hail	wounds that provide infection courts
High Winds	wounds that provide infection courts
Chemicals	
Pollution	foliar injury
Salt	foliar chlorosis, witches' broom, death
Herbicides	deformity, chlorosis, death
Fertilizers	dwarfing, pH problems, deformity, death
Soil/Site	
Drainage	see moisture
pH	nutrient availability, dwarfing
Structure	see moisture, pH
Nutrient	dwarfing, deformity, death
Mechanical	
Animal	Infection court, girdling, death
Construction damage	Infection court, girdling, death
Lawn mower	Infection court, death
Planting	transplant shock, too shallow or deep
Vehicles	Infection court

Biotic Agents of Plant Disease

Biotic agents of plant disease are living organisms that infect healthy plants, reproduce and often spread to other plants where they cause new infections.

Fungi

Before any discussion about fungi as agents of plant disease, it must be stressed that most fungi are beneficial and a necessary part of carbon cycling. If we didn't have fungi and other microorganisms, we'd be buried under miles of wood! Problems develop, however, when fungi begin their decomposition before we want them to! Fungi are a unique group of organisms that are grouped together because they share some common features. Fungi are usually composed of a threadlike tissue referred to as hyphae (singular: hypha, Greek

for web), and a hyphal mass is referred to as mycelia (singular: mycelium). The hyphae and mycelia are vegetative structures.

Reproduction requires the formation of specialized structures. These structures, referred to as fruiting bodies, allow the fungi to reproduce sexually or asexually by spores, tiny seedlike structures. Most fungi are capable of both sexual and asexual reproduction. Because this reproduction often looks so different, and occurs in isolation from the other phase of the life cycle, many fungi have two names, although the name for the sexual state is the preferred one. To add to the confusion, names have been changed over time to better reflect our better understanding of how fungi relate to one another.

Asexual reproduction is a simply reproduction without genetic change. This allows the successful fungus to rapidly spread and colonize new sites, or produce resting structures.. Fruiting bodies or the development of specialized hyphal structures (called conidiophores) are often needed for this type of reproduction to occur. Sexual reproduction involves genetic recombination between two different individual fungi (but still the same species) and results in specialized sexual structures, also called fruiting bodies (a mushroom is the sexual fruiting body of some fungi). Often the sexual spores are the overwintering structure; some fungi produce asexual overwintering structures in the form of sclerotia (thick walled fungus balls) or chlamydospores (thick walled spores).

Although fungi are grouped together because they share common characteristics, they are an extremely diverse group of organisms. So diverse, in fact, that some members of the Kingdom:Fungi aren't really fungi at all! They are actually more closely related to plants or to animals. This is an incredibly important point to remember, particularly when devising management strategies. For example, the Oomycetes (e.g., *Phytophthora* and *Pythium*), which are sometimes called pseudofungi, are actually more closely related to plants, even though they produce hyphae and spores. Most fungicides labeled for "true" fungi have no affect on *Phytophthora* or *Pythium*. Conversely, many fungicides labeled for these fungi have no affect on the "true" fungi. This is an important point to remember when choosing chemical controls. Finally, not only are some "fungi" really plants, but other "fungi" are neither plant nor "fungi." Slime molds, those colorful growths on mulch and turf, produce spores and hyphae, but are more closely related to animals.

For more information on slime molds and other fungi, go to: http://helios.bto.ed.ac.uk/bto/microbes/slime.htm#crest
http://www.wisc.edu/botany/fungi/volkmyco.html

Bacteria

Bacteria are single celled organisms that have a rigid cell wall. They may be rod-shaped, spherical, spiral, or filamentous. Bacteria, although capable of sexual reproduction, usually reproduce by fission. This process allows one cell to divide into two cells. Under optimal conditions, cells can divide every 20 minutes. If this continued, over 10 million cells could be produced in 12 hours! Fortunately for us, this doesn't happen very often, but it does allow you to see how a plant can be quickly "overrun" with bacteria!

Unlike fungi, which can forcibly enter a plant, bacteria require an infection court. The most common site is at a wound. Other entry points include natural plant openings, like stomates and lenticels, or leaf or flower scars. Young succulent shoots are especially susceptible to bacterial infection. Wounds from hail damage or insect feeding sites provide easy entry for bacteria and can set the stage for severe epidemics.

Unlike the "true" fungi, most bacteria are motile and move through the use of a flagellum, a whiplike tail. This permits movement over a short distance. Some bacteria are capable of producing endospores that enable them to survive adverse environmental conditions. Fortunately for us, no plant pathogenic bacteria are able to do so! In our climate, most bacteria survive in cankers of perennial plants, on or in seeds or other reproductive structures (buds, corms, tubers etc).

Phytoplasmas (formerly called mycoplasma-like organisms) are closely related to bacteria. Like bacteria, they are prokaryotic, meaning their organelles are not membrane bound. And like bacteria, they are also easily killed by antibiotics, particularly tetracycline. However, unlike bacteria, they have no cell walls. Aster yellows, X disease of peach and cherry, and ash yellows are caused by different phytoplasmas.

A great site for the basics on bacteria can be found at:
http://www.ucmp.berkeley.edu/bacteria/bacteria.html

Viruses

A virus is the simplest form of life and the smallest. Viruses are composed of small stretches of DNA (DeoxyriboNucleic Acid) or RNA (RiboNucleic Acid), the genetic material that is the basic building block for life, and often a coat protein to protect the genetic material. These organisms are so simple in fact, that they don't have all the genetic material to reproduce themselves, and "commandeer" the cellular machinery of the host to reproduce.

Viruses are too small to be seen with naked eye or even a light microscope. Viruses are only observable by electron microscopy. This is a necessary step in determining the shape of a virus. Virus shape, due to properties of the coat protein, is used to classify viruses. Basic viral shapes include crystals, filaments, helixes, polyhedrons, rods and spheres.

Viruses are not spread by wind or water, but instead require contact between healthy and infected plants. In general, viruses need to be injected into a plant by mechanical means, whether it is contaminated tools, or through the mouthparts of insect vectors. Some common vectors of viral disease include aphids, thrips, nematodes, fungi and mites.

For the basics on virus, go to: http://library.thinkquest.org/23054/basics/

For more information on plant viruses, check out:
http://ag.arizona.edu/~zxiong/plp611/httoc.html

Nematodes

Nematodes are members of the animal kingdom. Unlike earthworms, which have segmented bodies, nematodes have no segments and are referred to as round worms or eel worms. Their small size requires the use of a hand lens or microscope to visualize them. Nematodes are classified based on their feeding habits, and all have a hollow stylet, or mouthpart that is used to puncture plant cells. Some nematodes puncture a cell, feed and move to the next cell, while others, like the root knot nematode, feed at one site on the surrounding cells.

Nematodes are able to reproduce either sexually or asexually. Most nematodes live at least part of their life in the soil, but a few, like *Aphelenchoides,* are considered foliar pathogens and persist in the buds and crowns of perennials. Nematodes can vector disease (*Tylenchus* vectors tobacco rattle virus) or be vectored by other insects (*Bursephalenchus,* the pine wilt nematode, is vectored by cerambycid beetles).

For more information on nematodes, go to: http://www.ianr.unl.edu/son/whatarenematodes.htm

Phanerogams

There are two parasitic plants that Minnesota Master Gardeners need to be aware of: dwarf mistletoe and dodder. Dwarf mistletoe, which infects spruce in the northern part of the state, is a native parasitic plant. Dodder, on the other hand, is an unusual and introduced occurrence that appears on occasion in bedding plants. Parasitic plants cause disease by diverting nutrients and water from the host for their own reproduction.
For more about dodder, go to:
http://www.ipm.ucdavis.edu/PMG/WEEDS/dodder.html
For more about dwarf mistletoe, go to: http://www.na.fs.fed.us/spfo/pubs/fidls/dwarf_mistletoe/fidl-dm.htm

Diagnosing Plant Disease

Diagnosing plant disease is as much art as it is science. In many respects, you are a criminalist, trying to determine what happened to your victim, a dying or dead plant. To do so requires an investigative approach and an inquisitive mind. Like a criminalist, there are a lot of factors to put together to determine "What is wrong with a plant?" Without accurate diagnosis, you cannot proceed to the next step, and any management strategy that you develop is useless.

It must be stressed that there isn't one approach, or flow chart, or cheat sheet of questions that will lead you to the correct answer. Like a criminalist, you need to develop a series of deductive steps that allow you to formulate a picture of what occurred. These deductive steps often begin with a series of broad questions that allow you to work your way down to specific questions. As you progress through the questions, the number of possibilities is reduced, until, hopefully a single probable diagnosis is reached.

Define the problem

In defining the problem, the first question that must be asked is: What is the host plant?

By identifying the host, you've managed to eliminate 99.999% of possible disease problems. Because most pathogens do NOT infect most plants (e.g., oak trees don't get rose downy mildew), identification of the host provides you with a subset of disease problems. These subsets of disease that affect a given host can be found in the following textbooks or web pages:

The Organic Gardener's Handbook of Natural Insect and Disease Control. Barbara Ellis and Fern Marshall Brady, editors.
Diseases of Trees and Shrubs W. A. Sinclair et. al.
Westcott's plant disease handbook. Revised by R. Kenneth Horst.

http://www.extension.umn.edu/projects/yardandgarden/diagnostics/
http://plant-disease.orst.edu/index.cfm
http://plantpathology.tamu.edu/Texlab/index.htm

Host identification, and research into the biology of the host may provide you with clues, or at least arm you with additional questions to pose. These questions include: Is the host hardy in this location? Is the host planted in a suitable location? If possible, try to compare the "diseased" plant to the healthy plant. Waxy "bloom"(a yeast-like or wax like covering) on some leaves may be mistaken for powdery mildew, legumes have nodules on roots that may be mistaken for root knot nematodes, and sori on the underside of ferns can be mistaken for rust. Conversely, people who have regularly seen the orange "blooms" every spring on a juniper may be surprised to learn that their plant has a disease (cedar-apple rust)!

Before you jump to any conclusions, Ask questions! Some questions to consider include:
What is the problem?
Defining the problem will usually produce a series of symptoms and signs. Remember, **signs** are disease causing agent and **symptoms** are the plant response to biotic or abiotic factors. Some common symptoms and where they are found are:

Roots

Rots: Roots appear darkened and soft. Plants may be easily pulled from soil, and rooting mass does not appear in proportion to aboveground growth. Very few root hairs are present. Earliest symptoms usually include wilting or stunting. Fungal signs in the form of mycelia or fruiting bodies may be present.

Galls/Knots: Roots attacked by nematodes often have galls or knots. Some bacteria can cause galls or unusual root proliferation. Look for signs with a hand lens.

Stem/Trunk/Branches

Cankers: Sunken or swollen dead areas in the stem. May be target shaped in woody perennials. These are usually associated with wounds, which served as an infection court. Small pustules (fungal fruiting bodies) may be present, or bacterial ooze may be observed during wet weather.

Galls: Round or elongated swellings in the main trunk or branches. Galls can be small or large, and like cankers, prevent nutrient flow. Galls can be fungal or bacterial.

Wilt: Always check roots first to make certain the problem doesn't lie below ground. Wilt disease affects the water-conducting vascular tissue of the plant. Discoloration of the vascular tissue is usually present.

Rot: Stem and branch rotting organisms are usually secondary.

Rust: Rust fungi affect both leaves and branches. The fungal signs are usually only visible for a few weeks in the spring.

Blight: Shoot blights result in death of new growth, usually with shoots blackening, curling and dying. Young shoots are more susceptible than older shoots. Witches' Broom: A proliferation of new growth from a single site. These may be due to parasitic plants or certain rust fungi, which produce signs. Phytoplasmas also produce witches' brooms, but the signs are not visible.

Leaves and Fruits

Leaf spots: A common plant disease, rarely fatal. Circular spots, with or without concentric rings may appear. Pimple-like fruiting bodies may appear on the diseased tissue. Bacterial leaf spots are usually angular and water soaked.

Anthracnose: A leaf spot with the ability to progress past the leaf and into the woody stem of the plant. Can produce blight-like symptoms.

Powdery mildews: A white dusty covering that is the sign of the disease. Round black balls (cleistothecia) may appear in the fall.

Rusts: Orange pustules (the sign) that appear on the leaves. May produce chlorotic symptoms in areas surrounding the pustule.

Mottlings, mosaics: Varying shades of green or yellow that produce a variegated appearance.

Ringspots: Round target-shaped symptoms of viral disease.

After identifying the host and the symptoms of the plant in question, it is important to identify how the damage occurs and if it is progressing. To do so, you need to examine the site. Some questions to ask are:

What were the environmental conditions prior to disease development?
Where is the plant located?
Can an observable pattern be identified?

If an observable pattern can be identified (e.g., only the plants in front of the drier vent are affected), it is likely that an abiotic disorder is the underlying cause of the disease. Disease causing agents and insect usually produce symptoms in a random fashion. However, if only one host is affected, care must be taken: Some plants are more susceptible to specific events (e.g., air pollution, drought, flooding) and specific pathogens. Examine your symptoms! Remember your research on the host and evaluate the situation thoroughly.

It is important to gather information about any possible herbicide/fertilizer (i.e., "weed and feed") use; construction damage (which may have occurred years ago); change of drainage patterns, to name a few. Don't forget to ask about plant care, watering and fertilizing practices. Remember: Abiotic disorders do not progress whereas disease problems can if environmental conditions favor their progression.

Finally, remember that there are thousands of plants used in the home landscape. Each plant has dozens of disease problems. It is impossible to know them all. Seek professional help when in doubt. Consult the University of Minnesota Extension Service staff and resources. Don't rely on a single text or website. Remember, incorrect diagnosis results in management practices that are doomed to fail.

Questions to Ask and Why:

1. **What is the host plant?** Identifying the host eliminates most disease possibilities and creates a subset of possible disease problems.
a. **Can you identify it to species?**
b. **Can you identify the cultivar?** Some species or cultivars are susceptible to certain diseases. This information can further reduce your pool of "suspects."

2. **Is the host plant appropriately planted?** Plants put in the wrong site are a leading cause of plant disease.
a. **Is it zone hardy?**
b. **Is it receiving the proper amount of sun or moisture?**
c. **Is it the right plant for the soil type?**

3. **What is the problem?** Carefully examine plants and don't jump to conclusions!
a. **Compare to a "normal, healthy" plant-What is wrong?**
b. **What are the symptoms?** Thoroughly examine and catalog your findings. Remember, you can't get too much information!

4. **Obtain background information.**
a. **How was the site planted?**
b. **Where were plants obtained?**
c. **How were they cared for?**
d. **Has there been construction within last 5 years?** Many problems, particularly with trees and shrubs, don't appear for several years after a particular "insult," such as construction or severe weather.
5. **Examine the affected plant.**
a. **What portion is affected?**
b. **When did symptoms appear?**
c. **How did symptoms progress?** Look at leaves, stems, branches and roots whenever possible.
6. **Examine the site.**
a. **Is there a pattern?** Random patterns usually indicated disease.
b. **Are only certain plants affected?**

Managing Plant Disease.

Not all disease needs to be managed, and the reality is that very few can be controlled. Most homeowners want to know what they can spray to cure a problem. Unfortunately, there are no silver bullets, although people want to believe that fungicides are a panacea. Usually cultural practices can be implemented to reduce, prevent or avoid disease. Prevention is the best management strategy. However, even the "best" gardeners will have disease problems at some point. Keep in mind that in many instances, there are no chemical controls. Finally, if you recommend chemical controls YOU MAY BE HELD RESPONSIBLE IF YOUR RECOMMENDATION IS INCORRECT!

Planning a management regime.

Before even contemplating a management regime, you need to consider whether controlling the disease is necessary. For example, late blight can strikes in fall, but causes no reduction in yield because the tubers are already established and leaves are contributing little to tuber development. In this case, management may consist of crop rotation to prevent the possibility of late blight next year. If, however, a late blight epidemic occurred in June, management should be quickly undertaken, or the end result will be no tubers at all. If you think that control of some sort may be necessary, don't forget to factor the following aspects that will be necessary to execute your management regime.

Time- Consider the time necessary to:
Remove (cull) infected plant.
Spray (some regimes require multiple sprays over the growing season
Expense- Is a $10 fungicide appropriate for a $1.69 flat of bedding plants?
Cost of protective gear
Cost of spraying equipment
Hazards- What are the risks involved in any chemical I utilize?
Risks to yourself
Family
Wildlife
Community

All of the above factors must be considered in the development of a management regime. Too many times after a diagnosis is made, the only concern is "What can I spray on it?" The reality is that numerous things could have been done to prevent the disease in question from ever occurring. Another reality is that management regimes that require multiple or long term control strategies aren't performed adequately, which contributes to pesticide resistance.

Integrated Pest Management. Most cultural practices incorporate several of the above strategies to manage a disease. In fact, Integrated Pest Management (IPM) by definition is the incorporation of several management practices with a goal of overall disease reduction-not elimination.

Prevention: One of the best ways of managing plant disease is to prevent them from gaining a foothold. Methods of disease prevention include:
Quarantines. This is a legal method to reduce disease spread. To prevent the problem of introduced pathogens, most countries introduced limits on the plants, and even the soil, which can be moved from one part of the world to another. You can do the same on a smaller scale by examining plants prior to incorporation into a landscape. Or, you may consider planting perennials to another part of the garden, away from other plants, where the plant can be evaluated for the year prior to introduction to the garden.

> **Quarantines are in place to prevent the introduction of destructive diseases (like sudden oak death in California) from being transported from one geographic region to another. Quarantines were initiated after diseases like Chestnut blight or Dutch elm disease were introduced to the country.**

Avoidance. Avoidance is a management practices that allow the plant to avoid disease, even though the pathogen may be present. This usually requires the implementation of certain cultural practices that minimize or prevents infection. Crop rotation is considered an avoidance tactic. Not planting Rhododendron on heavy clay soil (to avoid Phytophthora root rot) would be another.

Eradication. Rapid response to pathogen introduction may prevent its spread. This may be done on a wide area, such as a country, state or single yard. Eradication is not always successful, as we have recently learned with the newly introduced daylily rust pathogen. Another approach, eradication of alternate host, is often employed to prevent disease spread or genetic recombination, such as the elimination of *Ribes* spp. to prevent white pine blister rust. Eradication is an extreme form of:

Sanitation. Homeowners should be concerned with introducing pathogens to their own yards. However, most diseases exist in most areas. When planting in an area with disease pressures, it is important to have a "clean" start with as little inoculum as possible. Quite simply, the less inoculum you start the season with, the less disease that will result in the end of the season. Use of certified disease-free seed, plants or cutting, chemically treated seeds, disposal (not composting!) of infected plants are all important management tools in reducing disease.

Resistance. The best method, when available, of managing disease problems. Unfortunately, using a resistant cultivar can lead to a sense of false security.

Monoculture, even of a resistant cultivar, is never a good idea. Cultural controls still need to be implemented. Unfortunately, widespread planting of resistant cultivars often result in the identification of an unknown susceptibility to an unknown pathogen (Think purple coneflower and aster yellows! Purple coneflower was considered quite broadly "disease resistant" and given the 1997 perennial plant of the year designation. That same year, aster yellows was diagnosed infecting purple coneflower).

Regardless of what resistant cultivars are available, some people will insist that a susceptible cultivar be used, and used immediately. In this case, cultural controls can be used to reduce the possibility or severity of disease. Although little can be done about temperature, or rainfall, steps can be taken to minimize disease.

Cultural controls:
Match the plant to the site.
Light. Make certain that the plant is appropriately planted. High light plants are reduced in vigor when planted in partial shade. Conversely, shade loving plants suffer heat and drought stress when planted in full sun.

Soil. Plants evolved under certain conditions and thrive when maintained on these conditions. Rhododendron require well drained soil and often develop root rot on poorly draining clay. Acid loving azalea will fail on more alkaline, clay soils.

Watering and Planting density. Space plants adequately to allow foliage to dry. When watering, water early in the morning to allow foliage to dry, or utilize drip lines to minimize leaf wetness. Prune to keep plants open.

Choose healthy plants. Easier said than done, use disease-free seed or stock.

Promote pest tolerance. Healthy plants can overcome opportunistic agents of disease. Water and fertilize appropriately, and mulch to keep plants healthy. For lawns, de-thatch and aerate on a regular basis.

Planting dates. Adjust planting times to minimize weed competition or insect infestation. Seeds planted too early, when it is cold and wet, are all but guaranteed to succumb to damping-off.

Variety. Monoculture begs epidemics. By planting several varieties (sometimes called companion planting), many diseases can be avoided or reduced in severity. This approach also increases the likelihood of some of the natural enemies of plant disease (Biological control).

Other Management Strategies:
Biological control. Every problem organism has its own "problem organism." Research the biological controls available. Some species of Trichoderma feed off the fungi that cause damping-off. Streptomyces bacteria can be used to control fire blight.

Scouting. Early detection can lead to early diagnosis that will allow you to manage a disease before it becomes an unmanageable epidemic.

Chemical Controls
Pesticides. For our purposes, we are talking about fungicides, bactericides and nematicides. Prior to using any chemical, you must be certain that you have made the correct diagnosis. Many fungicides are only labeled for specific diseases and don't work on other diseases, so "guesses" aren't helpful. Most disease problems aren't a simple "spray and solve" and require an integrated approach. Don't forget that preventative measures and good cultural practices are the cornerstone to good IPM practices. Even so, pesticides are often necessary to "jump start" control and prevent an epidemic from occurring and are an important component of any disease management strategy.

Contrary to popular belief, most of these products do not "cure" the infected plant, but prevent further infections from occurring. Pesticides have a broad range of toxicity. It is important to remember that organic does not equal safe (in fact, the organic insecticide rotenone, which is no longer available, was one of the most toxic of insecticides to fish), and horticultural oils, which are not "organic" (they are petroleum by-products) are as safe as mineral oil (which is almost the same thing).
After diagnosis, you are confronted with a new set of decision: What type of pesticide do I want to use. The ingredient, chlorothalonil, is the active agent in many different fungicides made by many different companies. Before selecting any chemical, read the label and honestly ask if you or the homeowner can carry out the instructions. Are you able to adequately cover the plant surface and provide the coverage necessary for disease control, or should a professional be called? Lack of completeness (not covering plant, or leaf undersides, or spot spraying) is a leading cause of failure, after inaccurate diagnosis.

Many pesticides require proper timing and multiple applications. The first application usually corresponds to a time when the pathogen is released, or a point in the host life cycle when infection can occur. The first application usually acts as a barrier. Plant growth affects barrier completeness. New leaves and shoots often require additional protection to prevent infection from occurring. Most fungicide labels provide guidelines on reapplication. It is important to remember that excessive rainfall may mean even more applications are necessary.

Regardless of which type of pesticide that you use, it is imperative that you follow the label instruction.

There are several different types of pesticides:

Contact (Disinfectants or Disinfestants). Kill spores and germinated spores on the surface, but cannot arrest infections that have already begun. Bleach, copper and hydrogen peroxide (often labeled as hydrogen dioxide) are three active ingredients found in contact disinfectants.

Protectant. Prevents infection from occurring and not much different than contact pesticides. Bordeaux, copper, sulfer, lime-sulfer are a few of the more common protectants that inhibit spore germination. Protectants are often used as seed treatments in the prevention of damping-off.

Eradicant. Systemic in action, these compounds translocate throughout the plant and eradicate the infective organism. Propiconazole, used to treat elm trees with Dutch elm disease, or oaks with oak wilt, is an effective eradicant if the disease was diagnosed early.

Types of Chemicals Used in Plant Disease Management in the Home Landscape.

Hundreds of chemicals are used in plant disease management; Most of these fall within the following classes:

Naturally-occurring Pesticides

Copper Compounds.
Liquid or Fixed Copper. Available but rarely used, copper is toxic both to plants and microbes (and humans in large amounts!). Usually, it is more toxic to microbes than to most plants, and is less phytotoxic than Bordeaux mixture, but also less effective. This form of copper is applied as a basic copper(cupric) sulfate or copper chloride.

Bordeaux Mixture. Produced through the mixture of lime and copper sulfate, it is the most widely used fungicide in the world. The phytotoxicity of Bordeaux mixture can be reduced by varying the ratio of lime to copper, and it is the presence of lime that reduces the phytotoxic affect of the copper.
Copper Hydroxide (trade name Kocide). A copper hydroxide formulation used to control fungal and bacterial diseases. Hydroxide increases the availability of the copper ion, so smaller amounts of the pesticide is used.

NOTE: Copper compounds are phytotoxic and can cause leaf burning and fruit russetting when applied in cool, wet weather. Young, actively growing plants are also more susceptible to copper phytotoxicity. Always test small areas prior to treating an entire plant.

Sulfur. The oldest used fungicide in the world. Although considered organic, sulfur is really an inorganic compound. Certain plants, like viburnum, are known to be extremely sensitive to sulfur phytotoxicity. Used to primarily control powdery mildews and rusts.

Lime-sulfur. Like Bordeaux mixture, the combination of lime and sulfur produces an equally effective fungicide that is less phytotoxic.

NOTE: Sulfur compounds, when applied in hot dry weather, may cause severe phytotoxic injury. Tomato, melon and grape are especially sensitive.

Manufactured Pesticides. Note: Organic, when used here, denotes the presence of a carbon atom. These products are manufactured and should not be confused with those products considered "organic," but are in fact, inorganic because there are no carbon atoms present.

Organic sulfur compounds:

Dithiocarbamates: This group of fungicides are derivatives of dithiocarbarmic acid and are toxic to microbes by inhibiting the production of life-requiring enzymes. Fungicides include: Thiram, Maneb and Zineb. Maneb, which contains manganese, is often used for control of vegetable diseases.

Quinones: Usually used as a seed treatment, quinones mimic naturally occurring plantmade antimicrobial compounds. Dichlone is a commonly used protectant and eradicant spray on vegetables and fruit.

Aromatics: A broad group of unrelated compounds that possess a six-carbon ring and are usually used against soil born pathogens. PCNB and chlorothalonil are well known examples of this group of fungicides.

Heterocyclic compounds. Containing multiple carbon-rings, captan and iprodione are the most widely used.

Systemic fungicides. Absorbed through the roots and translocated throughout the plant, these fungicides are capable of preventing disease spread within the plant. Unfortunately, resistance to this class of fungicides arises quickly, so these fungicides should be used in conjunction with a broad-spectrum contact fungicide and on a rotating basis.

Acylalanines. Used to control the Oomycetes, or water molds, metalaxyl is the best known. Resistance to metalaxyl in certain species of Phytophthora has resulted in it only being used in conjunction with other fungicides.

Benzamidazoles. Controls numerous diseases, the best known members include Benomyl, Thiophanate and carbendazim. Benlate, with the active ingredient benomyl, recently ceased production.
Organic Phosphates. Another fungicide effective against oomycetes, the active ingredient includes fosteyl-Al, sold as Aliette.
Triazoles. Systemic fungicide that includes Bayleton, Tilt and Banner. These fungicides are broad spectrum against the "true" fungi. Alamo, used to control Dutch elm disease and oak wilt, is a propiconazole.
Antibiotics. Similar to those used by humans and livestock, these compounds are effective against bacterial diseases such as fire blight, or phytoplasmas such as ash yellows. One antibiotic, cycloheximide, is effective against many fungal diseases.

The Usual Suspects

As you develop your skills as a plant pathologist, you will begin to recognize that specific diseases are associated with certain plants. We call these diseases "The Usual Suspects." When confronted with a new plant disease, be sure to check this list as a starting point in your diagnosis process.

FRUIT

SPECIES	FOLIAGE	BRANCH/STEM/ROOT	FLOWER/FRUIT
Malus ((Crab)Apple) Hawthorne	Apple Scab Fire Blight Powdery Mildew Cedar Apple Rust	sooty mold Fire Blight Nectria canker Leucostoma canker	Apple Scab Fire Blight Cedar apple Flyspeck Sooty blotch
Grape	Downy mildew Anthracnose Powdery mildew Botrytis Black rot	Downy mildew Anthracnose Botrytis	Downy mildew Anthracnose Powdery mildew Botrytis Black rot
Pear	Pear Scab Fire Blight	sooty mold Fire Blight	Pear Scab Fire Blight
Plum	Taphrina (plumpockets) Shot Hole	Taphrina Black knot	Taphrina Brown rot
Raspberry	Anthracnose Rust Leaf spot Virus	Anthracnose Cane Blight Virus	Botrytis Virus
Strawberry	Fungal Leaf Spot Bacterial leaf spot	root rot Red stele	Botrytis leather rot
Currant	Rust Powdery mildew Anthracnose	Anthracnose Armillaria root rot	Rust Powdery mildew
Rhubarb	Leaf spot Anthracnose	Verticillium wilt Anthracnose Root rot	
Blueberry	High pH Botrytis blight Twig blight Virus	High pH Botrytis blight Twig blight Virus	High pH Botrytis blight

TREES

SPECIES	FOLIAGE	BRANCH/STEM/ROOTS
Maple	Tar Spot	Verticillium wilt
	Anthracnose	Eutypella canker
	Shot hole	Sunscald
		Armillaria
Fir	Rhizosphaera	Rust
	Lirula	
Juniper/Cedar	Phomopsis	Phomopsis shoot blight
	Kabatina shoot blight	Kabatina shoot blight
		Cedar apple rust
Ash	Ash rust	Ash yellows
	Anthracnose	Verticillium wilt
Elm	Elm black spot	Dutch elm disease
Oak	Anthracnose	Oak wilt
	Leaf blister	Bark smooth patch
Mountain Ash	Fire blight	Fire Blight
		Botryosphaeria Canker
Pine (2-3 needle pine)	Sooty mold	Pine-oak rust
	Dothistroma needle blight	Pine-pine rust
	Brown spot needle blight	Sphaeropsis
	Needle rust	
Pine (5 needled)	White pine blister rust	White pine blister rust
	Sooty mold	Armillaria
Spruce	Cytospora	Cytospora canker
	Rhizosphaera	Sirococcus
	Lirula	
Birch	Anthracnose	Inonotus heart rot
	Sooty mold	
Aspen/Cottonwood	Rust	Hypoxylon canker
	Leaf spot	
	Venturia shoot blight	
Sycamore	Anthracnose	Anthracnose
		Normal bark sloughing

VEGETABLES

SPECIES	FOLIAGE	BRANCH/STEM/ROOT	FLOWER/FRUIT
Tomato/Potato	Late blight	Late blight	Late blight
Eggplant/Pepper	Early blight	Fusarium	Early blight
	Septoria	Anthracnose	Anthracnose
	Virus	Verticillium	Virus
Cucurbits	Powdery mildew	Bacterial Wilt	Powdery mildew
	Alternaria leaf spot	Fusarium crown rot	Blossom end rot
Cucurbits cont.	Angular leaf spot	Fusarium root rot	Virus
	Virus		Virus
Peas	Ascochyta	Ascochyta	Bacterial blight
	Bacterial leaf spot	Aphanomyces	Virus
	Virus		
Bean	Halo blight	Fusarium	Halo blight
	Rust		
	Botrytis		
Carrots	Aster yellows	Nematodes	Aster yellows
	Cercospora		
	Alternaria		
Beets	Virus	Virus	
	Leaf spot		
	Powdery mildew		
Lettuce	Downy mildew	Rhizoctonia bottom rot	
	Anthracnose		
	Virus		
Corn	Leaf blight	stalk rot	Ear rot
	Smut	Smut	Smut
	Rust	Rust	
	Virus	Virus	
Asparagus	Rust	Rust	
	Stemphylium Purple spot	Stemphylium purple spot	
		Fusarium wilt and crown rot	
Cabbage	Black rot	Black rot	Black rot
Broccoli		Club root	
Brussel sprouts	Blackleg	Black leg	Soft rot
Cauliflower		Phytophthora	

FLOWERS AND BEDDING PLANTS

SPECIES	FOLIAGE	BRANCH/STEM/ROOTS	FLOWER/FRUIT
Rose	Black spot	Brand canker	Botrytis blight
	Downy mildew	Downy mildew	
	Powdery mildew	Common canker	
	Rust	Crown Gall	Virus
	Virus		
Lilac	Powdery mildew	Bacterial blight	Botrytis blight
	Bacterial blight		
Coneflowers	Aster yellows	Stem rot	Aster yellows
	Powdery mildew		
	Leaf spots		
Zinnia	Powdery mildew	Stem rot	Botrytis
	Leaf spots	Fusarium wilt	
Marigold	Powdery mildew	Stem rot	Botrytis
	Leaf spots	Fusarium wilt	Aster yellows
	Aster yellows		
	Virus		
Pansy/Viola	Powdery mildew	stem rot	Botrytis
		Thielaviopsis root rot	
Sunflower	Powdery mildew	Sclerotinia wilt	
	Leaf spot	Fusarium wilt	
Iris	Leaf spot	Fusarium	Botrytis
	Anthracnose		
Cosmos	aster yellows		aster yellows
	Powdery mildew		
Peony	Botrytis blight	Botrytis blight	Botrytis blight
	Leaf spot	Stem rot	
Phlox	Powdery mildew	Stem nematode	
Beebalm	Powdery mildew		
	Virus		
Begonia	Powdery mildew	Verticillium	Botrytis blight
	Virus	Virus	Virus
Impatiens	Botrytis blight	Botrytis blight	Botrytis blight
	Virus	Virus	Virus
Hosta	Virus	southern blight	
	Colletotrichum		
	Fusarium		
	Foliar nematode		Foliar nematode

RESOURCES

Master Gardeners receive many of these publications as a part of their training or Core Course. New publications are continually added to the Distribution Center. The most up-to-date listing is available online at http://www.extension.umn.edu. Click on Publications, or search the site for publications of interest. Many of these fact sheets can be read online and are also available from county extension offices. Longer publications or those containing many photographs or illustrations may not be available online. Master Gardeners should order publications through their home county extension office. Public orders may be placed by calling
1-800-876-8636 (outstate) or 612-624-4900 (local).

BU 6659	Disease Management Recommendations for Trees and Shrubs
FO 0675	Home Fruit Spray Guide
FO 1164	Verticillium Wilt of Trees and Shrubs
FO 1411	Protecting Trees and Shrubs Against Winter Damage
FO 1413	Minimizing De-icing Salt Injury to Trees
FO 2412	Disease Resistant Vegetable Varieties
FO 3386	Lawn Diseases
FO 5890	Lawn Care Practices to Reduce the Need for Fertilizers and Pesticides
FO 6135	Protecting Trees from Construction Damage: A Homeowners's Guide
FO 6426	Diseases of Trees and Shrubs
FO 6709	Sustainability in Urban Ecosystems
FS 1148	Strawberry Diseases
FS 1148	Raspberry Diseases
FS 1153	Diseases of Peony
FS 1154	Gladiolus Diseases
FS 1155	Parasitic Diseases of Tomato
FS 1156	Nonparasitic Disorders of Tomatoes
FS 1163	Rose Diseases
FS 1167	Damping Off of Seedlings
FS 1168	Tomato-Tobacco Mosaic Virus Disease
FS 1169	Diseases of Cole Crops
FS 1170	Bacterial Leaf Diseases of Foliage Plants
FS 1172	Diseases of Cucurbits
FS 1420	Native Elm Bark Beetle Control
FS 1427	Controlling Diseases in the Home Vegetable Garden
FS 3034	Turf Patch Diseases
MI 0766	Leaf and Needle Diseases of Trees
MI 3170	Plant Disease Clinic
MI 3174	Oak Wilt in Minnesota
MI 5898	Ash Yellows in Minnesota
MR 3765	History of Dutch Elm Disease in Minnesota

Yard and Garden Briefs
Anthracnose and Rust of Garden Beans
Anthracnose of Ash Trees
Anthracnose and Other Fungal Leaf Spot Diseases of Maple
Apple Scab
Armillaria Root Rot
Ash Rust
Aster Yellows
Bacterial Blight of Lilac
Bacterial Leaf Diseases of Houseplants
Bacterial Diseases of Garden Beans
Birch Dieback
Bird's Nests, Sphere Throwers and Shotguns
Black Knot
Black Rot Canker
Canker Diseases on Minnesota Pines
Cankers on Trees

Cedar-Apple Rust
Cherry Shot Hole
Common Smut
Cultural Practices to Help Manage Disease Problems in Home Lawns
Cytospora Canker of Spruce
Diseases of Daylilies
Diseases of Geraniums
Dothistroma Needle Blight
Dutch Elm Disease-Resistant Elm Cultivars
Fairy Rings
Fireblight
Geranium Rust
Hollyhock Rust
Honeysuckle Leaf Blight
Hosta Leaf Spots
Hypoxylon Canker on Aspens and Willows
Iris Leaf Spot
Iron Chlorosis
Late Blight of Potato and Tomato
Leaf Spot and Leaf Scorch of Strawberry
Leaf Spot and Melting Out in Turf
Lichens on Trees
Lirula Needlecast
Nectria Canker
Oak Anthracnose
Pea Diseases
Pine Needle Rust
Pine-Oak and Pine-Pine Gall Rust
Postharvest Diseases of Fruits & Vegetables
Powdery Mildew on Ornamental Plants
Powdery Mildew in the Home Lawn
Pythium Blight of Turf
Rhizosphaera Needle Cast
Root Rot of Azaleas and Rhododendrons
Septoria Leaf Spot
Septoria Leaf Spot and Canker of Poplar, Aspen and Cottonwood
Shade Tree Decline
Sirococcus Tip Blight
Slime Molds
Smooth Patch
Snow Molds in Lawns
Sooty Mold
Sooty Blotch & Flyspeck on Apple Fruits
Sphaeropsis Shoot Blight
Stem Rot of Clematis
Stinkhorns
Sweet Pea Diseases
Wetwood
White Pine Blister Rust
Wood Decay

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Westcott's Plant Disease Handbook, 5th edition. 1990. R. K. Horst, editor. Van Nostrand Reinhold Company, New York, NY. 953 pp.

Additional Internet References:

Plant Disease Diagnostics
http://www.extension.umn.edu/projects/yardandgarden/diagnostics/

Forest and Shade Tree Health
http://www.cnr.umn.edu/FR/extension/foresthealth/forestandshadetreehealthpage.htm

An On-line Guide to Plant Disease Control
http://plant-disease.orst.edu/index.cfm

The Texas Plant Disease Handbook
http://plantpathology.tamu.edu/Texlab/index.htm

Pests of Agricultural Crops, Floriculture and Ornamental Nurseries, and Commercial Turfgrass: UC Pest Management Guidelines
http://www.ipm.ucdavis.edu/PMG/crops-agriculture.html

Ornamental Plant Disease Fact Sheets
http://www.cas.psu.edu/docs/CASDEPT/PLANT/ext/fact.html

Plant Disease Information Notes
http://www.ces.ncsu.edu/depts/pp/notes/
Diagnostic Keys to Major Tree Fruit Diseases in the Mid-Atlantic Region
http://www.caf.wvu.edu/kearneysville/wvufarm6.html

UDSA Forest Service Publications
http://www.na.fs.fed.us/spfo/pubs/fth_pub_pages/howto.htm

Ohio Line: Yard and Garden
http://ohioline.osu.edu/lines/hygs.html

The Berry Diagnostic Tool
http://www.hort.cornell.edu/department/faculty/pritts/BerryDoc/

Forest Insect and Disease Newsletter
http://www.dnr.state.mn.us/forestry/publications/forestdi/index.html

American Phytopathological Society
http://www.apsnet.org/

The Mycological Society
http://www.erin.utoronto.ca/~w3msa/

chapter 7

landscape

chapter 7

landscape

BASIC ELEMENTS OF LANDSCAPE DESIGN

by Brad Pedersen
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INTRODUCTION

Landscape design can be defined as the art of organizing and enriching outdoor space through the placement of plants and structures in agreeable and useful relationship with the natural environment. There are no hard and fast rules for landscaping. Each design is a unique creation.

LEARNING OBJECTIVES

Learning objectives of this section for Master Gardeners are to:

1. Understand landscape design process
2. Understand the importance of site evaluation relative to plant selection.
3. Understand the importance of good landscape design relative to sustainability.
4. Learn essential elements of design principles.

LANDSCAPE DESIGN AND SUSTAINABILITY

Merely planting trees and shrubs is not landscaping. Designing a landscape is an art and, as in all art forms, it is based on certain elements and principles of design.

Today, landscape design should include designing for plant health. This concept is also called sustainability. A sustainable landscape is a functional, environmentally sound, and aesthetically pleasing landscape. The goals of a sustainable landscape include: improved plant health and function, reduced product inputs, decreased maintenance costs, and decreased time and labor.

These considerations are not new nor have they been without considerable discussion. Problems arise, however when some considerations are forgotten or unrecognized until after the design process is complete and implementation has started.

Sustainability in the design process is also affected by the order of the main considerations. Having a visually pleasing landscape is usually the most important consideration and is addressed first in the design process. This is easy to understand since it is the primary concern for most.

Close second, or of equal importance, to a client, is cost. In a sustainable landscape design, the consideration of cost effectiveness is impacted by the processes, plants, and hard-goods used in the implementation of that landscape, and by the quality of each.

Cost should not dictate whether the landscape is functional, maintainable, or environmentally sound. These considerations should be met regardless of the budget. In other words a simple low-cost landscape should be as sustainable as an extensive high-cost landscape. In many cases, the installation cost of a sustainable landscape may be less. Certainly the ongoing maintenance costs of a functional, maintainable, and environmentally sound landscape will be lower, which means considerable savings throughout the life of the landscape.

Sustainable designs need to be functional. A functional landscape allows for the easy accomplishment of movement, work, recreation, and leisure that occurs in and around the landscape. These functions are related to the actual process or activities associated with a family, a business, or a public place.

The functional and maintainable considerations are closely related. A functional design has more to do with the users of the landscape while a landscape that is maintainable is easier for landscape managers to take care of. In other words, a landscape should be functional from both a use and maintenance standpoint.

A maintainable landscape provides for reduced maintenance at a particular maintenance level or condition. This lowers labor costs and makes maintenance operations easier. A maintainable landscape also reduces the need for inputs such as fertilizers, pesticides, equipment, water, and others. It is important to note that it only reduces the amount of input needed; it does not eliminate it.

An environmentally sound landscape design must first be functional and maintainable. In addition, the proper design of plants and related hardscaping greatly affects the quality of that landscape over its entire life. For example, a philosophy of "right plant, right place" as well as "right plant, right purpose" can dictate the amount of environmental, disease, and insect stress that a plant can tolerate. A plant continually in stress will require more maintenance. That means more labor, fertilizer, pesticides, and ultimately cost.

With a sustainable approach to landscape design, the visually pleasing and cost effectiveness considerations should be the last ones evaluated. This in no way diminishes the importance of a "good looking" or cost effective landscape, but challenges the designer to create that beauty from a more sustainable approach.

It is important to note that none of these considerations are mutually exclusive in the design process. The development of any design will require that each piece be revisited several times in light of the others before the best solution is reached.

PRINCIPLES OF DESIGN

Scale

Scale refers to the proportion between two sets of dimensions. Knowing the eventual or mature size of a plant is critical when locating it near a building. Both the mature height and spread of a plant should be considered.

Balance

Balance in landscaping refers to an aesthetically pleasing integration of elements. It is a sense of one part being of equal visual weight or mass to another. There are two types of balance, symmetrical and asymmetrical. Symmetrical balance is a formal balance. It has an axis with everything on one side being duplicated or mirrored on the other side. Asymmetrical balance is balance which is achieved by using different objects to achieve equilibrium.

Unity

To achieve unity it is necessary to group or arrange different parts of the design to appear as a single unit. The design should be a pleasant picture from every angle.

Rhythm

Rhythm is a repetition of elements which directs the eye through the design. Rhythm results only when the elements appear in regular measures and in a definite direction. Rhythm can be expressed in color as well as form.

Accent

Accent or emphasis is important in the total picture. Various parts, if skillfully organized, will lead the eye towards the focal point. This may be a garden accessory, plant specimen, plant composition, or water in some form. Emphasis may also be obtained through use of contrasting texture, color, or form, or by highlighting portions of a plant composition with garden lights.

Repetition

By subtly repeating such design elements as bed lines in the yard, you can achieve a sense of continuity or flow in the entire landscape. For example, curves may begin in bed lines in the front yard, continue in the side yard, and be picked up once more in the backyard.

Simplicity

Every square foot of landscape does not have to have something in it. Such objects as bird baths and plastic yellow daisies are often overused in the landscape. Keep the landscape simple and it will look its best. Avoid cluttering the yard with unnecessary objects. Create open spaces; avoid the temptation to fill them up.

Harmony

Harmony is achieved through a pleasing arrangement of parts.

Analysis of Site and Family Needs

The fundamental principle of landscape design is that each development should be based upon a specific program. Plan for complete development, but there is no need to develop all of the lot at once. There should be an overall plan so that when any work is done, it is part of the general scheme. Carrying out the landscape plan is generally a matter of years and plants need time to grow.

This program should be based upon the people who will use it, their cultural needs, individual desires, and economic abilities; the climate; the site; its immediate surroundings; topographic and ecological conditions, and all objects, natural and man-made, now existing on the site or planned for the future; the available materials and methods of fabrication; and the anticipated maintenance level.

The landscape designer must study the habits of people, and what they do; understand their desires and needs; and determine what space and materials are available and how they may be used to accommodate these goals.

The first step in landscape design is to divide available space into use areas:

- The public area is the section that passers-by view. It is generally in front of the house and should present an attractive public view.
- The living or private area is for the family and may contain a patio, deck, or porch for outdoor sitting, entertaining, or dining.
- A recreation area may be incorporated, depending on the family's interests and/or the presence and ages of children.
- A service or storage and work area should provide a place for garbage, oil tank, garden tools, etc. that is convenient for use but may need to be screened from the other areas. You may also want to include space for a compost pile.

In planning the home grounds, give careful consideration to foot traffic patterns so there will be easy access from one area to another. This traffic may be served by walkways, terraces, or open stretches of lawn. In areas of heavy use, paved surfacing material is best.

The Lot and Its Characteristics

In laying out a design, preserve all the best natural resources on the site such as mature trees, brooks, ponds, rock outcroppings, good soil, turf, and interesting variations in the terrain. These natural elements affect the ease of construction and landscape possibilities. A careful survey of the area should be made to determine whether site conditions will be a deterrent or can be incorporated into a design plan.

Changes in elevation can add interest and variety to the home landscape. The character of the land, its hills, slope, and trees should determine the basic landscape pattern. A hilly wooded lot lends itself to an informal or natural design, with large areas left in their natural state. In such a setting, large trees can be retained.

Although natural slope variations are an asset, avoid creating too many of them artificially. Excess grading of terraces or retaining walls should be avoided. If these features are necessary to facilitate construction or control water drainage, they should be designed to detract as little as possible from the natural terrain.

Neighborhood Sights and Sounds

Keep good views open and screen out the undesirable. Often a shrub or two will provide all the screening that is necessary. Use plantings as noise barriers. The principal rooms of the house should look out on the lawn or the garden. Design special areas to be viewed from favorite windows.

Climate

Climate includes sunlight, precipitation, wind, and temperature. All these affect the way a house should be placed on a lot, how the land is used, and what is planted. In planning the grounds, don't fight the climate; capitalize on its advantages. In cold regions, plant so that the winter scene is enjoyed from the inside. Evergreens and hedges are picturesque when covered with snow. Since people respond differently to sun and shade, it is important to study the amount and location of each on the lot. Sun and shade patterns change with the seasons and vary each minute of the day. The sun is higher and shadows are shorter in the summer than in the winter.

Northern exposures receive the least light and therefore are the coolest. East and west receive more light; western exposures being warmer than eastern because they receive afternoon light. The southern orientation receives the most light and tends to be the warmest.

Plan future shade from tree plantings with great care in order to keep sunny areas for garden, summer shade for house and terrace. Deciduous trees (those that shed their leaves) shade the house in summer and admit the sun in winter. Place trees off the corners rather than the sides of the house where they will accent the house and not block views and air circulation from windows. Remember that an overplanting of trees tends to shut out sun and air.

Family Activities

Use of the land should be a determining factor in landscape design. Analyze the activities of the family. For example, small children need open lawn for playing, gardeners need space for growing vegetables and flowers. Make allowances for future changes. Consider outdoor living, playing, gardening, and household servicing. The family routine follows a general pattern, but varies with each family's way of living.

Cost Effective Maintenance

Decide on maintenance standards. A low maintenance plan is the goal of most homeowners and may be achieved by adopting one or more of the following possibilities:

- Have little high-maintenance lawn area.
- Use ground covers or mulches.
- Use paving in heavily traveled areas.

- Provide mowing strips of brick, concrete, or plastic lawn edging around flower beds and shrub borders.
- Use fences or walls instead of clipped formal hedges for screening.
- Design raised flower beds for easy access and to help control weeds.
- Have small flower beds. Use flowering trees and shrubs for color.
- Be selective in the choice of plant materials. Some plants require much less pruning, spraying, and watering than others. Pruning can also be decreased with proper spacing.
- Use plant materials that naturalize easily, like some native plants.
- Keep the design simple.
- Use mulches for weed control when possible.

DRAWING A LANDSCAPE PLAN

The following section provides the information necessary to draw a landscape plan that embodies the elements of good design. These five steps are for those who want the fun and satisfaction of preparing their own landscape plan. Completing these steps will enable you to develop a final plan that can be implemented over several years as time and money permit.

Step 1 - Preparing Baseline Map

Prepare a scale map of the home grounds. Use graph paper and let one square equal so many feet or draw to scale using a ruler or an engineer's scale.

Suggested Scale	Small Lot	Large Lot
Engineer	1" equals 10'	1" equals 20'
Ruler	1" equals 8'	1" equals 16

The map should include the following:

- Property lines and 15-20 feet beyond to include nearby trees
- Undesirable features of home grounds or adjoining property
- North point
- Views—point arrows in direction of each good view
- House, garage, other buildings
- Doors, windows, porches, and location of rooms
- Existing trees, rock outcroppings
- Walks and driveways, if already constructed
- Contour of the land (an arrow can show direction of surface water flow)
- Scale used
- Location of septic tank or sewer lines
- Easements

Step 2 - Deciding the Ground Area

Items listed below are most often included in the final development. Make a list that suits your individual needs.

- Front lawn area or public area
- Outdoor living or private area
- Laundry area
- Family and individual recreational activity area
- Vegetable garden
- Small fruits (strawberries, raspberries, etc.)
- Cooking and eating area
- Driveway
- Garden pools
- Guest parking
- Walks
- Turnabouts
- Flower beds
- Garage and other outdoor vehicle storage area
- List other items particular to your land area

Step 3 - Placing Use Areas on the Map

Place the use areas on the map. Fit them together with two considerations, traffic flow and use. How will people move from one area to another or from the house to an outside area be functional in relation to the house? Will it make use of existing features such as views or changes in the terrain? Try different combinations in relation to rooms of the house, surrounding areas, and potential views.

This is one of the most important steps in designing the landscape. All individual considerations need to be placed in concept and to create spacial areas that are not only functional but pleasing to look at. The shape of the turf area, if attractive, will indicate that all the rest has been tied together properly.

Step 4 - Develop the Landscape Plan

Draw in new driveways, parking areas, and walks.

Indicate where plant masses are needed for (1) separating areas, (2) screening undesirable views, and (3) providing shade, windbreaks, beauty.

Do not attempt at this point to name the trees and shrubs, but think in terms of plant masses that will serve a purpose and help tie the various areas together into a unified plan considering design elements previously discussed.

In preparing the plan, use landscape symbols to indicate trees and shrub masses.

Draw symbols to scale to represent the actual amount of space that will be involved. For example, a white pine tree at maturity will have a spread of approximately 20'. Make the scale diameter of the symbol in this case 20'. Indicate on the map where paving, plants and structures will be.

In developing the plan, check to see if the proposed scheme is practical and if you can answer the following questions satisfactorily:

- Is the driveway design pleasing, useful, and safe? What about a safe entrance? A turnabout? Guest parking? Will guests use the front door? Will the proposed drive be too steep?
- Are the walks convenient?
- Will the view be attractive from the living room? Picture window? Porch? Dining room?
- Has a living area been provided, and is it screened from neighbors? Service area? Buildings?
- Is the clothesline close to the laundry?
- Do all the parts fit together into a unified plan?

THINGS TO CONSIDER WHEN SELECTING PLANTS

Environment Requirements

This depends on where the plant is to be located in the garden. Some plants just cannot take the sun while others require full sun for best display. Some need moist soil, others need dry, well-drained soil.

Maintenance

When selecting plant materials, consider the more practical aspect of maintenance. Try to choose trees and shrubs that tend to be disease and insect resistant.

Aesthetic Value

This includes texture, form, and color of foliage, flower, fruit, and bark to create seasonal interest. Select colors related to the house exterior, especially if the plant is used close to the house. Strongly contrasting textures can create interesting effects.

Plant Characteristics

Plant size

A plant's mature size must be considered when selections are made for the landscape plan. A common mistake is the selection of plants which soon become too large for their location. The drastic pruning which then becomes necessary adds to the cost of maintenance and may reduce the grace and beauty of the specimen. Overgrown plants which are left unpruned will alter the balance and accent of the design, and may partially hide the house which they are supposed to complement.

The landscape picture is constantly changing because the plants which give it form and substance are continually growing. This fact presents a challenge to the landscape architect that is not found in most other artistic media. Great care must be exercised in selecting plants which will immediately create the desired composition, and yet retain an appropriate size over a long period of years.

Plant form

Trees and shrubs used in landscaping develop many distinct forms. The more common forms are:

- prostrate or spreading
- round or oval
- vase
- pyramidal
- columnar

The form of mature shrubs and trees usually is more open and spreading than that of young plants. For example, the head of a young oak tree may be pyramidal in shape, during middle age the head is an irregular oval, and during old age a large, massive oak may have a spreading vase form.

Ground covers such as turf, low-spreading shrubs, creeping plants, and prostrate vines are essential materials in landscaping. The principal use of turf is for the lawn area.

Trees are long lived and relatively inexpensive in initial cost and maintenance compared to lawns, flower beds, and many other features of the design. Plant as large as you can afford, making sure the trees have a root system that will support the tree's size. In the past, many builders committed costly errors by destroying trees in establishing new residential subdivisions. Most real estate developers now appreciate the value of trees and attempt to save them when land is graded prior to the construction of houses. Regardless of our affection for trees we must recognize they do not live forever. Old and improperly located trees should be removed and new more suitable specimens should be planted.

Plant texture

The texture of plant materials is dependent on the size and disposition of the foliage, twigs, and bark. Plants with large leaves which are widely spaced have coarse texture. A plant with small closely spaced leaves has fine texture. Extremes in texture that prevent harmony in the composition should be avoided. Don't change textures from plant group to plant group too rapidly. On the other hand, some variation in texture is needed to give variety. Texture can be influenced on a seasonal basis depending on whether the plant is deciduous or evergreen.

Plant color

Green is the basic color of most plant materials in the landscape picture. Desirable variety may be secured by using plants with lighter or darker foliage tones. Accent may be introduced by the selection of flowering shrubs or those which produce colorful persistent fruit. Also consider variegated foliage for accents or highlights.

RESOURCES

University of Minnesota Extension Service Publications

Master Gardeners receive many of these publications as a part of their training or Core Course. New publications are continually added to the Distribution Center. The most up-to-date listing is available online at http://www.extension.umn.edu. Click on Publications, or search the site for publications of interest. Many of these fact sheets can be read online and are also available from county extension offices. Longer publications or those containing many photographs or illustrations may not be available online. Master Gardeners should order publications through their home county extension office. Public orders may be placed by calling
1-800-876-8636 (outstate) or 612-624-4900 (local).

FS 0466	Native Trees That Can Be Used for Landscaping
BU 0545	Trees, Shrubs and Vines for Minnesota Landscapes
FO 0604	Fitting Trees and Shrubs into the Landscape
FO 0897	Selecting Preservative-treated Wood
FS 1114	Ground Covers for Rough Sites
FS 1428	Gardening in the Shade
FO 1430	Choosing Landscape Evergreens
FS 2386	Azaleas and Rhododendrons for Minnesota
SB 3017	Caring for the Countryside: A Guide to Seeing and Maintaining Rural Landscape Quality
MR 3037	Cardinal Dogwood
MR 3039	Princess Kay Plum
FO 3825	Planting and Transplanting Trees & Shrubs
BU 5777	Ground Covers for the Midwest
PC 5976	The Right Tree Handbook

Videos of Minnesota Gardening TV Programs

These are 30-minute videos developed as a series of programs aired in the Twin Cities for the general public. They are available from the University of Minnesota Extension Service Distribution Center: call
612-624-4900 (local) or 1-800-876-8636 (outstate).

VH 2725	Home Landscape Gardening
VH 5589	An Introduction to Home Landscape Design
VH 5983	Landscape Design
VH 5988	Gardening on a Slope
VH 5990	Children's Gardening
VH 6002	Japanese Gardens
VH 6003	Gardens of Minnesota
VH 6016	Minnesota Prairies
VH 6020	Home Landscape Ideas
VH 6253	Garden Birds
VH 6025	Gifts from the Garden
VH 6035	Rock Gardens
VH 6459	Using Native Plants in the Landscape

Minnesota Extension Service Slide Sets

These vary in length and depth. All have a script and/or audio tape. These are also available from the University of Minnesota Extension Service Distribution Center: call 612-624-4900 (local) or 1-800-876-8636 (outstate).

SS 1918 Landscape Plants for Southwestern Minnesota
SS 2225 Landscaping Between Your House and the Street
SS 4023 Annual Flowers for Minnesota
SS 4088 The Children's Garden
SS 4274 Gardens to Stay Home In
SS 4306 Herbs in Minnesota Gardens
SS 4346 How to Plan and Plant Flower Gardens
SS 4347 How to Start a Garden
SS 4391 Landscaping Minnesota Homes
SS 4488 Perennial Flowers for Minnesota
SS 4504 Planning and Planting a Vegetable Garden
SS 4588 Shade Trees for Southern Minnesota
SS 4593 Shrubs for Use in Landscape Plantings
SS 4611 Spring Flora of Northern Minnesota Bogs
SS 4646 Trees and Shrubs for Northwestern Minnesota
SS 4694 Wildflowers for Minnesota
SS 5629 Ornamental Grasses for Minnesota
SS 5630 All America Selections in Flowers and Vegetables

Yard and Garden Briefs
American Bittersweet
Anthracnose of Broadleaf Trees
Anthracnose and Other Fungal Leaf Spot Diseases of Maple
Anthracnose and Rust of Garden Beans
Aphids on Trees & Shrubs
Armillaria Root Rot
Ash and Honeylocust Plant Bugs
Ash Rust
Aster Yellows
Bacterial Blight of Lilac
Bacterial Diseases of Garden Beans
Bacterial Leaf Diseases of Houseplants
Birch Dieback
Bird's Nests, Sphere Throwers and Shotguns
Black Knot
Buckthorn Rust
Calla and Canna Lilies
Canker Diseases on Minnesota Pines
Cankers on Trees
Cherry Shot Hole
Chestnuts, Horse-chestnuts, and Ohio Buckeyes
Common Buckthorn
Common Smut
Cytospora Canker of Spruce
Diplodia Blight of Pines
Diseases of Daylilies
Diseases of Geraniums
Dothistroma Needle Blight
Dutch Elm Disease Resistant Elm Cultivars
Edible Flowers
Fertilizing Evergreens
Fourlined Plant Bug
Gall Diseases on Minnesota Pines
Garlic
Gardening in Raised Beds
Geranium Rust
Goldenrod and Ragweed
Growing Asparagus
Growing Basil
Growing Chives & Dill
Growing Herbs
Growing Luffa Gourds
Growing Parsley
Hackberry Psyllids
Hardy Roses
Hibiscus

Hollyhock Rust
Honeysuckle Leaf Blight
Honeysuckle Witches' Broom Aphid
Horseradish
Hosta Leaf Spots
Hypoxylon Canker on Aspens and Willows
Iris Borer
Iris Leaf Spot
Iron Chlorosis
Jack in the Pulpit
Lace Bugs
Late Blight of Potato and Tomato
Lichens on Trees
Lirula Needlecast
Minnesota Tip Method of Protecting Garden Roses
Mulberry
Nectria Canker
Oak Anthracnose
Pea Diseases
Peppers
Perennials for Moist Soils
Perennials for Season-long Bloom
Physalis
Pine Needle Rust
Planting Vegetables in Midsummer for Fall Harvest
Poison Ivy & Its Control
Potatoes
Powdery Mildew on Ornamental Plants
Preserving Gourds for Lasting Color
Pruning Large Trees—Thinning out vs. Topping
Purple Loosestrife
Raising Leeks in Minnesota Gardens
Rhizosphaera Needle Cast
Root Rot of Azaleas and Rhododendrons
Rose Chafer
Sap & Fungus Beetles
Saving Vegetable Seeds: Tomatoes, Peppers, Peas & Beans
Season Extenders for Minnesota Gardens (Coldframes/Cloches)
Septoria Leaf Spot
Septoria Leaf Spot and Canker of Poplar, Aspen and Cottonwood
Shade Tree Decline
Sirococcus Tip Blight
Slugs
Smooth Patch
Sooty Mold
Spring Flowering Bulbs
Squash Vine Borer Management in Home Gardens
Starting Seeds Indoors
Stem Rot of Clematis
Sweet Pea Diseases
Toxicity of Black Walnuts Towards Other Plants
Trees and Shrubs for Clay Soil
Trellises and Cages
Using Dog & Cat Manure on Home Gardens
Wetwood
White Pine Blister Rust
Wood Decay
Woolly Aphids on Deciduous Trees & Shrubs

Books

Booth, Norman K. and James E. Hiss, 1991. Residential Landscape Architecture. Englewood Cliffs, NJ: Prentice Hall.

Sand, Margaret, 1991. Planting for Energy Conservation in the North. Minnesota Department of Natural Resources.

chapter 8

lawn care

chapter 8

lawn care

HOME LAWN CARE
by Robert Mugaas, Extension Educator

INTRODUCTION

A lawn is an area of land covered by many individual turfgrass plants. In fact, a lawn may be considered a garden area comprised of many individual grass plants rather than just a few flower or vegetable plants. It has been reported that in a typical 1,000 square feet of lawn there are about 1 million grass plants.

A lawn can be an environmental asset or liability depending on how we care for it. Lawns not only serve a decorative purpose in landscapes but they also prevent soil erosion, clean the air by trapping dust, absorb pollutants, and cool the air. Lawns also provide recreational areas for family activities.

Over the last 10 to 15 years there has been a growing public interest in home lawn care that does not negatively impact our environment or ourselves, while at the same time consciously reducing the amount of inputs needed to maintain a healthy, vigorous lawn. This concept of lower input lawn care is sometimes referred to as having a more sustainable lawn.

Whether a lawn requires high, medium or low amounts of care, the primary goal of any lawn care program should be to provide the environment and level of care necessary for healthy turfgrass growth and function. A vigorous, dense lawn is the best defense against weed invasion. Also, a healthy lawn is much more capable of quickly recovering from modest amounts of damage caused by insects, diseases, or physical wear and tear.

Creating a healthy lawn environment is like any other type of gardening. The same good practices used in vegetable and flower gardens are just as appropriate for growing grass plants. The means to achieve those conditions are somewhat different for lawns than gardens, but are just as important for healthy grass plants as for healthy tomatoes.

As with other garden plants, knowledge about the plant and how it grows is often the key to successful growing. Large juicy tomatoes, fresh crisp lettuce, and colorful marigolds are the result of applying knowledge about those plants to growing them in the garden. Likewise, similar knowledge about the grass plant will be very helpful in successfully growing it and creating a healthy attractive lawn. The remainder of this session will focus on integrating the growth and development of grass plants with the various cultural practices commonly used to maintain a healthy, vigorous lawn.

LEARNING OBJECTIVES

Learning objectives of this section for Master Gardeners are to:

1. Understand the basic requirements for growing a lawn.
2. Learn the difference between the major cool-season grasses such as fine fescue, perennial ryegrass, and Kentucky bluegrass and the warm season grasses.
3. List and explain the steps in starting a new lawn.
4. Understand basic lawn care culture and maintenance techniques such watering, fertilization, aeration, and weed control.
5. List the steps in turf renovation and overseeding.
6. Be acquainted with major pest problems of lawns.

GRASS PLANT GROWTH AND ITS RELATIONSHIP TO A SUSTAINABLE LAWN

The major grass parts are shown in Figure 1. The part of the grass plant familiar to most people is the leaf. The leaf is composed of two parts: the leaf blade and the leaf sheath. Looking at the grass plant closely will reveal that the leaf rolls itself around the stem (or shoot), forming the leaf sheath.

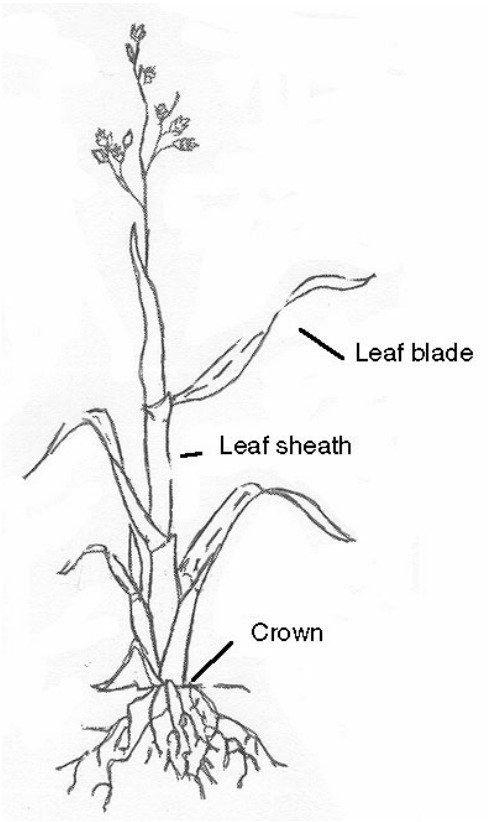


Figure 1. Parts of a grass plant.

The leaves, stems, and roots all originate from the crown area of the plant. The crown is a very tightly compressed stem or growing point that pushes the new leaves upward as they are formed and grow. This is a different growth habit than found in other garden plants such as tomatoes, marigolds, trees, and shrubs. In those instances, the outward growth extends from the tips of the branches or shoots. The location of the grass crown near the base of the plant and usually at, or slightly below, the soil line allows us to mow our lawns regularly and have continued growth.

A common growth characteristic of grass plants is their ability to spread out from a parent plant. Growth habit describes the type of shoot growth present in a particular grass plant and is directly related to its ability to spread out from the parent plant and ultimately form a lawn. There are three general classifications of grass plants by shoot growth: bunch-type, stoloniferous, and rhizomatous. The specific type of shoot growth along with the rate of shoot growth determines how quickly and easily these grasses will establish a lawn area or fill in bare spots.

Rhizomatous grasses spread by belowground stems known as rhizomes (Figure 2). These rhizomes terminate in a shoot that emerges some distance from the mother plant. As these new shoots mature they will also produce rhizomes that eventually produce new shoots, thus creating a lawn. Healthy, vigorous rhizome-type grasses such as Kentucky bluegrass tend to form dense, uniform lawns with shoots oriented in an upright position.

Stoloniferous grasses spread by lateral stems, called stolons, that creep over the ground and give rise to new shoots periodically along the length of the stolon (Figure 2). Lawns formed from these type of grasses appear to have their aerial shoots growing laterally along the ground rather than upright as in bunch or rhizomatous grasses. Creeping bentgrass is a good example of this type of growth. When it is mowed at heights greater than 3/4 inch, it forms a relatively loose mat of grass with most aerial shoots growing horizontally. In bluegrass lawns, creeping bentgrass is usually considered a weed. Creeping bentgrass is considered very desirable on putting greens, croquet courts and other fine turf areas as it will adapt to very low mowing heights (about 1/4 inch or slightly less) and create a very smooth playing surface.

Bunch-type grasses spread primarily or entirely by the production of tillers. Tillers originate from the crown area and grow upward from the base of the plant. It is this type of continuous shoot production by means of tillers that gives the plant a clumpy appearance; hence the name bunch-type grass (Figure 2). Seeding rates need to be higher when bunch-type grasses are a significant portion of the seed mixture or blend. When seeding rates are too low or where growth develops from individual isolated plants, small clumps are formed creating a nonuniform lawn surface. Common cool-season lawn grasses associated with this type of growth habit are perennial ryegrass, tall fescue, hard fescue, and chewings fescue.

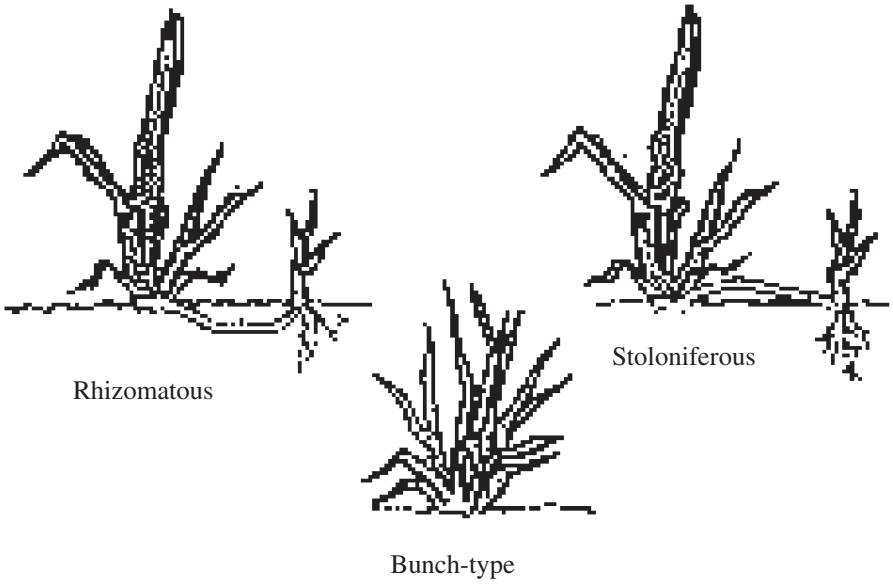


Figure 2. Growth habits of grasses.

Root growth also originates at the crown. However, roots continue to lengthen and grow from the root tip whereas shoots and leaves are pushed upward and outward from the crown at the base of the plant. Roots are naturally sloughed off and new ones regrow as a normal part of grass plant growth. Also, adverse environmental conditions can significantly shorten the life of grass plant roots. For example, weather and soil stresses associated with drought conditions or excessive rainfall can cause significant root injury or loss and inhibit growth.

Growth Cycle of a Cool-Season Grass Plant

Grasses grown for turf use in Minnesota and other north central states are known as cool-season grasses. Turfgrasses adapted to the southern states are known as warm-season grasses. The cool-season grasses have growth peaks in the spring and fall, indicating a response to the cooler conditions at those times of the year (Figure 3). The warm-season grasses have a peak growth period during the summer months (providing ample water is present), indicating their response to the warmer conditions. Annual weedy grasses, such as crabgrass and foxtail, also follow the warm season growth curve. Crabgrass and foxtail begin their life cycle from seed while perennial warm-season grasses, such as bermuda grass, begin growth from existing plant structures.

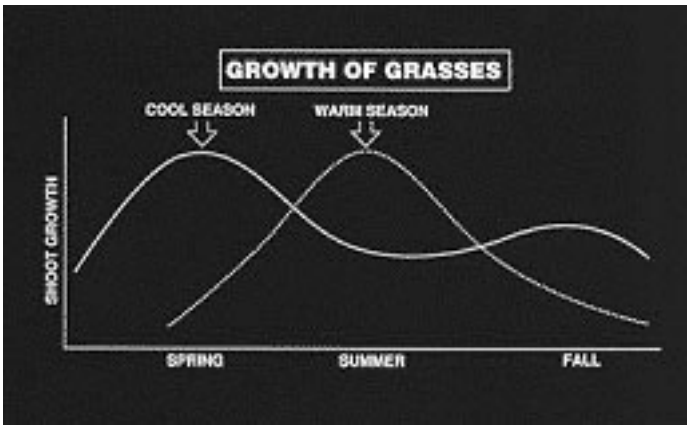


Figure 3. Typical shoot growth patterns of cool-season turfgrass species.

During the short days and cool temperatures of late fall, mature shoots of cool-season grasses go through a permanent biological change. The shoots cease to produce only leaves and sheaths and “switch” over to shoots, which will produce flowering shoots during the long days and warm temperatures of late May through June. Most of the shoot growth that occurs during spring is the production of flowering stems. However, since regular mowing is being done during this period, flowering stems often go unnoticed in home lawns.

Occasionally, someone questions the presence of an "undesirable" grass in the lawn during this spring time period. Usually what they have noticed is the flowering stems on the cool-season grasses actually blooming, especially if their mowing heights are quite high. These flowering stems are quite tough and coarser in texture than the grass leaf blades.

Once the grass shoot has completed its flowering cycle, it dies along with its associated roots. Since these dead shoots are continually being replaced by new ones and those which were not mature enough to flower, there is little detectable difference in the lawn. It may simply appear somewhat thinner by the end of June or early July. Rejuvenation of the grass plant begins again in late July or early August and the process starts over.

In our cool-season grasses, most root initiation and growth occurs in the spring with a smaller peak of growth during the cool weather of fall. Root growth begins and peaks before peak shoot growth activity in the spring. While there is some shoot growth during the summer months (providing that the grass plant is not in summer dormancy), root growth is very slow. Finally, there is another peak period of root growth lagging slightly behind the late summer shoot growth period. It should be noted that maximum root growth and shoot growth do not occur at the same time. In fact, they may be considered somewhat antagonistic to each other. Adjusting turf management practices to optimize growth of either roots or shoots is a significant factor in establishing and maintaining a healthy turf.

SITE CONDITIONS + USE + QUALITY DESIRED = LAWN CARE REQUIRED

Home lawns should be designed, constructed and maintained to minimize any adverse effects to the environment and ourselves while minimizing the inputs needed to keep it healthy and vigorous. The primary goal of any lawn care program is to provide the necessary resources (for example, water and nutrients) to promote plant health and vigor. This allows the lawn to successfully compete against weed invasion and quickly recover from even modest levels of injury due to pest damage, play or other uses. In addition, a healthy lawn retains the positive environmental functions of stabilizing the soil against water and wind erosion. The successful establishment and long term health requires an evaluation of current site conditions as well as the desired quality and expected use for that lawn area. Remember, even with high-use lawns that require high maintenance turfgrass varieties, the necessary inputs to preserve plant health will just be higher.

While not mentioned above, site conditions also play a significant role in determining the most appropriate lawn care strategy for that site. For example, shade, soil type, drainage, droughty areas and exposure will all be part of a successful lawn care equation. These site conditions are discussed as various points of this text as they influence things like grass selection, cultural practices and/or pest management.

Table 1. Maintenance Needs for Various Lawn/Turfgrass Use and Quality Expectations

Typical Home Lawn Use/Quality Expectations	Watering Needs	Mowing Heights (inches)	# of N per season*1	Fertilizer Application Timing*2	% Weeds Tolerated	Weed Control	Diseases or Insects Controlled
Low use with medium quality	only as needed	2.5 to 3.5	1 to 2	early September; (late October)	20 - 30	once per year or less	rarely
Low use with high quality	regularly	1.5 to 3.0	3 to 4	early May, (mid-June), early September, late October	≤5	two to three times per season	preventatively, and/or as needed
Medium use with medium quality	as needed	2.0 – 3.0	2 to 3	(early May), early September, late October	10 – 30	once or twice per season	rarely or as needed
Medium use with high quality	regularly	1.5 – 3.0	3 to 4	early May, (mid-June), early September, late October	5 – 10	two to three times per season	usually only as needed
High use with medium quality	regularly	2.0 – 3.0	3 to 4	early May, (mid-June), early September, late October	10 – 30	once or twice per season	only as needed

*1 If grass clippings are left on the lawn, one fertilizer application could be eliminated from the high use and/or high quality lawn care programs.
*2 Note that times included in parentheses are for the higher number of application frequencies. For more northern parts of the state, back up the timing a week or two to allow for seasonal differences in fall weather patterns. Likewise timing can be delayed a week or two to account for these same seasonal differences in the spring.

Lawn Use Descriptions:

Low use characteristics –
These lawns are primarily for aesthetic and/or utilitarian purposes and do not receive much wear and tear injury. Generally, these would be typical of many home lawn situations where the lawn area helps set off the rest of the landscape plantings or stabilizes the soil against erosion. While there may be some foot traffic, the lawn receives little other play or use. For home lawns, quality expectations generally range from medium to high.

Medium use characteristics –
Most home lawns probably fall into this category. Generally, they receive moderate levels of foot traffic from both children and adults. They may also be subjected to periods of higher traffic during times of family get-togethers, picnics, yard games, etc. For the most part, these lawns receive about 8 to 10 hours of activity during a weeks' time. Over the course of the season, some repair of damaged and/or thin areas is usually necessary. Quality expectations for these lawns range from medium to high.

High use characteristics –
These lawns must endure significant time periods of relatively concentrated activity. Examples include those lawn areas connected to children's day care facilities, very active families where lawn areas support a variety of yard games as well as extensive foot traffic. These lawns may also receive significant levels of wear due to pets, bicycles and other outdoor children's play things. High use lawns will of necessity require greater levels of lawn care to maintain a relatively dense lawn throughout the year including some overseeding or resodding to repair badly worn areas. Quality expectations usually range from medium to high. In high use situations, achieving high quality levels often requires significant levels of time and lawn care inputs.

Lawn Quality Descriptions:
High quality characteristics: good turfgrass density covering 100% of the soil surface such that no soil is visible; have a good green color and are maintained that way throughout the growing season; automated irrigation systems often present; little to no weed presence, low tolerance permitted for insect or disease damage – preventative applications often used

Medium quality characteristics: good turfgrass density although thin areas may be present with some soil surface exposure visible; some loss of color and slower growth rates permitted during hot, dry periods of summer – water applied only as needed to prevent death of turfgrass plants during summer stress periods, low levels of weeds are acceptable, insect or disease problems dealt with only as necessary to prevent significant turfgrass loss.

Cool-Season Lawn Grasses

Kentucky Bluegrass (Poa pratensis)

Kentucky bluegrass is the most widely used cool-season grass planted in northern portions of the United States. Kentucky bluegrass has a number of desirable adaptations over other lawn grasses. The strong rhizomatous nature of Kentucky bluegrass allows it to quickly establish an area and repair itself from damage due to pests and use. Kentucky bluegrass will form a relatively dense lawn of good green color that mows cleanly. Kentucky bluegrass is adapted to a wide range of environmental conditions but does best in soils of moderate to high fertility and soil pH of 6 to 8. When mowed at 2 to 3 inches, Kentucky bluegrass is very competitive against weed invasion. It is best suited to lawn areas receiving full sun to light shade.

Two disadvantages are its rather shallow root system and relatively high demand for water. However, older, common types of Kentucky bluegrass (and a few of the modern elite bluegrass varieties) have the ability to survive extended drought periods by going into dormancy. During dormancy, the plant can lose its leaf tissue (as evidenced by the plant turning brown) and most of its root system. However, the crown and rhizomes remain alive for much longer and are responsible for the recovery observed when watering or rainfall is resumed. During extended periods of very dry conditions and very high temperatures, some water may be necessary to prevent permanent injury to the crowns and rhizomes. Once these are permanently damaged, the plant will not recover even if watering is resumed or rainfall becomes more frequent.
Many varieties of Kentucky bluegrass have been developed, each differing in aggressiveness, tolerance to low mowing heights, resistance to various diseases, shade tolerance, and level of management required. Although all the differences in individual varieties are beyond the scope of this program, it may help to group some of the varieties according to suitability for low or high maintenance lawns.

Kentucky bluegrass varieties are often divided into two groups: common types and improved or elite types. Common varieties, or public varieties as they are known in the seed industry, are older varieties (or selections from older varieties) that have been around for many decades. Up until the late 1960s, common types of Kentucky bluegrass were the predominant types grown in home lawns. Table 2 lists the major plant and use characteristics of common Kentucky bluegrasses (KB) varieties.

Table 2. Plant and use characteristics of common KB varieties

Plant Characteristics

- Medium to medium-dark green color.
- Medium texture.
- Growth habit rhizomatous, but taller and more upright.
- Will go dormant during temporary hot, dry periods; recovers when moisture supplied and temperatures cool down.
- Plants do have physiological limits to stress that once exceeded, the plant will not recover.

Use Characteristics

- Little to no shade tolerance.
- Lower wear tolerance than improved types.
- More drought tolerant than many improved types.
- Lower moisture and fertility requirements than most improved types.
- Example varieties: Park, Kenblue, South Dakota Certified, Commons.

For the most part, improved or elite Kentucky bluegrass varieties have been developed in the last 30 to 40 years. Since most of the introductions to date have been selected under systems of generally high fertility and ample moisture, many have limited use in low maintenance landscapes. However, there is an increasing amount of research being conducted to improve the water and nutrient conservative nature of improved types.

As this continues, it is likely that improved varieties, with their superior disease tolerance, will also have increasing levels of tolerance to environmental stresses and lower fertility levels. Table 3 lists the major plant and use characteristics of improved bluegrasses.

Table 3. Plant and use characteristics of improved KB varieties

Plant Characteristics

- Medium-dark to dark green color.
- Medium to medium-coarse texture.
- Lower more spreading growth habit.
- Broad disease tolerance or resistance.
- Vigorous rhizomatous growth giving good stand density.

Use Characteristics

- Little to no shade tolerance.
- Good wear tolerance and recovery potential from injury.
- Higher maintenance, requiring ample water and fertilizer for optimum health.
- Need for more frequent dethatching.
- Poor soil conditions (such as compaction, waterlogging) increases vulnerability to various root diseases

It should be noted that where the landscape situation calls for the maintenance of a green lawn surface throughout the growing season and ample moisture and fertility can be provided it would not be a sustainable turfgrass choice to select common types of bluegrass. Under those conditions, common types of bluegrass are more prone to disease and generally do not perform as well, thereby potentially increasing weed invasion and an increased need for herbicides. The list of improved cultivars adapted to higher and lower maintenance levels is based on research at conducted Iowa State University and listed in Table 4.

Table 4. Maintenance levels of KB cultivars

Examples of some cultivars adapted to higher maintenance levels

Midnight	Vanessa
Ram I	Rugby
Merit	Banff
Eclipse	Nugget
Aspen	Touchdown
Baron	Parade
Columbia	Geronimo

Examples of some cultivars adapted to lower maintenance levels

Kenblue	Monopoly
Argyle	Ram-I
South Dakota Common	Harmony
Vanessa	Barblue
Fylking	Parade

Fine-leaved Fescues (Festuca spp.)

The term fine-leaved fescues is generally applied to three similar species commonly used in our lawn mixes. There are creeping red fescue (*Festuca rubra spp. rubra*), chewings fescue (*Festuca rubra var. commutata*), and hard fescue (*Festuca longifolia*). Occasionally, sheep fescue (*Festuca ovina*) is utilized in mixes to be used in very low maintenance areas. Creeping red fescue does spread by rhizomes but is not nearly as aggressive as Kentucky bluegrass. Chewings fescue and hard fescue are considered bunch-type grasses as they lack rhizomes or stolons and spread primarily by tillering. Table 5 lists the major plant and use characteristics of fine leaved fescues

Table 5. Plant and use characteristics of fine-leaved fescues

Plant Characteristics

- Chewings, hard and sheep fescues are all bunch-type grasses.
- Creeping red fescue is rhizomatous, but less so than Kentucky bluegrass.
- Medium to slow growth rates.
- Medium to dark green color.
- Fine to very fine in texture.

Use Characteristics

- Shade tolerant.
- Drought tolerant.
- Low moisture and fertility tolerant.
- Less tolerant of high wear conditions.
- Does not mow well in pure stands; better mixed with bluegrasses.

Fine fescue species and their respective cultivars are well adapted to our northern climate. There should be little difficulty in successfully growing the fine-leaved fescues in our area. They are also good to include in a lawn seed mixtures when introducing low maintenance varieties into an existing lawn or establishing a new lower maintenance lawn. Fine fescues are not normally sold or grown as sod.

Perennial ryegrass (Lolium perenne)

Perennial ryegrass is a cool-season, medium textured, wear-tolerant, bunch-type grass. It is a high maintenance grass well adapted to areas receiving high amounts of foot traffic, such as athletic fields or intensively used backyards. One of the biggest drawbacks of perennial ryegrass for some parts of the northern plains region is its poor cold tolerance. It is considered the least hardy of our cool-season lawn grasses and can thin out significantly or be completely killed during cold, open winters. Varieties that have shown good cold tolerance to date include Blazer, Delray, Diplomat, NK200, and Pennant.

In a pure stand, the tough fibrous nature of the blades makes it more difficult to mow cleanly. Therefore, it is always important to mow with a sharp mower blade. The newer, turf-type perennial ryegrasses have been selected and developed to blend well with other types of lawn grasses, especially Kentucky bluegrass. These are the ones that should be used when considering perennial ryegrass use in a seed mixture. They are normally not sold or grown as sod. Table 6 lists the major plant and use characteristics of turf-type perennial ryegrasses.

Table 6. Plant and use characteristics of turf-type perennial ryegrass

Plant Characteristics
- Bunch-type growth habit.
- Moderate to rapid growth rate, good rooting potential.
- Germinates quickly allowing for rapid establishment, "nurse crop" role.
- Turf types are medium to medium fine in texture.
- Medium to dark green color with shiny leaf undersides.
- Can compete excessively in mixed seedings.

Use Characteristics
- Performs best in medium to high maintenance programs.
- Some drought tolerance.
- Little to no shade tolerance.
- Can encounter rust problems under low N fertility and normal water.
- Mixes well with improved Kentucky bluegrass varieties.
- Tends to be thin; becomes clumpy and coarser texture under low maintenance.

National Turfgrass Evaluation Program
One of the best resources available for turfgrass variety evaluation is through the National Turfgrass Evaluation Program (NTEP; website: www.ntep.org). This program evaluates all the major turfgrasses for a wide array of uses, from golf courses to very low maintenance conditions. Various seed producing companies enter their selections and varieties into the various tests that in turn are conducted at many of the major universities around the country that have a turfgrass science and management research program. Results from these tests are compiled through NTEP and made available free via the internet to anyone interested in seeing which varieties have performed well for any particular situation or condition. The site is relatively easy to use although it may take a little practice to become proficient at finding what you are looking for.

ESTABLISHING A NEW LAWN

In this part of the country, there are two primary means of establishing a new lawn: seeding or sodding. Either can result in a healthy, good quality lawn once established. The most important difference between seeding and sodding is the time necessary for developing a mature and durable turf. Sodding is essentially transplanting a mature turf that has been cared for by a professional. Seeding involves the same process used in the establishment of sod and can be accomplished by a professional or the homeowner. The number of variables involved in seeding make it difficult and sometimes unsuccessful for homeowners. Table 7 lists advantages and disadvantages of each establishment method.

Table 7. Seeding and sodding comparison

Seeding Advantages
- More grass types and varieties to choose from.
- Less expensive than sodding.
- Stronger root system development initially.

Seeding Disadvantages
- Initial establishment takes longer.
- For best results, time of seeding is limited mainly to late summer and early fall.
- Moisture is critical for the young seedlings.

Sodding Advantages
- Rapid establishment and relatively weed-free in the beginning.
- Good for slopes or areas prone to erosion.
- Can be laid any time during the growing season.

Sodding Disadvantages
- Expensive.
- Less selection or control over kinds of grasses, especially shade or drought tolerance.
- Not adapted for use in low maintenance situations.

Sometimes the best approach to lawn establishment is a combination of the two methods. This can help reduce costs and meet specific site needs with the use of the most appropriate method as the best-adapted plants are established in the right place.

Proper Soil Preparation

Regardless of which method you choose, success will depend on good soil preparation. If this step is done properly, the lawn will give you years of satisfaction. If you neglect this step or try to economize too much, it will be more costly to correct the problems you may encounter after the lawn is installed. Remove existing perennial broadleaf weeds and grasses. Examples of broadleaf weeds include dandelions, thistles, plantain, and clover. Examples of perennial weedy grasses include quackgrass and orchardgrass. Leaving existing weeds and grasses only invites weed problems in the newly establishing lawn.

Test the soil and add the necessary potassium and/or phosphorus by rototilling it into the top 4 to 6 inches. Don't assume the topsoil you add is rich in nutrients, regardless of its color. Test it and make any nutrient additions that are necessary. Topsoil should be of a sandy loam texture with a good black color. Avoid heavy muck soils high in clas or silt contents sometimes offered as topsoil.

If you add topsoil or peat, rototill it into the upper 4 to 6 inches. This step can be combined with the fertilizing step just described. For sandy or clay soil, spread 12 to 18 cubic feet of baled peat per 1,000 square feet. However, it should be noted that sandy soils are excellent for growing grass without the need for peat additions IF consistent irrigation can be supplied. If you are adding topsoil, apply it at a rate of 3 to 4 cubic yards per 1,000 square feet. Don't let anyone talk you out of proper soil preparation if you are adding topsoil or peat. Leveling with a grader blade is not a substitute for rototilling. However, rototilling under trees will disrupt their feeder roots and may cause considerable damage. A better method is to use a vertical mower to simply scratch the soil surface when you prepare the area beneath trees.

Don't pack the soil too firmly before seeding or sodding; use a garden rake to level uneven areas

Seeding the Lawn

In the upper Midwest, Kentucky bluegrass, fine fescue, and some of the perennial ryegrass cultivars are recommended. However, before a seed mix is selected, carefully evaluate your site and note potentially troublesome areas. For example, note the amount of sunlight available, excessively wet or dry spots and areas of extreme exposure (e.g., open south and west facing slopes). It is also important to consider the amount of wear and tear the area is likely to receive along with one's own desire and ability to take of the lawn.

A Kentucky bluegrass blend containing at least two or three varieties is a good choice for sunny lawns. The benefits of a blend is that each variety may be different in its resistance to diseases and environmental stresses, such as drought and shade.

Some turf-type perennial ryegrasses have been used in home lawns for durability and foot traffic tolerance. To grow well, many perennial ryegrasses require more fertilizer and water than do the Kentucky bluegrass/fine fescue lawns.

Fine-leaved fescues are often mixed with Kentucky bluegrass in areas that have more shade. For these areas, use a mix consisting of 60 percent fine-leaved fescues and 40 percent Kentucky bluegrass varieties. Fine-leaved fescues can also be added to a bluegrass mix to lend drought tolerance in a sunnier location. For low maintenance turf, mixtures of common Kentucky bluegrass varieties and fine fescues will offer a durable lawn.

No more than 5 to 10 percent of any grass seed mix should be made of Italian or annual ryegrass. These plants are annuals and will not come back after the first winter. Also, due to their rapid germination and early seedling growth, they can overpower the more desirable lawn grasses that take a longer time to germinate, grow, and become established.

The availability of specific varieties will vary from year to year; however, within a particular kind of grass (for example, fine fescue or improved Kentucky bluegrass), most varieties will perform equally well. Your local seed distributor, garden center, or county extension educator can help you evaluate the best varieties for your lawn. Some varieties can be special ordered, but usually at a higher cost.

Grasses Not Generally Suited to Home Lawns in Minnesota

Annual ryegrass has been widely used as a temporary grass in lawn mixtures. It is short-lived and not recommended for lawn use since the plants will all die during the winter. Where a temporary cover is needed during the growing season, such as in areas used as ice rinks, this may be a suitable, cost-effective choice.

Turf-type *tall fescue* varieties are suitable for athletic fields and low maintenance lawns in some areas of the country, but do not have sufficient cold tolerance for Minnesota conditions. Further testing and variety development may lead to varieties of tall fescue that will consistently withstand Minnesota winters. At present, tall fescue is not recommended for Minnesota lawns.

Creeping bentgrass is adapted for golf course use and requires a great deal of care. Since it can be mowed down to less than 1/4 of an inch, it is ideal for golf greens. However, creeping bentgrass requires too much maintenance to be acceptable in most home lawn situations. In fact, bentgrass patches in Kentucky bluegrass lawns are a major weed problem in the northern United States.

Zoysia grass is a warm season grass commonly advertised for use in this area. While zoysia will often survive our winters, its warm-season growth habit doesn't allow it to turn green until the warm temperatures of late spring to early summer. It again turns brown with the first cool weather of late August to early September. Also, without sufficient water during the growing season it remains rather brown during the growing season as well. It is also very slow to establish a lawn due to our relatively short and often cool summer conditions.

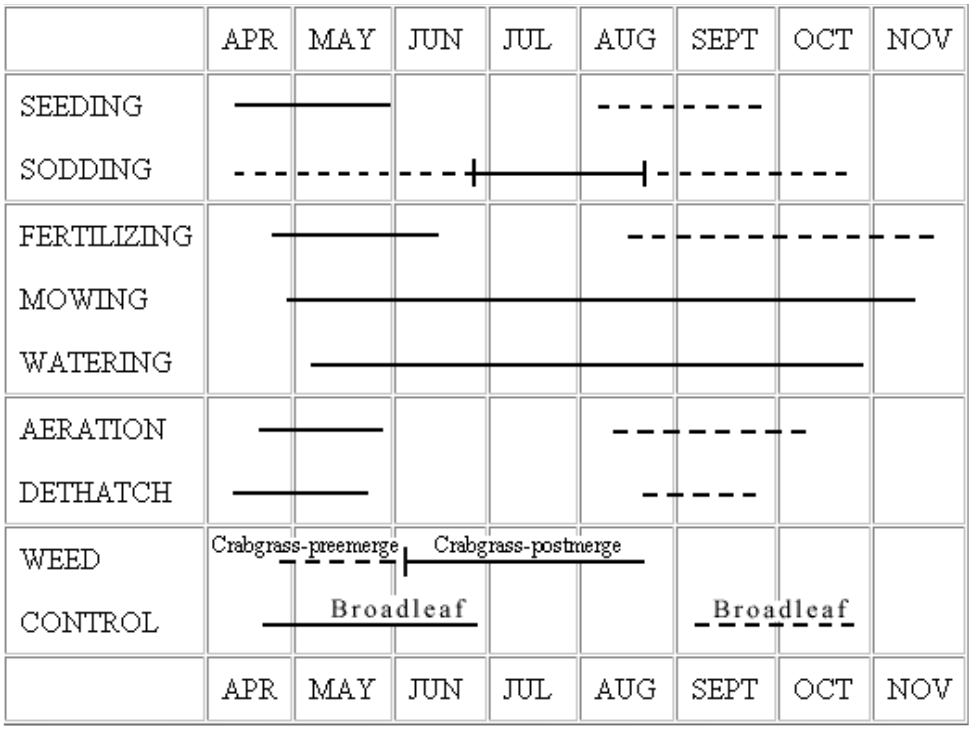
Buffalograss is a very drought tolerant, warm-season grass native to many of the short-grass prairies of the great plains. It is a very low maintenance turfgrass, growing only 6 to 8 inches high. There is considerable research being done to evaluate its use in areas with more humid growing conditions, where it is very difficult to establish and often short lived. It could be considered an alternative grass in west central to southwest Minnesota. Again, through continued evaluation and research it is likely that its range of successful adaptation and use will be expanded.

Timing

The best time to seed in Minnesota is late summer (mid-August to mid- September) when conditions are favorable for germination and growth. In addition, fewer weed seeds are germinating that might compete with the grass seedlings. This allows ample time for the plants to be well established before winter. See Figure 4.

Seeding can also be done in early spring. However, weeds and high summer temperatures often reduce the chance of success. Most annual weeds that compete with new grass seedlings germinate in spring. Only the selective preemergent herbicide Siduron (trade name Tupersan), may be used on newly seeded lawns. It will help reduce problems with crabgrass competition while the newly seeded area is getting established. In addition, the short growth period in spring allows less time to develop a root system to survive the summer heat stresses.

Figure 4. Upper midwest home lawn care calender for cool-season grasses



Legend _____ Indicates times when lawn care practices can be done.
- - - - - - - Indicates preferable times to carry out certain lawn care practices.

Note: Preemergence herbicides are put down before the crabgrass seedlings have emerged from the ground. Postemergence crabgrass herbicides are applied to the visible growing crabgrass plants. These products are best applied when the crabgrass plants are small.

Germination among the different cool-season lawn grasses is quite variable. For example, Kentucky bluegrasses can take 14 to 28 days to germinate while perennial ryegrasses will germinate in as little as 5 to 7 days. The fine-leaved fescues generally require 14 to 21 days to germinate. Thus, perennial ryegrass, like annual ryegrass, can seriously compete with the Kentucky bluegrasses and fine-leaved fescues. This can significantly reduce the amount of these two types of grasses in the established lawn. It should be noted that summer germination times are usually faster due to warmer soil temperatures while the longer times are more typical of spring sowings.

Dormant seeding involves sowing the seed after cold weather has set in but the ground is not yet frozen. Usually this is sometime in early to mid-November in the Twin Cities area. The principle is that the seed will remain dormant in the cold soil conditions but will begin to germinate as soon as the soil starts to warm in the spring. This avoids having to prepare the soil when it is still wet and cold in the spring and can result in several weeks' head start in getting the lawn established. This method generally works best when the newly seeded areas are quickly covered with several inches of snow that remains in place over the entire winter period. Open winters with extended warm periods followed by extremely cold periods can be disastrous for dormant seeded lawns.

Purchasing Seed

Purchasing the highest quality seed possible is always a good investment. Improper cultural practices will waste the money invested in purchasing high quality seed. However, poor quality seed will almost never result in a well-established lawn no matter how good the cultural practices. Determining what is high quality seed can be difficult for most people. Purchasing high quality seed

can be easier if you understand a few basic terms on the grass seed label. See Figure 5 for an example seed label. All labels must provide information about the grass seed purity, its germination potential, crop seeds present, weed seeds present, noxious weeds present, and inert components in the package.

Figure 5. Example seed label (company and variety names are fictitious)

WILL-GROW SEED COMPANY, TURFTOWN, OREGON
Lot No: 1234-B Test Date: month/year

Pure Seed	Variety	Germination
44%	Arctic Creeping Red Fescue	85%
31%	Blue Ribbon Kentucky Bluegrass	80%
9%	Wilson Chewings Fescue	85%
12%	Gopher Perennial Ryegrass	90%
1.56%	Crop	
2.11%	Inert Matter	
0.33%	Weeds	

Noxious Weed Seed: 25 Canadian Thistle Seeds Per Pound

Purity is the percent by weight of pure seed, crop, weed, and inert ingredients in the package. These percentages added together should total 100 percent. Purity is concerned only with quantity, not quality. That is, not all seeds present in the package are capable of growing. To determine the seed that will actually grow or what is known as pure live seed, the percentage purity should be multiplied by the germination percentage. For example, 90 percent Kentucky bluegrass (purity) multiplied by 85 percent germination equals 76.5 percent pure live seed. This is the percentage of Kentucky bluegrass that one would expect to grow under optimum germination conditions. It should be apparent that you should always seek to purchase the grass seed with the highest purity and germination percentage possible.

Germination is the percent of pure seed that will germinate and grow in an ideal laboratory environment during a prescribed length of time. Since field conditions rarely duplicate these laboratory conditions, it is especially important to purchase seed with the highest germination percentage possible. As noted above, this is the percentage used to determine pure live seed.

Crop is the percent by weight of seeds normally considered to be grown as an agricultural crop such as grain. This can include other types of grasses that may be undesirable in a lawn. This percentage should be as close to zero as possible.

Weeds refers to the percent by weight of all seeds in the package that are not otherwise listed in pure seed or crop. It is not required to identify these weeds or how many there are since this is on a percent by weight basis. For example, one or two large seeds of a weed would pose no particular threat to the new lawn. However, some tiny seeds that weigh very little, such as chickweed, can account for many thousands of weed seeds distributed over a 1000 sq. ft. of lawn area. This percentage should always be as low as possible.

Noxious weeds are listed as the number per pound, not the percentage per pound. Noxious weeds are weedy plants considered by individual states to be very difficult to control and that could pose hazards to both humans and livestock. While this is often more of a problem in farm crop seed, one should always purchase grass seed without the contamination of any noxious weeds.

Inert is the percent of material contained in the package that will not grow under any condition. Broken and damaged seeds, chaff, and empty seed hulls are just some of the more common inert material included. Obviously, this percentage should be as low as possible.

Considering seed count vs. seed weight

The Federal Seed Act requires that grass seed be listed on the label by weight and that it be separated into two broad categories: fine-textured grasses and coarse-textured grasses. However many of the grasses vary significantly in their respective seed sizes and consequently vary significantly in the number of

seeds per pound. A more accurate description of the grass seed contents contained in a package would be to list their percentage by seed count rather than percentage by weight. For example, large seeds (such as those of perennial ryegrass) are quite heavy and take only about 225,000 seeds to make one pound. On the other hand, Kentucky bluegrass is much smaller and therefore a much lighter seed by weight than perennial ryegrass. In fact, Kentucky bluegrass requires from 1 to 2 million seeds, depending on variety, to make a pound.

Given the above example, a 50 percent perennial ryegrass : 50 percent Kentucky bluegrass mix by weight actually contains only about 112,500 seeds of perennial ryegrass per pound of mix. The number of Kentucky bluegrass seeds present in this same mix would be about 500,000 to 1 million. Therefore the percentage of perennial ryegrass : Kentucky bluegrass contained in this sample mixture based on seed count is about 11 to 23 percent perennial ryegrass and 77 to 89 percent Kentucky bluegrass. Using this example, one may need to add a certain amount of one type of grass or another based on seed count to create the best mix for a particular site condition. For example, adding some additional pure creeping red fescue seed to an off-the-shelf seed mixture for shady areas will increase the number of seeds of the more shade tolerant creeping red fescue. This should provide greater potential for establishing a lawn area in the more shady parts of the landscape.

Seeding rates and planting methods

Seed Kentucky bluegrass blends (a combination of several Kentucky bluegrass varieties) at a rate of 2 to 3 pounds per 1,000 square feet. Use 3 to 4 pounds per 1,000 square feet when the seed mix contains Kentucky bluegrass and fine-leaved fescues. Using too much seed will result in higher costs and slower establishment due to competition between grass plants. Using a rate that is too low will prolong the time it takes for the grass to completely cover the soil surface and allow more opportunity for significant weed invasion to occur.

Seeding by hand or hand-powered equipment

Hand seeding is most practical where only small areas are to be established. First, lightly rake the soil surface loosening at least the top 1/2 inch of soil. This will allow for easier incorporation of the seed into the soil surface helping insure good seed to soil contact. Next, spread the seed by hand or by using a drop type fertilizer spreader calibrated to deliver the appropriate seeding rate. Whether you use a drop spreader or spread seed by hand, apply half the desired rate in one direction, then spread the second half at a right angle to the first to insure a good pattern of distribution. Follow up with a light raking allowing about 10 to 15 percent of the seed to show. Lightly roll the area to ensure good seed to soil contact. Note: Drop spreaders are generally preferred for seeding as they are more accurate due to less influence by windy conditions and differential seed size (that is, larger seeds are thrown further than smaller seeds when using a rotary spreader, resulting in uneven distribution of grass species within the area).

Be careful not to bury the seed too deeply. Seed that is buried too deeply may not germinate. Always gauge depth of planting by the smallest seed in the mix. For example, when mixtures of Kentucky bluegrass, perennial ryegrass, and fine-leaved fescue are used, depth of planting should be determined by the Kentucky bluegrass seed as it is the smallest of those in the mix. In this example, planting depth for all seeds would be about 1/4 inch for the mixture. This would be the normal recommended planting depth for Kentucky bluegrass.

Larger areas are better seeded with mechanical devices that either can be rented or provided by a turfgrass professional. A walk-behind machine known as a slit seeder loosens the soil just ahead of a series of discs that cut a groove to a specified depth in the soil. A series of tubes drop down from the seed hopper beside each of the discs. Seeds are dropped through the tubes at a preset rate into the groove and are lightly covered by the rotating disc. This allows precise placement of the seed at the proper depth and spacing. Again, it is usually desirable to seed in two directions at right angles using half the seeding rate in each direction.

Seeders known as cultipackers are commonly used for seeding large sites. These units are tractor mounted and provide very uniform seed distribution while also firming the seedbed after planting. The cultipacker seeder is equipped with a ridged roller component to help ensure the proper seed placement. While seed may germinate somewhat uniformly across the surface, better germination is often observed in the parallel valleys made by the ridged roller immediately after seeding. This type of seeding is very efficient for large areas and produces excellent results. Splitting the seed amount in half and going in two directions will help speed establishment.

Once seed is planted, make sure that the soil is kept evenly moist, although slight drying between waterings is not detrimental and may even be beneficial. South-facing slopes and other parts of the yard exposed to hot afternoon sun may dry out more rapidly and require additional watering on a more frequent basis

Moisture is critical once seeds start to germinate. They should not be allowed to dry. After the majority of seeds have germinated, you can water more heavily, but less frequently, to encourage deeper rooting. Be sure that all of the different grasses contained in a mix have germinated before cutting back on moisture. Establishment should take 6 to 12 weeks. If you seed in late summer (mid-August to mid-September), the lawn should be usable the following spring.

Mow the lawn when it reaches a height of 3 inches. Cut off no more than one inch, otherwise you will slow the establishment process. Mowing regularly in this way encourages deep rooting and helps maintain good growth. In addition, when the fast germinating perennial ryegrass is used in the mix, mowing when it reaches 3 inches will help prevent excessive competition with the much slower germinating fine-leaved fescues and Kentucky bluegrass.

When seeding in the late summer or early autumn, a preemergent herbicide should not be needed. Weed control using contact herbicides in a newly seeded lawn will have to wait until it has been mowed three to four times to allow the plants to become well established. Also, many of the troublesome broadleaf weeds that appear during the early establishment period will disappear once a regular mowing schedule has begun.

Perennial ryegrass is known for rapid germination and establishment; it is therefore useful where quick repair and establishment of a turf cover is needed. A drawback of this characteristic is that it can quickly shade and overpower slower germinating grasses seeded at the same time. To the unobservant, the bluegrasses and fine-leaved fescues may be totally lost from the stand due to the excessive competition from perennial ryegrass.

Because of its bunch-type growth habit, ryegrass does not spread rapidly. When seeding areas with mixes containing more than 50 percent perennial ryegrass, you will need to increase seeding rates to quickly cover an area. If perennial ryegrass is allowed to thin out due to improper maintenance, the turf becomes bunchy and loses quality. If the degree of soil exposure is increased on sloped areas due to thinning out, there is an increase in the potential for erosion and thereby the potential for pollution of nearby lakes, streams, and rivers. Remember, grasses are one of the very best stabilizers of soil when they are maintained in good health and completely cover the soil surface.

Hydroseeding and hydromulching:

Hydroseeding and hydromulching are a couple of seeding variations available from professional installers. While the terms are used somewhat interchangeably, they are distinctly different processes. Hydroseeding is the more commonly done practice. It involves spraying a liquid mixture of grass seed, mulch and fertilizer over an already prepared soil surface. The mulch consists of a wet pulpy material to which the desired grass seed and (usually) some starter fertilizer have been added. This can be very effective method of seeding difficult to reach areas, sloped areas or other situations where it is problematic to get in with traditional seeding equipment.

On the other hand, hydromulching involves spraying a similar pulp-like mulch material over an area that has already been seeded and (usually) fertilized. This process can also be used in similar applications to hydroseeding. However, where doing the actual seeding is problematic due to slopes, or difficult to reach areas, hydroseeding will usually be more practical.

With refinements in both application technology and equipment, either method can work very well when it comes to establishing a new area from seed. While the mulching materials provide additional protection from drying out, one should be ready to apply some additional water during periods of warm, dry conditions. Like regular seeding processes, newly emerging seedlings, especially those germinating in the mulch material not directly in contact with the soil, must never be allowed to dry out even with a mulch present.

A homeowner version of hydroseeding is available in the form of bagged mulch material that already comes with seed mixed in and occasionally a fertilizer added. In this instance the material is spread over the surface in its dry form and then moistened to form the "mulch mat" over the surface. If proper seeding is done first, these same materials or mulch materials without the seed or fertilizer added, can be spread over the soil surface in their dry form and then watered-in to create the same effect as a hydromulch. In either situation, remember to maintain the area in a slightly damp condition until the seedlings have begun to emerge and establish themselves.

Sodding the Lawn

When sodding a lawn, the consumer has limited varieties available. Most of the sod grown in the Upper Midwest is a blend of Kentucky bluegrass varieties and is therefore unsuited to shady conditions, although some may tolerate light shade.
NOTE: To insure good results, the same soil preparation must be done to sod a lawn as to seed it. With proper soil preparation and care, both upland and peat sod will perform equally well.

Sodding can be done any time after the ground thaws in spring, right into autumn. The limit on fall sod laying is the amount of time the sod has to develop roots before the ground freezes. The later sod is laid, the more risk that it will suffer damage if there is an "open" winter with poor snow cover.

Purchase sod as fresh as possible. Ideally, it should have been cut no more than 24 hours prior to delivery. The sod should be laid as soon as possible, or within one day after delivery. If the sod needs to be stored for a time, it should be kept in a cool, shaded area, and exposed rolls should not be allowed to dry out.

Suggestions for successful sodding

- When your sod arrives, have it stacked in the shade to prevent heating.
- Make sure you keep the outer rolls lightly watered.
- Complete your sod laying within 24 hours from delivery to minimize heat buildup in the sod rolls that can kill the plants.
- Lay the sod on slightly moistened ground.
- Stagger sod joints, butting the edges as close together as possible.
- Lay sod the long way across slopes and peg it down to prevent it sliding when it is watered.
- After sod is laid, go over it with a light roller, no more than 1/3 full of water, to insure good sod to soil contact.
- Water sod thoroughly, followed by lighter, frequent watering. Continue to water frequently during the two- to three-week establishment period, then gradually water less often, but more heavily.
- Aerification may help prevent soil layering caused by peat or soil that came with the sod. Aerify the spring or fall after establishment. Be sure to aerify deep enough so that the tines penetrate through the sod and at least two to three inches into the soil.

Establishing a new lawn from sod or seed can be a very satisfying experience on its own. Once the lawn is established, it will provide its many benefits such as cooling, erosion prevention, runoff control, and allergen reductions. Having planned and installed a well-designed landscape with appropriate areas devoted to lawn grasses that will meet family needs and be sustainable can be particularly gratifying.

Lawn Renovation

Where lawn quality and function has declined to the point of being unacceptable, renovation may be necessary. Renovation involves planting grass seed into an existing lawn area, often adding new grass varieties to repair damage or increase tolerance to drought, shade, or wear. Renovation usually isn't necessary until approximately 20-25% of the lawn is bare or covered with weeds. However, renovation alone will not be sufficient if problems are too severe. In these situations, starting a new lawn may be the best option. Removal of the existing turf, tilling, adding topsoil, and changing the soil grade may all be needed to satisfactorily prepare the area for either seeding or sodding. The following conditions may warrant starting over:

- an excessively compacted soil
- greater than 50% weeds and/or bare soil
- a thatch problem (discussed later) that isn't corrected by renovation efforts

Renovation should be considered if any of the following conditions exist in your lawn:

- Approximately 20-40% of the lawn is dead or has very sparse growth. This may be due to a variety of factors such as low soil fertility, drought and heat, insect damage, poor mowing practices, disease, moderate soil compaction, or increasing shade and competition from growing trees.
- The lawn is soft and spongy when walking across it and responds poorly to regular watering and fertilizer applications. This condition usually indicates excessive thatch (greater than 1/2 inch). Thatch is a layer of partially decomposed grass stems, roots, and rhizomes (not leaves) at the soil surface but below the green vegetation.
- Broad-leaved weeds such as dandelion, plantain, and knotweed, or grassy weeds such as crabgrass cover about 20-40% of the lawn area.

Before You Begin

There are several things to consider before beginning a lawn renovation project.

First, it is valuable to determine why the lawn deteriorated so that corrective measures can be initiated during the renovation process. For example, if the lawn is thinning due to an expanding tree canopy that now shades the lawn and competes for water and nutrients, you should select shade-tolerant grass varieties. Also consider pruning some of the tree limbs so more light and rainfall can reach the lawn.

Knowing the cause for lawn failure can also make you aware of changes in cultural practices such as mowing, watering, and fertilizing that may be necessary. A soil test is always recommended before starting a renovation project (check with your county extension office for information on how to conduct a soil test).

Second, decide whether to do the renovation yourself or hire a professional to do all or part of it for you. There are several steps to lawn renovation and some of them are best accomplished using specialized equipment available through rental outlets. You may decide, for example, to prepare the site yourself but hire a professional to seed the lawn using a slit seeder. Check with lawn and landscape companies providing this service.

Late summer to early fall is the best time of year for lawn renovation because environmental conditions are favorable and weed competition is much lower than in spring. In Minnesota, the best time for seeding is between mid-August and mid-September. Reseeding at this time allows the lawn to establish before winter arrives.

Finally, you need to determine the types of grasses to use. Lawns are intended to meet a range of expectations, based on input levels of time and expense as well as environmental conditions. In selecting grass types you should select those that most closely match your site conditions and use expectations.

For a thorough discussion of the lawn renovation process including a step-by-step description of properly renovating a lawn, refer to Lawn Renovation, University of Minnesota Extension Service publication FO-3914. This publication can also be accessed through the U of M extension website: www.extension.umn.edu

WATERING PRACTICES

Efficient watering practices are important to all homeowners who want to conserve water, maintain a sustainable, healthy turf, and reduce maintenance costs. Understanding how grass plants use water and their ability to tolerate dry conditions is the first step to putting the right plant in the right place to perform the right function. This is one of the key concepts in establishing a more sustainable lawn.

Lawn Grass Water Use

Water is an essential ingredient of all living cells. Lawn grasses are about 90 percent water by weight. All nutrients taken into lawn grass roots from the soil are in solution (that is, dissolved in water). Once nutrients have been absorbed into the plant, they are moved to the individual cells of the stems, leaves, and other grass plant parts where they are involved in numerous plant growth processes. Water vapor eventually diffuses out of the leaf through small pores called stomata. These small pores are spaced close together on upper and lower leaf surfaces. This evaporation process helps cool the turfgrass plant and its surrounding microenvironment.

Lawn grasses differ both in physical properties that influence water needs and biochemical processes that determine water use. Thus, lawn grasses have a combination of structural and chemical characteristics that make them more or less efficient users of water, as well as more or less drought tolerant. Among our commonly used lawn grasses, the fine-leaved fescues and older, common types of Kentucky bluegrass are more tolerant of dry conditions than either perennial ryegrass or most of the newer, improved types of Kentucky bluegrass.

The depth and extent of root development influence drought tolerance. A grass with a larger, more extensive and deeper root system has an increased volume of soil from which to obtain needed water. This would permit the grass to survive longer under drought conditions. Root development of our common, cool-season lawn grasses is generally confined to the top foot of soil with a majority in the top 6-8 inches.

Determining Amount of Water to Apply

Watering schedules should be managed to at least partially replenish the water lost to evaporation and used by the plant. This generally provides a healthier turf and minimizes the potential problems associated with leaching and run-off concerns.

In most years, Minnesota's climate makes lawn watering optional. Water in the landscape is lost back to the atmosphere through evaporation and is used by the plant for cooling purposes (a process known as transpiration). Together these two phenomena are known as "evapotranspiration," abbreviated ET. Potential evapotranspiration is the estimated amount of water a lawn would use if water is always plentiful in the soil.

In the Twin Cities, on average, the amount of rainfall is greater than the amount of water needed by grass plants in each month of the year except June, July,

August, and September. Consequently in most years, lawn irrigation during October, November, April, and May should be minimal or unnecessary. In an average year, lawns use about 4 to 6 inches of water per month during June, July, and August. Therefore, to maintain a healthy green lawn all summer, about 1 to 1 1/2 inches of water per week, including rainfall, will be needed.

The amount of water to apply depends on the soil type and moisture content of the soil. The preferable method is to thoroughly wet the soil down to a depth of five or six inches. When too much water is applied at one time, much of it may be lost or wasted because it moves too deeply into the soil for the grass roots to be able to use. For example, in sandy, well-drained soils it may be more efficient to apply two 1/2 inch applications per week than a single, one inch application. If the soil is initially very dry, it may take 1/2 inch of water to wet a sandy soil down to a depth of 5 inches, while 1 to 2 inches of water may be needed to wet a clay soil. Once the soil is thoroughly wet to a depth of 5 inches, any additional water will simply move beyond the root zone of the grass plant.

Remember that water should not be allowed to run off the surface or to form puddles, as these lead to poor distribution and use of water. Occasionally, the rate at which water can enter the soil is less than the amount applied by the sprinkler after watering has continued for a time. If you notice water running off the surface or forming puddles but you still want to apply more water, turn the water off for 15-30 minutes, then resume watering until the desired amount has been added. Repeating this wait period as often as needed.

Occasional extraction of soil cores after normal irrigation can give some idea of how deeply you are watering. Another easy method is to sink a shovel into the soil and spread the hole so you can see how far the water has penetrated. Then remove the shovel and press the soil into place with your foot.
Determining the amount and uniformity of water applied in a normal irrigation can be done by placing a row of equal-sized, straight-sided cans in a line at one or two foot intervals from the sprinkler and out to the farthest point of watering. After a specified length of time (such as an hour), measure the amount of water collected in each can. This will tell you how much water has been applied during that hour. From this, you can determine the appropriate length of time needed to apply the desired amount of water.

Frequency of Watering

Frequency will also be affected by grass species, soil texture, climate, exposure, and amount of use the lawn area receives. Ideally, the grass plants should dictate the watering program. Slight wilting, a color change to a more grayish or bluish-green shade, or footprinting (when plants will not rebound after walking on them) are indications that irrigation is necessary.

It is desirable to keep the interval between watering as long as possible without allowing the plants to go into water stress. Thorough, infrequent watering causes plants to develop deeper root systems which can extract water from a much larger volume of soil than the shallow roots associated with light, frequent irrigation.

Some areas of the lawn will probably dry faster than the rest. This is common on southern exposures, sunny areas, borders of sidewalks, and slopes. Hand watering these areas may save water by extending the intervals between watering the entire lawn.

Deficit Irrigation

Recently, the concept of deficit irrigation has been employed to conserve water. In this concept, lawns are still watered thoroughly but at longer intervals than might be considered optimum to maintain plant health and vigor. For example, research has shown that delaying the application of an inch of water per week to an inch of water every 10 days to 2 weeks does not result in a significant decline in turf quality. Instead of trying to replace the average amount of water lost during a week's time (i.e., about 1 inch per week during the summer

months), you are basing the application of water more on a turf quality standard rather than just routinely applying 1 inch per week. The term deficit irrigation refers to the fact that under this practice, not all of the water lost on a weekly basis is being replaced in that same time period, hence a deficit.

This research is based on average summer conditions with respect to temperature and soil conditions. Potentially, this could save 35% to 50% of the water normally applied to lawns. During periods of very high temperatures and dry conditions the period between watering will need to be shortened. Likewise, under cool and dry conditions, such as in the late summer or fall period, the time between applications can be lengthened by a few days. This is primarily due to the fact that water loss is not as rapid during cooler conditions.

Timing of Water Applications

The most efficient time to water lawns is probably early in the morning, from 4 to 8 a.m. Less water is lost to evaporation due to lower temperatures and less sunlight. Also, wind velocities are usually lower than they will be later in the day, so distribution is improved. Water demand on municipal systems is usually less at that time as well.

Midday watering, though good for the plants since it cools them and reduces heat stress, is not as efficient because some of the water evaporates before getting into the soil. Watering in the evening should be avoided if possible. If grass plants go into the nighttime hours wet, they will remain wet for an extended period of time. This may favor the growth and development of turfgrass diseases.

Syringing

Syringing is a very light application of water to wet the leaves of the grass but not necessarily to get water down into the soil. Usually syringing is done during the hot part of the day to reduce heat stress by cooling down lawn and soil surfaces as well as the immediate air surrounding the grass plants.

There are three situations in which syringing might be considered on lawns:

- If the turf is infested with one of the root damaging patch diseases. Daily syringing during high temperatures can reduce the severity of damaging.
- If the lawn is newly seeded. Germinating seedlings have minimal root systems and can easily die from water stress. Light, frequent watering is necessary until the plants are established and have developed adequate root systems. Syringing during high daytime temperatures will help keep the seedlings cool and moist.
- When an established turf is showing stress on a hot day but cannot be watered adequately until later.

Heat, Drought, Summer Dormancy, and Watering

Generally, summer dormancy is an important way for our cool-season grasses to survive temporarily hot, dry periods during the summer. During dormancy the plants stop growth of leaves and shoots, causing the existing turf to turn brown. The plants usually do not die, although the leaves cease growing. When adequate water returns, new growth will occur with no long-term damage. The fine-leaved fescue grasses do not go dormant but are quite drought tolerant and grow very slowly under dry conditions, thus using less water.

Not all grass plants are sufficiently tolerant of dry periods to go without irrigation in Minnesota. Perennial ryegrass does not go into dormancy but temporarily survives hot, dry conditions by growing more slowly. Some of the newer, improved varieties of Kentucky bluegrass are not as drought tolerant as the older, common Kentucky bluegrass types. Perennial ryegrasses and most of the improved Kentucky bluegrasses will require some irrigation to keep them alive through hot, dry periods.

There are exceptions when it is important to keep the grass growing throughout the summer by supplemental irrigation. Any turf which is affected by or is recovering from pest damage such as from disease or insects, or mechanical injury, should receive plenty of water to aid recovery. Any area which has been recently seeded should be watered frequently enough to keep the soil just damp. Newly sodded areas should be kept moist, but definitely not soggy, while rooting is established—usually about 3 to 4 weeks. Whenever possible, areas subjected to wear, such as ball fields or play areas, should be watered to maintain tolerance to traffic and aid recovery.

Letting the Lawn Go Dormant

When lawn grasses become dormant naturally the soil dries out from the top down. During this process, roots grow deeper into zones of more moisture. When, finally, available moisture within the rootzone has been exhausted, the grasses wilt and foliage browns as dormancy sets in. Stress factors that contribute to this condition include both lack of moisture and high temperatures.

Life in the lawn grass crown

When lawn grasses go into summer dormancy, life does continue in each plant's crown. This is a small mass of tissue about the size of a very small pea located at the soil surface. Roots grow from the lower surface of the crown, and foliage from the upper surface. Healthy, vigorous crowns can withstand dormancy with ease. Weak, diseased, or insect-damaged crowns are less likely to survive dormancy.

Start of lawn dormancy

Dormancy starts with the wilting of lawn grasses. First, a blue-green cast to the foliage develops. At this time, footprints show as people walk across the turf. As the process continues, foliage shrivels, dries and turns brown. High nighttime temperatures (in the 70s and 80s) cause northern, cool-season grasses to deplete their carbohydrate energy reserves rapidly. Extended periods of these conditions can cause serious, permanent turf loss.

Also, lawns growing on compacted soils are very vulnerable when weather conditions turn hot and dry. Compacted soil prevents the development of a deeper root system and may encourage greater development of thatch (the brown, fibrous layer of material between the soil surface and the green grass plant parts). A shallow root system accompanied by an excessive (greater than a 1/2 to 3/4 inch) thatch layer provides little protection from potentially serious turf injury and/or loss during extended hot, dry periods. A watering program will have to be continued to prevent serious turf loss to lawns growing under these conditions. Aerifying the lawn, or better, properly preparing the soil before a lawn is installed, will help encourage a deeper root system and consequently improve the lawn's overall stress tolerance during hot, dry weather.

The process of conditioning your lawn to withstand these hot, dry periods is very important to insure its survival and ultimate recovery from summer dormancy. Several important items to help condition a lawn to the warm, dry periods of summer are listed in Table 8. Also, avoid use of broadleaf herbicides during this stress period as injury to lawn grasses can occur.

Table 8. Practices to increase turfgrass drought tolerance

- Choose tolerant species.
- Avoid excessive growth stimulation.
- Maintain adequate potassium levels.
- Raise mowing height.
- Allow turf to harden off into drought conditions.
- Limit traffic.

Generally, there is little that needs to be done to the lawn while it is dormant. However, there are limits as to how much constant hot, dry conditions our lawns will endure. Avoid play or traffic on dormant lawns. Even with properly conditioned turf, applying about 1/4 to 1/2 inch of water every 10-14 days on a heavier soil keeps the grass plant crowns from dehydrating beyond a point of no recovery. Shorter intervals may be needed on sandy soils or during prolonged periods of high temperatures to achieve the same results. Once cooler temperatures and natural rainfall returns in late summer or early fall, resume regular irrigation practices if needed.

Recovery from lawn dormancy

Dormant lawn grasses recover rapidly upon receipt of a good soaking rain accompanied by soil cooling. Kentucky bluegrasses, fine fescues, perennial ryegrasses and tall fescues all are able to withstand a certain amount of summer drought without major damage and recover when growing conditions again become favorable. Often only a minor lessening of lawn quality is noted at such times.

Because it takes some time to establish a balance between top growth and root growth following dormancy, it's good to let the lawn grow taller before resuming normal mowing practices. Do not encourage rapid foliage development with excessive nitrogen fertilizer applications. As growth conditions improve and turfgrasses increase in vigor, core aeration will help to improve the root zone for more rapid recovery.

While lawns developed and established to be sustainable usually require less water inputs, carelessly neglecting water needs of the grass plants may destroy all the effort put into creating a sustainable lawn ecosystem. Maintaining grass plant health is still the major objective of any lawn care program. Supplying supplemental water as needed remains a sound management practice for the lawn and the environment.

MOWING PRACTICES

Lawn mowing is more time-consuming than any of the other cultural practices involved in caring for a lawn. Regular mowing with a sharp mower blade at the proper height will help keep grass growing vigorously and maintain adequate density to completely cover the soil surface. In addition, mowing with sharp blades will cut the grass blades cleanly rather than tearing and shredding them as would be the case with dull blades. This will cut down on the amount of water lost from the grass plant, thereby conserving moisture and reducing the need for additional watering. Shredded ends of the grass blade are more susceptible to disease invasion and can increase the need for fungicides.

The general rules of thumb for mowing lawn grasses are to mow high, mow frequently, and allow the clippings to return to the lawn. Mowing frequency is based entirely on the growth rate of the grass. In spring and fall when grass is growing more vigorously, mowing should be more frequent than during midsummer when growth rates slow. Mow often enough so that no more than 1/3 of the leaf surface of the grass plants is removed at one time. For example, if the finished height is two inches, mow whenever grass reaches three inches in height.

Height of cut plays a very important role in determining the maintenance needs of a lawn. Generally, the higher the height of cut the less the maintenance required. This is primarily because higher heights of cut promote deeper more extensive root growth. Shorter heights of cut promote shallower root systems. Deep root systems have naturally greater access to soil water and nutrient reserves, thereby increasing their ability to tolerate environmental stresses. Shallower root systems require greater attention to supplementing soil water and nutrient needs to keep the plants healthy and minimize exposure to adverse environmental stress. For most lawn areas, mowing at a height of two to three inches will provide a good quality turf.

In addition to larger and deeper root systems, higher heights of cut restrict the amount of light reaching the soil surface. Since many lawn weed seeds require light for germination, the increased shading from a higher height of cut will actually suppress weed germination and growth, thereby reducing the need for herbicide use or other weed control measures. This can be particularly helpful in controlling our warm-season annual grasses such as crabgrass. In turn, this can reduce the dependence on preemergent herbicides for their control.

Mowing frequency is also increased with shorter heights of cut. For example, if the lawn is maintained at one inch, then only 1/2 inch of growth is needed before mowing is required assuming that no more than 1/3 of the top growth is removed at each mowing. On the other hand, if the height is maintained at 2.5 inches, then about 1 inch of growth could occur before mowing would be required. In general, the more growth needed before mowing is required, the longer the time interval between mowings.

Mowing too infrequently damages the lawn by removing too much of the plant at once. A substantial amount of leaf tissue is removed with infrequent mowing, while proper mowing removes a much smaller portion of leaf tissue. When mowed regularly, clippings filter down into the lawn, decompose rapidly, and recycle nutrients back into the lawn. Continually scalping the turf thinking that the frequency of mowing will be reduced can seriously weaken the grass plants, inviting unwanted weed invasion and competition.

Increasing the mowing heights by an inch during mid-summer will improve the lawn's ability to tolerate stress caused by heat and drying winds. It is also important to continue mowing throughout the fall until growth stops. The weather is usually warm enough for continued grass growth until early November. Lawns that are too tall at that time frequently mat down during winter, making them more susceptible to winter disease problems such as snow mold and invasion by mice or voles.

Change the direction of mowing each time to promote upright shoot growth. When the lawn is mowed in the same direction every time, the grass may lay down in the direction of mowing. By mowing at right angles every other time, this horizontal growth orientation will be minimized. In addition, the alternate mowing pattern will help prevent continuous scalping of high spots and help prevent soil compaction that may result from repeatedly following the same path.

Managing Grass Clippings

Grass clippings will always be a part of lawn care. Because lawns grow at different rates depending on environmental conditions and management practices, it is important to tailor mowing, fertilizing, and watering to meet plant needs, yet avoid excessive growth. Grass clippings an inch or less in length filter down to the soil surface and decompose relatively quickly. Longer clippings have a tendency to remain above the lawn where they appear unsightly and can shade or smother grass beneath. Long clippings need to be removed to avoid both unsightliness and lawn damage.

Bagging clippings did not become commonplace until the 1950s when bagging attachments were designed for rotary motors. In nearly every instance, proper lawn care can greatly reduce or eliminate the need to collect clippings. In fact, clippings are a valuable source of nutrients. University of Minnesota soil test recommendations call for less nitrogen fertilizer if clippings are returned to the lawn. Also, the addition of organic matter in the form of clippings may help to improve the status of your soil if it is sandy or low in organic matter.

Contrary to popular belief, returning clippings to the lawn does not normally contribute to increased thatch formation. Thatch is a layer of undecomposed organic matter that builds up between the soil surface and the actively growing green vegetation. A thatch layer will develop if organic matter is produced faster than it is decomposed by microorganisms. The major factors contributing to thatch development are vigorous grass varieties, excessive nitrogen fertiliza-

tion, infrequent mowing, and low soil oxygen levels usually associated with compacted soil conditions. Small clippings are composed primarily of easily degradable compounds which break down rapidly and do not accumulate. Long clippings may contain wiry stem material that is slower to decompose.

Options to leaving clippings

While leaving clippings on the lawn is recommended, certain instances make the practice inadvisable. Following are some exceptions to the rule:

1. If the lawn is heavily infested with certain leaf diseases, removing clippings may help reduce disease severity.
2. If the lawn must be mowed when wet, clippings can mat together and smother the grass.
3. If the grass has become too tall, clippings can mat together and smother the grass.
4. If your mower is unsafe to operate without a bagging attachment the bag should be left in place.

When clippings must be collected, using them as mulch in the garden or composting them are two good alternative disposal methods.

Grass clippings can provide an effective mulch around garden plants. Mulching helps reduce weeds, conserve moisture, and modify soil temperatures. However, do not apply more than one or two inches of grass clippings as a mulch at one time. Wet grass clippings can mat down and prevent oxygen and moisture from getting down into the soil. When oxygen is limited, anaerobic decomposition of the clippings may take place, leading to the production of offensive odors. Do not use grass clippings as mulch if the lawn was recently treated with a herbicide for dandelions or other broadleaf types of weeds. If clippings are to be used as a mulch, then wait until it has been mowed at least twice.

Composting involves mixing grass clippings and other plant materials with a small amount of soil containing microorganisms that decompose organic matter. Grass clippings are excellent additions to a compost pile because of their high nitrogen content. However, they should not be the only compost component. As with mulches, a thick layer of grass clippings in a compost pile will lead to bad odors from anaerobic decomposition. Mix them with dry materials such as leaves or straw. Clippings can be composted in the backyard or hauled to municipal composting sites.

What about those fall leaves?

Every year the question arises as to whether or not fall leaves can be left on the lawn or if they should be raked off. Recent research has indicated that if tree leaves are sufficiently chopped up via a standard or mulching type of rotary mower and dispersed over the lawn, there should not be any problems with grass survival. In fact, it has been observed that spring green up can be somewhat better where tree leaves have been chopped up and incorporated into the lawn surface the previous fall.

However, there are a couple of important caveats to this practice that will make it more or less successful. First, the amount of leaves deposited on the surface should be less than an inch or two prior to mowing them. Heavy layers of leaves (i.e. more than a couple of inches) should first be lightly raked off before mowing. Second, even after making several passes over an area, any heavy accumulations of leaves such as windrows or piles should be raked off such that the grass plants underneath them are not starved of sunlight and ultimately die. A good rule of thumb as to whether or not leaves have been properly chopped up and incorporated into the lawn is that, when you are done, the lawn should look like it has been thoroughly raked. That is, the surface should be relatively free of leaves and the grass fully exposed to take advantage of those sunny fall days without being covered by a layer of leaves.

Remember, any leaf material raked off the lawn can be composted or used as mulches in shrub borders, flower beds or incorporated into garden areas as an

organic soil amendment. Pine needles are harder to chop up properly with a mower and any heavy accumulations on the lawn should probably be raked off first and either composted or used as mulch. A small amount of needles left in the grass after raking or mowing will not pose a problem for grass plant survival.

Mowers and Mowing Safety

Choosing a mower

The two principal types of mowers available for use on home lawns are reel and rotary mowers. Regardless which type is chosen, it is very important to keep the mower blades as sharp as possible. Dull mowers tear grass blades rather than cutting them. This results in injured plants.

Reel mowers have a series of revolving blades that cut against a stationary bedknife, much like a scissors. While reel mowers provide the finest quality of cut available, they are expensive, not easily adjusted, and require specialized equipment for sharpening. Also, they can't be used where stones, twigs, or other debris are a problem because of potential damage to the cutting units.
Rotary mowers have a whirling horizontal blade. Rotating blades have the potential for throwing stones or other small objects in the path of the mower. Therefore, rotary mowers are more dangerous than the reel mowers. They cut the grass by impact, similar to the way a machete works. This causes a rougher, more uneven cut than reel mowers. However, rotary mowers do an acceptable job on virtually any lawn. In addition, they are easier to maintain than reel mowers and can cut taller grass.

Mulching or recycling mowers are now available. A mulching mower recuts grass clippings into smaller pieces and redistributes them uniformly back into the lawn for rapid decay. When the turf is wet, clumping is common with mulching mowers because of the excess water present.

Modern mowers are equipped with certain safety devices which should not be removed or tampered with. One safety feature is a blade that stops turning when the operator's hands are removed from the controls. Another is a rear-mounted rope pull for starting the mower. This reduces the chance of getting one's foot caught in the blades during starting. Many rotary motors have bagging attachments which affect mower safety. The manufacturer may have a special attachment which is required for safe mowing without a bag. Similarly, discharge chute shields on nonbagging mowers should not be removed.

Mowing safely

All mowing equipment should be kept in good working condition. Mowers should be sharpened and adjusted frequently to assure a clean cut. A dull rotary mower frays the ends of grass blades and results in brown tips, which are unsightly and increase the plants' susceptibility to certain plant diseases.

Slopes greater than about four to one are both difficult and dangerous to mow. These slopes are good candidates for groundcovers that will stabilize the bank and eliminate the need for routine maintenance such as mowing. Pick up rocks, wires, and sticks before mowing to prevent them from becoming dangerous projectiles.

Keep all spectators away from the mower while it is in operation. Young children should not be allowed to operate mowers until they can handle them easily. Use earplugs when operating noisy power mowers. Wear sturdy shoes that protect the feet. Always push the mower forward. Never pull it backward in a motion where a slip will allow your foot under the mower deck. Mow across a slope, not up and down for the same reason. Another safety tip is to delay mowing grass when it is wet. Dry grass is less apt to plug mowers. Footing is better on dry grass, and good footing is important on slopes.
Finally, there is a growing movement among people with small, easily managed yards, back to "old-fashioned" push-type reel mowers. Newer versions are smaller, lighter weight, and easier to push than the old models you may have

used as a youngster. They have the advantage of quiet, fuel-free operation, and can provide good exercise at the same time. If your property isn't too large, consider these mowers when shopping for a new one.

FERTILIZER PRACTICES

The goal of any fertilization program is to compensate for deficiencies in the soil of nutrients that are needed by the grass plant to sustain healthy growth and remain competitive against disease, insect, and weed invasion. While phosphorus (P) and potassium (K) are needed for a healthy lawn, it is nitrogen (N) that is required in the largest amounts by the grass plant.

Nitrogen (N)

Few soils have enough natural N available to maintain adequate turfgrass quality and recuperative capacity throughout the growing season. Nitrogen shortages can lead to very slow growth, yellowing of the plants, thinning of the turf, weed infestation, and increased incidence of some diseases. However, overfertilizing with N can lead to excessive shoot and leaf growth, reduced root growth, low plant carbohydrate (food) reserves, and increased susceptibility to environmental stresses and some diseases. In fact, in lawns containing grasses adapted to lower water and nutrient inputs as described earlier, overfertilizing with nitrogen and/or overwatering results in a decline in health rather than improvement.

Nitrogen release rates

Nitrogen contained in fertilizers may be derived from either inorganic or organic sources, and is either quickly or slowly available for the plant to use. Inorganic fertilizers, such as ammonium nitrate and, ammonium sulfate, and the organic fertilizer urea, are all water soluble or quick-release N sources. That is, N becomes available soon after water is applied to the turf. Their response is quite predictable and results are often visible in 5 to 7 days. However, the effects are relatively short lived. On sandy soils, high application rates of these products, combined with high irrigation or rainfall amounts, will likely result in higher N losses due to leaching. Leaching is the movement of water and nutrients beyond the turfgrass root zone.

Organic fertilizer products, natural or synthetic, are those containing carbon (C) in their chemical structure. Nitrogen from natural organic sources becomes available only after the product begins to break down due to soil microbial action. These are considered slow-release N sources because it is gradually released to the soil solution and available for plant use over a longer period. Soil temperature and moisture are key factors governing microbial activity and thereby the N release. Compared to quick-release sources, these have a lower leaf-burn potential and can be applied at slightly higher rates, less often, without damaging the turf.

The primary synthetic organic fertilizer product is urea. It is considered a quick-release N product. Urea has been further processed and/or combined with other materials resulting in products with more or less of a slow-release characteristic. Nitrogen release is dependent on soil chemical, soil temperature, and/or microbial action. These slow-release fertilizers have a fairly low leaf-burn potential and can be applied at slightly higher rates and less often than quick-release N sources. See Table 9 for a summary of different N sources.

Grass clippings should be returned to the lawn whenever possible. As grass clippings easily decompose once in contact with the soil, they do not contribute to thatch build-up. Grass clippings are a valuable organic source of nutrients, especially nitrogen (N). As they decompose, these nutrients become available for use by the grass plant. In fact, yearly nitrogen applications may be reduced by one-third to one-half when grass clippings are returned to the lawn.

Table 9. Characteristics of common turfgrass N sources

Classification, burn potential, leaching potential, low temperature response, and residual effect on common turfgrass N sources.

Fertilizer Source	Leaching Potential	Burn Potential	Low Temp. Response	Residual Effect
Inorganic				
Ammonium nitrate	High	High	Rapid	Short
Calcium nitrate	High	High	Rapid	Short
Ammonium sulfate	High	High	Rapid	Short
Organic-Natural				
Activated sewage sludge	Very Low	Very Low	Very Low	Long
Manures	Very Low	Very Low	Very Low	Long
Other natural products	Very Low	Very Low	Very Low	Long
Synthetic				
Urea	Moderate	High	Rapid	Short
Urea solutions	Moderate	High	Rapid	Short
Sulfur-coated urea	Low	Low	Moderate	Moderate
Resin-coated urea	Low	Low	Moderate	Moderate
Isobutylidene diurea (IBDU)	Mod. Low	Low	Moderate	Moderate
Methylene ureas and Ureaformaldehyde*	Low	Low	Low	Mod. Long to Long

*some products may contain urea in addition to the ureaformaldehyde component.

Recently, a number of organic products have appeared on the market as "biostimulants," "growth enhancers," "soil enhancers," and other effects claimed to improve both the soil and lawn. This has also been an area of active research to evaluate these materials and their effects. In some instances, there appears to be some benefit while in other situations results appear to be inconsistent at best. As these materials are further tested, evaluated, and used more widely, it is likely that some of them will provide consistently beneficial results to our soils and turfgrass communities. If you want to try some of these, it may be best to proceed cautiously and evaluate their use and effects on a limited area before expending the dollars and time to apply them to large areas

Late Season N Applications

Late summer and fall are the principal times of year to fertilize lawns. This is contrary to the traditional springtime application of most lawn fertilizer. Some advantages of fall rather than early spring applications are shown in Table 10. Excessive early spring applications of nitrogen cause a surge of top growth in plants which makes the lawn look nice in the spring but can severely deplete the plants' energy reserves going into summer. Consequently, when summer stress periods occur, plants are weaker and less able to survive. By applying fertilizer in late October or early November (when top growth is minimal but soil temperatures are still warm enough for root absorption of nitrogen), plants resume growth and green-up early the following spring. The rapid rate of shoot growth associated with excessive early spring nitrogen applications is not as apparent with fall application.

Table 10. Benefits from applying nitrogen in fall rather than early spring

- Lengthened period of green in the fall.
- Earlier green-up in the spring without stimulating excessive shoot growth.
- Carbohydrate reserves (a measure of the energy stored in the plant and available for growth)
- Reduced incidence of summer diseases.

Phosphorus (P)

Phosphorus is important in stimulating early root growth and promoting early plant vigor. Phosphorus moves very little in the soil because most of it is bound tightly to soil particles. Soils naturally high in phosphorus generally provide sufficient phosphorus to sustain plant health and growth for many years without supplying additional phosphorus from fertilizers.

There are three reasons for correcting phosphorus-deficient soil prior to seeding. First, since phosphorus moves very little in the soil, it is desirable to mix the phosphorus throughout the root zone. This is relatively easy prior to seeding but more difficult after establishment. Second, seedling plants with newly developing root systems are most likely to be affected by lack of phosphorus. Third, mixing phosphorus into the soil (rather than applying it to the surface) reduces the chance for phosphorus to move into lakes and streams. Fully developed turfgrass root systems can absorb phosphorus from a much larger volume of soil, reducing plant deficiencies.

A soil testing laboratory can determine the current level of phosphorus in a particular soil. This inexpensive procedure is the best way to accurately determine the phosphorus requirements of a lawn. Remember, it is currently illegal to apply any phosphorus-containing fertilizer to a lawn area in Minnesota without verifying a need by a reliable soil test, such as from the University of Minnesota, or at the time of seeding or sodding. The only other exception is use by golf course personnel who have gone through a certification training program on the use of phosphorus fertilizer in golf course applications.

Potassium (K)

Potassium is important in the synthesis of some plant components and in the regulation of many physiological processes. Potassium deficiencies in lawns have led to increased incidence of turfgrass diseases and reduced tolerance to environmental stress.

Potassium is held on the surfaces of soil particles and moves little in most soils; however, it can gradually move out of the root zone in very sandy soils. Where soils are high in native potassium, supplemental potassium fertilization may be unnecessary; however, where soils are low in native potassium, supplemental applications are very important. Soil tests are essential to determine the potassium level of a soil and to develop a potassium fertility program.

Recently, slow-release K sources have become available. Their use is intended to provide K over an extended period of time so the plant can utilize the material as it becomes available. Potassium can leach down through the soil beyond the turfgrass root zone although it is less prone to leaching than N. These products can be particularly useful on sandy soils with relatively high leaching potential as only small quantities become available at any one time. This reduces the leaching potential and allows greater opportunity for plant use.

Other Essential Elements

Adequate levels of the other essential elements are usually present in Minnesota lawns. Where deficiencies occur, they are usually associated with extremely sandy, highly acidic, or highly alkaline soils. For most lawns, attention to nitrogen, phosphorus, and potassium is all that is required.

Soil Tests

Soil tests are necessary to establish the proper lawn fertility program for a specific site. Soil tests can be obtained by submitting a soil sample to the University of Minnesota Soil testing Lab or a private soil testing laboratory. Informational sheets and materials can be obtained through county Extension offices.

The proper ratio of nitrogen, phosphorus, and potassium to apply to a lawn can only be determined by soil testing. Since nitrogen can move rapidly out of the root zone with percolating water, soil tests for available nitrogen are not very meaningful and are generally not performed. Phosphorus and potassium move little in the soil and consequently soil tests will be valid for several years. The most important soil test is the first one to establish the base levels of P and K in the soil. Subsequent sampling may not be necessary for several years if phosphorus and potassium levels are adequate.

Lawn Fertilization and Water Quality

Improper management and use of turf fertilizers can contribute to pollution of both surface waters and groundwaters. Avoiding over-application or misapplication of these materials and basing lawn nutrient requirements on a reliable soil test are the first steps in responsibly using fertilizers to protect water resources. Combining appropriate landscape management practices with a modest turf fertilization program may further reduce potential water pollution. Following are some additional general fertilization practices that can reduce water pollution from fertilizers.

- Never directly deposit or inadvertently apply fertilizers into lakes.
- Fill fertilizer spreaders on a hard surface where spills can be cleaned up easily. NEVER wash fertilizer spills into the street or other hard-surface areas where fertilizer can enter storm sewers and ultimately surface water.
- Close the gate on the fertilizer spreader when crossing hard-surface areas or go back and sweep up the material for reuse.
- Never apply fertilizer to frozen ground.
- Grass clippings, leaves, and other plant debris should be removed as soon as possible from street gutters, sidewalks, and driveways. This plant material can be composted, used in the garden as a mulch, or disposed of through appropriate community services.
- When mowing lawns, do not direct clippings into the street or lake.
- Drop spreaders are more precise but slower than rotary spreaders. Near shoreline areas, apply fertilizer near the lake with a drop spreader to create a 'buffer' zone. Then you can fertilize the area away from the shoreline with a rotary spreader. Take the same precautions when using liquid applications.
- Avoid getting fertilizer into natural drainage areas or pathways on a property. These may not necessarily be hard-surface areas. Fertilizer can be carried directly into surface water before it has a chance to infiltrate into the surrounding turf/soil area.
- For shoreline areas, try to leave a buffer zone of unmanaged grasses, or possibly natural vegetation, around the shoreline. This natural area helps prevent erosion from adjacent shoreland, and may retain nutrients that would otherwise go into the lake.

Protecting surface water and groundwater is not something to be taken lightly. Neglecting lawn areas for fear of introducing nutrients and pesticides into water supplies is not a way to protect these resources either. Properly maintaining lawn areas with appropriate, but modest, use of fertilizers and pesticides can do more to protect water resources than to hurt them.

WEED MANAGEMENT

It has been stated many times that a healthy, vigorous lawn is the best defense against weed invasion. Indeed, weakened lawns and bare areas in the lawn are the most common reasons for increased weed presence. Knowing and understanding a lawn's weaknesses is the first step to managing the encroachment of weeds into the lawn. Weakened and bare areas can be caused by many reasons. Some of the more common ones are listed below:

- Grass species and/or varieties not adapted to the particular site conditions or imposed maintenance program.
- Damage caused by animals, diseases, insects or people.
- Damage due to environmental stresses such as drought, shade, heat, cold, and poor drainage.
- Misuse of fertilizers and pesticides.
- Improper mowing height and/or frequency.
- Overuse of the lawn area resulting in severely compacted and poorly aerated soils.

It is important to determine the reasons behind increased weed encroachment into the lawn before reaching for a herbicide to kill the weeds. Killing

the weeds without correcting the problem only invites continued and often increased weed problems. Sustainable lawn care practices revolve around good cultural practices that promote plant health. This helps create a vigorous lawn able to prevent any serious weed problems from becoming established.

In addition to having a working knowledge of sustainable lawn care practices and how they relate to weed management, it is good to know something about the weeds that may potentially invade a lawn. This becomes important when determining whether or not control measures are needed and when they need to be carried out. It is also important in determining the most appropriate herbicide product to use, should one be needed. Following is general information about the growth and habits of potential lawn weeds.

Weed Identification and Characteristics

Lawn weeds may be conveniently divided into two classes based on the way in which they emerge from the seed. Monocots emerge with a single seed leaf whereas dicots emerge with two seed leaves. Most monocot weeds found in turf are termed weedy grasses. Examples include crabgrass, annual bluegrass, tall fescue, and quackgrass. Dicots, on the other hand, are termed broadleaf weeds and include such plants as dandelion, clover, ground ivy (creeping Charlie), knotweed, and plantain.

Grassy weeds and broadleaf weeds are further divided into groups according to how long they live. Perennial weeds have a life of more than two years, though new seeds may be produced every year. Biennial weeds have a life span of two years, generally storing up food reserves in the leaves and roots the first year and producing flowers and seed the second. Annual weeds germinate from seed, grow, flower, and produce seed in less than one year. Summer annuals germinate in the spring and mature in the fall, whereas winter annuals germinate in fall or late winter and mature in late spring.

Effective control of weeds in turf is based on correct identification. Many books and charts are available to help identify common lawn weeds. For additional help in weed identification you can contact your local county extension office. There are a number of weed publications listed at the end of this section.

Methods of Weed Control

The most effective method of controlling lawn weeds is to maintain a dense and vigorously growing turfgrass cover. Weeds are often an indication of problems in the grass plant environment. Killing the weeds without correcting the underlying problem will lead to unsatisfactory results. For example, a problem with knotweed is usually an indication of severe soil compaction. Control of knotweed without correction of the soil compaction will only lead to sparse grass cover until the area is again invaded by weeds that grow in compacted soil.

Often, turf weeds can be controlled simply by altering the cultural practices to favor the grass plants rather than the weeds. Cultural controls may include raising (or lowering) the mowing height, changing the frequency of mowing, lengthening (or shortening) the period between irrigations, increasing (or decreasing) the application of fertilizer, or aerifying the soil.

Hand weeding or pulling weeds is also an effective way to eradicate weeds from small lawn areas. The best time to pull weeds is after a good rain or thorough irrigation. This control is very economical (but labor intensive). It avoids needlessly applying herbicides over the whole lawn for only a few weeds. There are several tools on the market that will aid in hand pulling weeds.

Chemical control

A combination of proper cultural practices plus prudent use of herbicides is sometimes necessary to control weeds effectively in turf. When herbicides are used, container labels must ALWAYS be read and carefully followed.

The first step in using any pesticide product responsibly, including herbicides, is to follow the label directions exactly as stated on the product container. The label provides necessary information regarding proper product application and container disposal procedures. Labels are legal documents which are enforceable by law should the product be used in a manner inconsistent with directions.

Identify weeds to determine whether there is a need for a herbicide. You may find that only cultural practices need to be corrected. As with fertilizers, extreme care must be taken to prevent the direct application of herbicides into surface water areas.

Herbicides are subject to a number of different fates once they are applied to a turfgrass area. Some of them may be broken down by sunlight, the action of soil microbes, chemical action, or a combination of these processes. Others may volatilize back to the atmosphere, be absorbed by the plants, or stick tightly to soil particles limiting further movement in the soil. Herbicides may be subject to several of these different processes but some may be more important than others. Break-down processes and plant absorption are particularly important because they account for removal of pesticides from the environment.

Types of herbicides

Preemergence herbicides affect germinating seeds. To be effective, the herbicide must be applied two weeks before you expect weed seeds to germinate. Consequently, preemergence herbicides are most effective against annual weeds. To control summer annuals such as crabgrass, apply preemergence herbicides between May 1 and May 15 in a typical year or once soil temperatures are consistently in the 55-60º F range. Depending on where you are located in the state, these dates may need to be adjusted earlier or later to be most effective.

Postemergence herbicides are used to kill weeds after the weed plants are up and growing. To be effective, most postemergence herbicides must be absorbed through the leaves. Postemergence herbicides are most effective if applied when weeds are young and growing vigorously, or in the fall when perennial weeds are storing food in their roots for the next year.

Selective postemergence broadleaf herbicides are usually used to control annual, biennial, and perennial weeds because they will kill many broadleaf plants without damaging grass plants. These herbicides can severely damage or kill trees, shrubs, flowers, and vegetables; thus, they must be used with great care around these plants.

Postemergence broadleaf herbicides may be applied any time the weeds are actively growing, but most effective control is obtained when applied in early fall (September 15 to October 15) or in spring (late April to early June). Fall is preferred over spring due to the food storage process of plants and the reduced possibility of damage to flowers and other vegetation. Postemergence broadleaf herbicides should be applied when the air temperature is 60-80º F, when there is no wind, and when there is no rain in the forecast for 48 hours. For some weeds, repeated applications at 10 to 20 day intervals may be required for control.

In the case of postemergent broadleaf herbicides, it is usually unnecessary to thoroughly drench an area with the herbicide solution to achieve satisfactory weed control. This may be wasteful of both water and herbicide and moves the herbicide beyond the plants and into the soil where it may be more prone to leaching or affecting non-target plants. Spraying only to wet the foliage is usually sufficient to be effective.

Where only a few scattered weeds exist, or where weeds are confined to small areas, hand removing or “spot” treating with an appropriate herbicide may be the most appropriate control measure. You may need to apply preemergent herbicide only in those areas where crabgrass was found last year. These might include areas bordering sidewalks, driveways, or curbs. Crabgrass may not be a problem in the remaining lawn area where it is cooler and the other lawn grasses are more competitive.

It is also important to remember that an occasional weed is not uncommon in lawns. Hand removal and tolerance of a few "weedy" plants, while maintaining an otherwise healthy lawn can significantly reduce weed control inputs.

Nonselective postemergence herbicides kill most green plants, both desirable and undesirable. These herbicides are used to control perennial grassy weeds that are not affected by selective broadleaf herbicides. Spot treat infested areas using only enough product to wet the foliage. It is not necessary to thoroughly drench the area for satisfactory control.

Herbicide selection

The following postemergence herbicides provide good to excellent control of most common broadleaf lawn weeds when used according to label directions. Note that repeat applications may be required to achieve the level of control desired. Early fall is the best time to apply these materials for control of winter annuals and perennials. Spring is the best time for summer annuals. Best results occur when the plants are actively growing and not under heat or drought stress. It is often beneficial to water thoroughly a day or two before applying these products to make sure the plants are actively growing.

A. 2,4D; MCPP; MCPA; 2,4-DP; dicamba. Two or three of these are often mixed together to make what is termed a two-way or three-way product. *Trimec* is a very common three-way product containing 2,4-D, MCPP and dicamba.

Dicamba is potentially dangerous to trees and shrubs because it can move in the soil and be taken up by tree and shrub roots. Therefore, use extreme caution when applying any herbicide mixtures containing dicamba near root systems of trees, shrubs and other landscape plantings. Also, avoid applica tion where mulches have been used around trees and shrubs. The tiny feeder roots will be actively growing into the mulch and can readily take up dicambia and/or be directly killed by the herbicide. Compacted soils where there is extensive shallow root growth of trees as well as grass, is another area where unintended injury from the use of dicamba can result to trees, shrubs and other landscape plantings.

B. Triclopyr in combination with any of the above or triclopyr by itself - Note if product has good activity on some of the more difficult weeds such as wild violets, creeping Charlie, white clover, oxalis (yellow woodsorrel) and chickweed. Fluroxypry is a similar product with similar effectiveness but not yet available in homeowner formulations.

C. Carfentrazone or sulfentrazone combined with one or more of the ingredients in A-new products often added to these other ingredients providing quicker effectiveness; currently their availability is limited in the homeowner market.

The following preemergence herbicides provide good to excellent control of annual weedy lawn grasses and some annual broadleaf weeds. In general, these materials should be applied a couple of weeks prior to expected germination of annual weed seeds. Reseeding can follow siduron applications immediately while reseeding must be avoided for 2 to 3 months with all of the other products mentioned. Usually the product label will provide information on how soon grass seeding can occur after application of the product.

A. Because of their relatively consistent performance, the herbicides benefin, benefin + trifluralin (trade name 'Team'), pendimethalin, prodiamine have been the mainstay of home lawn preemergence herbicides for many years. They are available under many different trade names.
B. Other commonly available preemergence herbicides for home lawns include bensulide (trade name Betasan), dithiopyr (trade name Dimension) and siduron (trade name Tupersan).
C. A recent addition to the preemergent herbicide market is the natural organic material known as corn gluten meal (cgm). Researchers at Iowa

State University determined that this material did have some preemergence herbicide properties on warm season annual grasses such as crabgrass. CGM is a by-product of the corn processing industry containing 10% nitro gen. Therefore, its use is much like an organic weed and feed product. While its control is usually not at the level of many of those mentioned above, at least initially, it is one of the only known organic materials to have relatively good preemergence weed control properties. It is gradually becoming more available through retail garden product outlets. This material should not be used at the time of seeding as it will injure desirable grass seeds equally as well as weed seeds.

Postemergent herbicides are usually not recommended for annual grasses because they're only effective when plants are very small. Typically these weeds are too large for good control by the time they're obvious in the lawn. If there are only a few grassy annual weeds they may be pulled when the soil is moist. Dithiopyr also has some postemergence activity against very small, newly emerged grass seedlings. This can provide some additional control for plants that may have already emerged just before a preemergent herbicide was applied.

Perennial weedy grasses such as creeping bentgrass, quackgrass, brome grass or tall fescue are frequently found in home lawns. Since these grasses are biologically similar to the lawn grasses, there is no way to selectively remove them from the lawn without also killing the desirable grasses. When it is desirable to control these weeds regardless of whether the other lawn grasses are killed, one must use a non-selective herbicide such as glyphosate (trade names include Round-up or Kleenup) or glufosinate-ammonium (trade name Finale). Treat only the weedy areas to minimize the amount of other grasses killed by the application. These materials are usually most effective with air temperatures-between 50 degrees F to 80 degrees F., little to no wind, and weeds are actively growing. With either of these two materials, reseeding or resodding can usually be done within a week or two after application as neither product leaves a soil residue to interfere with new seed or sod establishment. For specific requirements regarding length of time to wait, always consult the product label.

Application timing

To minimize adverse environmental impacts while effectively eliminating weeds, proper timing of herbicide application is crucial. When weeds are quite large and mature, greater amounts of herbicide are usually needed and may not be effective. For example, it is relatively easy to control small, first-year dandelion rosettes with a minimal amount of herbicide. Larger, older dandelion plants have a greater capability to outgrow, and hence recover from small doses of herbicides. Where appropriate, small dandelion rosettes can be effectively hand removed and eliminated if most of the root system is removed.

Fall is the best time to control perennial broadleaf weeds. At this time of year (mid-September through mid-October), these plants are storing carbohydrates for winter, are actively growing, and will readily take up the herbicide. Often, a one-time, application of an appropriate herbicide will be effective. Since much of the other landscape plant material is either going dormant for the winter or has been removed from the garden and flower beds, there is less chance for off-target plant injury. However, that does not give one license to be careless.

Post-application irrigation

Preemergent herbicides, typically used for controlling crabgrass and other annual weedy plants, must be watered into the soil to be effective. They affect the seed as it begins to germinate, before the plant emerges from the ground. Depending on the soil type, 1/4 to 1/2 inch of moisture should be applied following application of these products. This not only puts the product where it will be the most effective, but moves the material far enough into the soil so it will not be carried away in run-off. Do not water for several days after postemergence applications. It will wash the herbicide off the weeds usually reducing its effectiveness.

Remember after weed problems have been reduced, proper lawn care practices will encourage vigorous, healthy grass plants, making future herbicide applications minimal or even unnecessary.

MANAGING DISEASES AND INSECTS

Properly maintained and healthy turfgrass will tolerate the presence of low levels of pest populations without suffering permanent damage. Healthy turfgrass usually recovers more quickly from insect and disease infestations. However, there may be times even in healthy lawns where some pest control is needed to prevent significant damage.

The visual symptoms or signs of lawn problems are often similar and can be easily confused. Poor cultural practices, environmental factors, and pest activity can produce symptoms that appear the same. The first step to solving any problem is proper identification. Correct and timely identification can not only save your lawn but your time, money, and unnecessary use of pesticides.

Each disease or insect has symptoms that can be associated with it; each also needs a specific set of circumstances for those symptoms to occur. These circumstances involve a host (in this case a turfgrass plant), the insect or disease itself, and favorable environmental conditions for the insect or disease to develop.

Reducing insect and disease activity begins with good cultural practices including mowing, fertilization, irrigation, thatch control, and lawn establishment. If an insect or disease is found to be causing serious turf damage, a proper control method can be selected. This may or may not involve the use of a pesticide. Pesticides need only be applied to those areas where the pest is evident instead of to the whole lawn.

Diseases

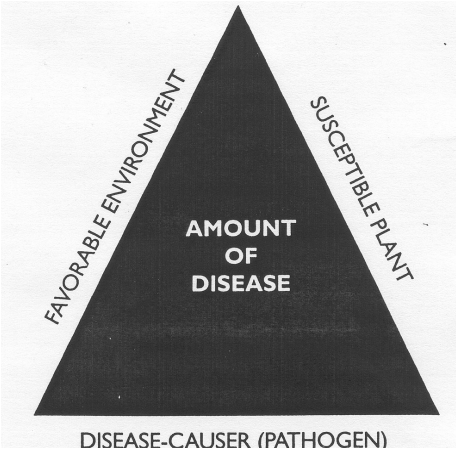
Diseases are defined as abnormal alterations of the internal (physiological) and/or external (morphological) development of the plant. In most cases, infectious microorganisms, called pathogens, enter the plant causing infection and symptoms to occur. Pathogens are considered the causal agents of disease.

Fungi

In turfgrass, the majority of disease infections are caused by microscopic organisms called fungi. Fungi are plants that lack chlorophyll and are incapable of manufacturing their own food through photosynthesis. Fungi produce spores (similar to seeds) and other structures that grow and penetrate turfgrass plants, often through damaged areas. Once penetration has occurred, the contents of the host cells are consumed and tissue function is disrupted. Therefore, fungi are said to be living on the organic matter of the grass (host) plant

The plant disease triangle

For a fungal disease to occur, three factors must be present. There must be a causal agent, a susceptible host, and a favorable environment. This three-sided relationship has been described as the plant disease triangle. It is especially important to note that all three factors must be present at the same time for infection to take place. Prudent plant health care would suggest that anything that disrupts this three-sided relationship will prevent a fungal disease from becoming a significant problem.



Plant Disease Triangle

Cultural practices contributing to fungal diseases

Cultural practices can contribute to the onset of fungal diseases. Variety selection, watering, mowing, and fertilization practices are especially important.

Disease prevention at seeding, overseeding, or sodding time is much easier and also less costly than dealing with an infection in progress. The time invested in the selection of disease-resistant turfgrass species and varieties will pay for itself many times over the life of your lawn. The use of improved grass mixtures is one of the best ways to prevent disease infection.

Fungi require moisture (in the presence of favorable temperatures) to develop. Many fungal diseases first become active during periods of prolonged wetness or heavy dew. This condition for fungi development is greatly accentuated by poor air circulation, shade, or cloudy weather. Careful attention to site selection, including tree placement, removal, or pruning, can have a continuing effect on the presence of disease. By the same token, a well-planned watering schedule can greatly reduce the length of time the grass plants are wet. Watering during early morning is better than late evening; as a general rule, deep, infrequent watering is better than shallow, frequent watering. However, where there is an urgent need for water, it is usually more important to apply the water regardless of time of day.

Fertilization is another cultural practice associated with fungal disease. Turfgrasses lacking nutrients, especially nitrogen, will be weak and susceptible. In some cases, even if disease is present, the grass plant can out-grow the disease by growing faster than infection can occur. Unfortunately, turfgrass that is improperly fertilized or over-fertilized can have lush succulent growth that is also more susceptible to some fungal diseases.

It is important to maintain a mowing height appropriate for the species. Mowing heights can be raised during environmentally stressful periods or disease occurrence. Kentucky bluegrass/perennial ryegrass lawns can be maintained at 2-1/2 to 3 inches while fine-leaved fescues should be a little higher, 3 to 3-1/2 inches during

Fungicides

The first step in responsible use of any pesticide product is to follow the label directions exactly as stated on the product container. The label provides necessary information regarding proper product application and container disposal procedures.

Sometimes disease occurs in spite of our close attention to the cultural controls available. If infection is present to a degree that will cause long-term damage to the turf, or is aesthetically unacceptable, the use of fungicides may be necessary.

Fungicides are chemicals used to control plant diseases. Fungicides can kill or, in most cases, retard the development of the disease. Fungal pathogens are hard to control because they are one plant living on or inside another.

Before applying fungicides to a lawn area, be sure that the apparent damage symptoms are being caused by a disease. Accurate diagnosis may require the assistance of a trained turfgrass professional. If a disease pathogen is found to be causing serious turf damage, then a proper control method can be selected. This may or may not involve the use of a fungicide.

Fungicide applications to lawns and general turf areas are usually infrequent and, when necessary, should be applied only to those areas affected. Immediate and correct diagnosis is required as many fungal diseases progress rapidly and then require high application rates and more frequent applications. Fungicides applied to a pathogen already affecting a plant are called contact fungicides. Fungicides applied before the pathogen has affected the plant are called residual fungicides. Some fungicides are a combination of both.

Properly timing fungicide applications is crucial to the overall effectiveness against the pathogen and to minimize adverse environmental impacts. Treating disease problems at very early stages of infection is more prudent and may require less total fungicide than attempting treatment of large, heavily infected areas. Normally, it is only under extraordinary conditions that a fungicide is recommended for a home lawn situation, especially under low maintenance conditions.

Insects

The number of identified species of insects has been estimated at between 800,000 and 1,000,000 of the speculated two to five million total insects. Of this tremendous number all but several hundred are considered to be beneficial. Of these, very few are serious pests of lawns.

Not all "insects" that you see in your lawn are really insects. Centipedes, millipedes, mites, spiders, and ticks are related to insects because they have an outer shell (exoskeleton) and jointed legs. Research has shown that there can be as many as 5,000 insect and insect relatives in a square foot of soil three inches deep.

Life cycles

The better you understand the insect pests in your lawn the better chance you have of managing them. There are two primary life cycles of insects that affect turfgrasses.

In complete metamorphosis the cycle includes an egg, larva, pupa, and adult stage. All young insects undergoing complete metamorphosis are termed larvae. Some larvae are also called caterpillars, maggots, or grubs. It is the adults that have the wings, legs, antennae, and reproductive organs. Also, larvae and adults of a species may feed at different sites on the same plant or different plants altogether. Examples of insects that undergo complete metamorphoses are beetles, butterflies, bees and ants.

In incomplete metamorphosis the cycle includes a nymph and an adult. Both stages look similar and do the same kind of damage. Nymphs and adults usually feed at the same site on the plant. Examples include grasshoppers, crickets, and boxelder bugs.

Insect Damage

Much of the insect damage done to your lawn happens during the larval or nymphal stage of the cycle. Many insects like webworms, cutworms, armyworms, grasshoppers, and beetles do damage by chewing on leaves, stems and roots. Other insects use sucking mouth parts to rob the plant of nutrients necessary for growth and development. Examples of these insects include aphids, leafhoppers, mites, and chinch bugs.

Just because you notice an insect does not mean it is a pest or that control is necessary. In our area, insect pests are usually less of a problem than weeds or diseases. A healthy, well-maintained lawn can often withstand significant numbers of insect pests.

Observation

Observation is an important step in preventing insect damage. Keep your eyes open while mowing, watering, and using your lawn. Make it a habit to observe your turf regularly for the presence of insect adults. Large numbers of moths or beetles can be an indication of future problems.

When symptoms do occur, study them carefully. Chlorosis, (yellow tissue with green veins), dieback, wilting, or stunting can also be caused by disease, drought, compaction, or fertility problems.

Inspect the soil surface, thatch layer, and root zone for evidence of pest activity or for the insects themselves. Identify the insect and its stage of development. Remember most insects are more easily controlled in the early stages of their juvenile form.

Determine if the problem is significant enough to warrant control. Your local Extension educator or garden center operator may be able to help you based on the number of insects you observe, the extent of damage, or other reports of damage in your area.

Economic pest damage threshold levels

Although not used extensively with turf pests, the concept of threshold values for economic damage levels has been applied to some turf insect pests. This concept recognizes that a healthy turf can withstand a certain amount of insect damage without causing permanent damage. Even though some grass plants may be lost to the pest, a healthy turf has a relatively high degree of recoverability. After an attack, the remaining turf plants respond by quickly filling areas thinned or left open by the pest. Following are some suggested threshold values for three common upper midwest turf insects.

White grubs are the larvae of the common May beetle or June bug. Damage caused by these root-feeding pests appears as irregular patches of yellowed or dead grass. Heavy infestation will loosen the sod so much that it can be easily rolled back. This type of damage becomes very apparent in July and August and is caused by large (third-year) grubs. Damage caused by the smaller first- or second-year grubs is much less apparent, often making turf look wilted and water-starved.

Checking for grubs should be done from mid-June through the middle of July. Look for them by rolling back the turf from a one square foot area of suspected white grub damage. The very small first-year grubs are difficult to find and damage is relatively unnoticeable. Grubs about 1/2 inch in length are probably second-year grubs. Damage from second-year grubs is usually more noticeable. The best time to control them is before significant damage occurs. Large, third-year grubs can cause extensive damage and control may not be warranted or practical. Therefore, so it's important to control them before they reach that stage. When scouting, if two to five grubs (usually curled up in a "C" shape) are found per square foot, control may be needed. Fall treatments are ineffective as grubs move down into soil for the winter.

Bluegrass billbug. If you've had a history of problems with this pest and you know what to look for (long-snouted, gray-to-black beetles with tapered abdomens, and about 1/4 inch long), you may be prepared and able to treat the adult females during May when they are laying their eggs. This is the best time for control; however, it's also possible to control the immature larvae as they feed on the roots. To control the adults, apply an appropriate insecticide about 10 days after adults are sighted (about mid-May). As they mature, the small, plump whitish larvae eventually move from grass stems down into grass roots. If there are 10 larvae per square foot or more, control may be needed. Treatment is not effective after late July or early August as larvae move one to two inches into the soil to pupate.

Sod webworms are the larvae of adult moths, which are frequently called lawn moths. They feed on grass leaves at night and hide in silk-lined tunnels or burrows at night. Most of the damage is caused by the second generation. Check for them by flooding the suspected area with water to force worms to the surface for counting. This is best done in June and again in early August as there are two generations per year. If 15 or more worms per square yard are present, control may be necessary.

> (See Extension publication"Managing Lawn and Turf Insects" for a summary of the insect pests affecting lawns in this region along with appropriate control measures.)

Insecticides

The use of insecticides is necessary when damage from insect pests threatens the survival of your lawn. As with all pesticides, careful attention must be directed to the safety and application information on the label. Insecticides also have the potential to cause harm to bees and other pollinating insects, earthworms, and beneficial soil insects. The product selected should have the least toxic effect on the environment and only be used in those areas where significant potential damage exists.

Those materials used for controlling soil- and thatch-inhabiting insects usually require some type of watering following application to move the product into the thatch and soil area. This puts the product where it will be the most effective, reduces the chances of it being carried away in a run-off, and potentially reduces exposure to the material. While thatch can facilitate tie-up of these materials and potentially reduce their effectiveness, it can also shorten their persistence in the environment.

Other controls

One of the best times to consider insect pest control is during overseeding, seeding, or sodding. Recent plant breeding has produced turf cultivars with the presence of nonpathogenic (not damaging to plants) fungi called endophytes. The presence of endophyte fungi have significantly improved resistance to webworms, billbugs, and chinch bugs.

At present endophyte presence is primarily in ryegrass and some fescues. However, research is being done with the other major cool-season grasses to determine its presence or how it can be transferred to the desired grass species.

Organic, natural, and biological controls are receiving increasing attention in the research world. As these methods become effective they will provide a valuable resource in the suppression of insect pest problems. One of the most promising controls involves the application of insect pathogenic nematodes for the control of cutworms and sod webworms.

RESOURCES

University of Minnesota Extension Service Publications

Master Gardeners receive many of these publications as a part of their training or Core Course. New publications are continually added to the Distribution Center. The most up-to-date listing is available online at http://www.extension.umn.edu. Click on Publications, or search the site for publications of interest. Many of these fact sheets can be read online and are also available from county extension offices. Longer publications or those containing many photographs or illustrations may not be available online. Master Gardeners should order publications through their home county extension office. Public orders may be placed by calling: 1-800-876-8636 (outstate) or 612-624-4900 (local).

BU 3703	Lawn Weeds and Their Control
BU 5726	Turfgrass Management for Protecting Surface Water Quality
FO 3338	Fertilizing Lawns
FO 3386	Lawn Diseases
FO 3914	Lawn Renovation
FO 3915	Lawn Clipping Management
FO 1008	Managing Lawn and Turf Insects
FO 6551	Responsible Fertilizer Practices for Lawns
FS 1114	Ground Covers for Rough Sites
FS 1123	Thatch Control in Lawns and Turf
FS 1137	Weed Control in Lawns and Other Turf
FS 2364	Watering Lawns and Other Turf
FS 2923	Preventing Pollution Problems from Lawn and Garden Fertilizer
FS 3034	Turf Patch Diseases
FS 5775	Seeding and Sodding Home Lawns
MI 0488	The Home Lawn
MI 3821	Fertilizing Garden and Landscape Plants and Lawns

Yard and Garden Briefs

Annual Bluegrass
Black Medic
Chickweed
Choosing a Lawn Care Company
Clover, How to Grow It/How to Eliminate It
Controlling Crabgrass
Creeping Bentgrass
Creeping Charlie
Cultural Practices to Help Manage Disease Problems in Home Lawns
Dandelion
Fairy Rings
Growing a Lawn in Shady Places
Leaf Spot and Melting Out in Turf
Moss in Lawns
Nightcrawlers
Perennial Grass Weeds in the Lawn
Plantain
Powdery Mildew in the Home Lawn
Prostrate Knotweed & Its Control
Prostrate Spurge
Pythium Blight of Turf
Sandburs
Seeding or Sodding the Home Lawn
Shepherd's Purse
Snow Molds in Lawns
Thistle Control
Yellow Nutsedge
Yellow Woodsorrel
Zoysia

Some helpful University of Minnesota websites:

Sustainable Urban Landscape Information Series (SULIS)
http://www.sustland.umn.edu

Turfgrass Science and Management Program
http://www.turf.umn.edu

Extension publications on lawns and lawn care
http://www.extension.umn.edu/topics.html?topic=5

Links through the Yard and Garden Line website accessed from the U of MN Extension home page
Insect journal
http://www.extension.umn.edu/projects/yardandgarden/EntWeb/Ent.htm

Plant Disease Diagnostics
http://www.extension.umn.edu/projects/yardandgarden/diagnostics/

chapter 9

indoor plants

chapter 9

indoor plants

INDOOR PLANTS

by Deborah Brown, Extension Horticulturist

INTRODUCTION

You could say there's no such thing as an "indoor plant." Most plants we grow indoors as houseplants originated in the tropics or subtropics or were developed from plants native to those areas. So our houseplants -- or their ancestors -- didn't experience wide temperature fluctuations from one season to the next.

Our homes are similar to the tropics and sub-tropics in that regard; air-conditioning and central heating keep most interior environments relatively constant year-round.

Regardless of whether you're deciding on a tree or shrub for the landscape around your home, or a houseplant for your living room, picking the right plant for the site will go a long way in determining how successfully it will grow.

It's smarter -- and certainly easier -- to choose houseplants with environmental requirements similar to what you can provide in your home or office, rather than trying to alter your home or office to suit the plants. However, minor modifications such as the addition of supplementary lighting can often make a world of difference.

LEARNING OBJECTIVES

After studying this section, Master Gardeners will:

1. understand basic growth requirements of houseplants.
2. understand how various aspects of light affect plant growth.
3. know how to water indoor plants in containers.
4. become familiar with cleaning and grooming houseplants.
5. know methods of controlling common houseplant insect pests.
6. describe how environmental factors affect houseplants.
7. be able to use this information to diagnose houseplant problems.

ENVIRONMENTAL FACTORS AFFECTING PLANT GROWTH

- light
- water
- soil
- nutrients
- temperature
- humidity
- ventilation

Problems of excess, insufficiency, or quality in any of these areas can interfere with good plant growth indoors. Try to duplicate the plant's natural growing conditions as much as possible. For instance, give a cactus lots of light but be careful not to over-water it. You needn't worry about humidity levels because cacti evolved under harsh, arid conditions.

Some plants, such as scheffleras and weeping figs, grow outdoors as trees in full sunlight while others, such as Swiss cheese plant, pothos, ferns and philodendrons, are understory plants in their native habitats, adapting to light that's filtered through the branches of taller trees. Because of their more modest light requirements which are easier to meet, these understory plants make up the bulk of our most popular commonly grown houseplants.

Light

Light is the most essential factor for good houseplant growth, as well as the most commonly limiting factor. It's needed for **photosynthesis**, whereby the plant converts light energy to food energy necessary for growth and day to day functioning. The way plants grow and develop as well as how actively they grow depends on the amount and quality of the light they receive.

- Without adequate light, plant growth will be *etiolated* (stretched out, tall, and spindly).
- Pigments responsible for pink, red and purple leaf color are directly related to light levels. The brighter the light, the more color develops.
- Light is also required to produce chlorophyll; the green part of the tissue that is responsible for photosynthesis.
- Plants appear to grow towards the light, and must be turned regular ly. This response is called *phototropism.*
- Flowering often depends on light levels and daylength.

The definition of light includes three separate areas, each of which is important for healthy plant growth. They are: *intensity, duration* and *quality*.

Intensity: How bright is the visible light?

Light intensity is measured in footcandles, a unit of measurement that represents the amount of light cast by one "standard" candle at a distance of one foot. Although it seems an arbitrary measure, footcandles can be read by special light meters that are used by interior landscapers.

Light intensity influences the manufacture of food energy, stem length, leaf size and color, and flowering. Houseplants can be classified according to their light needs as high, medium, or low light plants, though there isn't always good agreement on exactly which category some plants fall into.

The intensity of light a plant receives indoors depends upon how bright the light source is, as well as how close the plant is to that light source. Light intensity decreases rapidly as you move further from the source of light, particularly if it is a point source of light, rather than diffused.

The direction the windows in your home or office face will affect the intensity of natural sunlight that plants receive. Southern exposures produce the most intense light. Eastern and western exposures receive about 60% of the intensity

of southern exposures, while northern exposures receive only 20% of the light intensity found in a south-facing window. (A southern exposure also generates the most heat, followed by western, then eastern exposures. Northern exposures are coolest.)

Several other factors can influence the intensity of light that comes through a window. Sheer curtains or film that filters UV light, trees that leaf out in spring but are bare all winter, other buildings close by, weather (especially wet and cloudy), seasonal variations that affect the sun's angle, and window pane cleanliness all have an impact on light intensity. Low-e glass, which is installed to keep homes warmer in winter and cooler in summer also reduces light intensity by a slight amount -- though usually not enough to have much impact on houseplants.

Reflective (light colored) surfaces inside a home or office help increase the intensity of light available to plants. Flat or matte white paint on the walls works best to reflect light. Dark or patterned surfaces absorb light and decrease overall light intensity.

Though it's less common, too much light can be as harmful as too little light for houseplants. Often it is accompanied by excessive heat. If a houseplant gets too much light (and heat) its leaves may fade or sunburn, turn brown, then die. You may have to protect some plants from too much sunlight during the bright light months of spring and summer. These symptoms can also occur when plants are too close to an "artificial" light source.

Duration: How long a period of light does the plant experience during every 24 hour period?

Light duration is important because longer hours of illumination can be used to compensate for lower light intensity. Increasing the length of time a houseplant is exposed to light each day might allow it to make sufficient food to survive and/or grow. However, most plants require a period of at least three or four hours of darkness every night in order to develop normally, so they should not be lit twenty-four hours a day.

In theory, a houseplant that needs an average of 80 footcandles of light over a twelve hour time frame would do just as well with an average of 60 footcandles for sixteen hours. (80X12 = 960 footcandle/hours, 60X16 = 960 footcandle/hours also.)

Light duration is also involved in triggering flowering in some houseplants. Poinsettia, kalanchoe, and Christmas cactus bud and flower when daylength is short (11 hours of daylight or less). Most houseplants are indifferent to daylength, but spider plants also send out tiny white flowers and new little plantlets in response to short days.

Quality: At which wavelength or part of the spectrum does the light occur?

In this case, "quality" does not mean judging whether the light is good or bad.

When it comes to light quality, natural daylight supplies everything a plant needs and more. The trick is to come up with satisfactory light quality to supplement or replace sunlight in situations where natural light levels are too low to sustain good houseplant growth or maintenance.

If electric lights are to be used for growing plants, the quality of light they emit (wavelength) must be taken into consideration. For photosynthesis, plants require light mostly in the blue and red spectrum. Whatever amount of natural daylight reaches houseplants is usually a sufficient source of red light without adding any supplementary light from the red spectrum.

Incandescent lights are inexpensive and easy to place, but not a good choice. They're an unsatisfactory light source for houseplants because they produce a great deal of heat relative to the amount of light they give off, and they're completely lacking in the blue spectrum. They emit light in the red and far-red end of the spectrum only.

Additional lighting may be supplied by fluorescent lights. These lights are cool enough to position quite close to houseplants, typically about a foot away. Some special fluorescent tubes do add red light, but it's usually at the expense of light intensity. Much of what you gain on one hand, you lose on the other. The real benefit of fluorescent lights is that they emit light from the blue spectrum.

Cool white fluorescent lights produce more blue light and are deficient in red light. Warm white or "natural daylight" fluorescent lights are adequate in the blue spectrum, but provide slightly more red light. They're also more flattering to human skin tones.

Using supplementary lighting:

- Use cool white fluorescent lights alone or combined with warm white (also called "natural daylight") fluorescent lights. Cool white lights are no longer manufactured, but there are still some available.
- Special fluorescent "grow tubes" are fine, but cost more than cool white or warm white fluorescent lights. You can also buy metal halide or high pressure sodium bulbs that are long lasting and use very little electricity, but they cost $200 and up, depending on the size you choose.
- Run lights 12 or more hours daily if plants receive little or no natural day light, or use them early and/or late in the day to supplement available natural light.
- Position lights 12 inches above houseplants (or to the side of them, if you hang the tubes vertically).

Other strategies to use when available light is low:

- Choose "low light" plants such as Chinese evergreen, snake plant, heartleaf philodendron, Janet Craig dracaena, or pothos.
- Rotate plants into brighter locations for several weeks at a time to give them an energy boost.
- Put plants outdoors in a sheltered but bright location during the summer months.

Take Care of A Plant's Roots and the Top will Take Care of Itself!

Watering

The most common question home gardeners ask is, "How often should I water my plants?" The answer is not an easy one. It is determined by the type of plants being grown, differences in soil or potting medium, and the sizes and types of containers they're grown in. The problem is compounded by plant care tags that say "keep evenly moist," a statement that is open to all kinds of interpretation ....and misinterpretation! WHAT DOES IT MEAN?

Environmental influences also play a key role, and they change from day to day as well as from one season to the next. Is the weather sunny or cloudy? Is the air humid or dry? Are there fans moving the air around? Are either the furnace or air-conditioner running? All these factors influence how rapidly houseplants take up and lose moisture, and how soon they'll need their supply replenished by watering.

Problems that arise when houseplants are over or underwatered include:

- Lower leaves yellow and drop; scattered leaves may turn yellow, too, if the plant is over-watered. This is because the excess moisture has resulted in roots rotting.
- *Oedema* (corky bumps where cells have burst) can develop on the under sides of leaves, when plants are kept too moist, especially in a cool or

humid place. This tends to show up primarily on plants with thick or succulent foliage.

- Many adventitious roots can grow on stems when soil is constantly saturated. Jade plants are notorious for this. We feel it's the plant's attempt to get enough oxygen to the root area.
- Leaves dry when roots rot and can't deliver water to the foliage; the plant may wilt even though it sits in moist soil. Rotted roots simply aren't functional.
- Dry or brown tips and margins develop when soil is kept too dry. This condition is made worse by interaction with fertilizer salts in soil.
- Allowing houseplants to wilt, then snap back when watered takes a toll on the foliage. You may not see injury the first time, but if it happens repeatedly, leaves will begin to brown and die.

Suggested safe watering methods: Water when houseplants need to be watered, not just regularly by the calendar. Never wait until you see them begin to droop. Here are ways to tell when a houseplant needs water:

- Feel the soil. The larger the container, the deeper you should probe the soil. Most plants should feel dry a little below the surface. Never water if the soil surface feels moist. (except for cyperus species, which are aquatic rushes.)
- Lift the container to feel its weight right after you water. Then lift it every few days and water when it feels lighter.
- Become sensitive to slight color changes in foliage; leaves change from fresh green to a duller, greyish green before they lose turgidity and wilt. The ability to detect this subtle change prior to wilting is a skill you can learn by observing your plants closely every day.

Always water thoroughly so water drips through the drain hole, regardless of houseplant type. Spill out any water that collects in the tray or saucer after a few minutes. This flushes excess salts (fertilizer residue) from the soil. It also guarantees that the bottom 2/3rds of the pot receives sufficient water.

If you allow the pot to sit in that saucer or tray of water, eventually the moisture will all wick back into the soil. This would interfere with the soil drying and allowing oxygen into the tiny spaces that open up as water is used. It would also wick the flushed fertilizer residue back into the soil, rather than getting rid of it.

Choose containers with drain holes or **double pot** your plant so the inner pot can drain into a larger outer pot where it won't be wicked back into the soil. The inner pot must be small enough to sit on several stones or potsherds inside the larger container. You can disguise the fact that plants are double potted by covering the soil and space between the inner and outer pots with the same kind of peat moss used to line hanging wire baskets.

Use room temperature water; cold water can injure roots and leaves. (Remember, most indoor plants originated in the tropics and sub-tropics where rains are never icy cold.)

Avoid softened water if possible (most water softeners add sodium or potassium salts). If you must use softened water, water very thoroughly each time. Hold your plant over the sink or washtub, and allow water to flow freely out the drain holes. That way, even though you're adding some salts when you water, you're also leaching some through the soil so there's little net gain. Be sure to cover the drain in your sink or tub with a piece of fine mesh screening to trap any soil particles that might wash out of the pot.

It is okay to "bottom water" by setting a pot in a tray of water and allowing it to wick moisture through the drain holes. However, you must remove the pot once the soil surface feels moist. You should also water it thoroughly from the top at least once every four to six weeks to help flush soluble salts from the soil. Many "self-watering" containers depend on bottom watering.

Potting Soil

Soil must be well-aerated. Don't use garden soil to grow houseplants. Even if you pasteurize it, it usually becomes compacted after repeated watering, so it must be mixed with peat, vermiculite, perlite, polystyrene beads or other soil amendments to insure proper aeration and drainage. (Soil that has not been pasteurized might also contain disease organisms, insects or insect eggs, and weed seeds.)

It's best to purchase good potting soil from a local florist or garden center or mix your own, using peat and vermiculite or a combination of peat, vermiculite and perlite, or a mix that also includes pasteurized soil and sand, and possibly well broken-down compost.

The type of potting soil you buy or mix should be based partly on how much drainage or water retention you are looking for. Plants growing in "soilless" mixes that have no real soil in them, only peat and other materials, require more frequent fertilizing than those growing in mixes containing soil. They may also run low on trace or minor nutrients which will need to be replenished.

A potting soil that is mostly peat will be difficult to water if it is allowed to get too dry. If it's dry when you buy it, add some hot water to the bag, then seal it closed for several hours. When you open the bag, your potting soil will be damp and easy to work with.

If you wait too long to water a plant potted in a peaty soil mix, chances are the water will just rush down cracks in the soil or along the insides of the container walls without truly wetting the root ball. To overcome this problem, set the container in a sink or basin in several inches of lukewarm water for as long as it takes to slowly seep up into the soil -- then be careful not to wait so long to water next time.

Nutrients and Fertilizers

Plants make their own food through photosynthesis; fertilizer provides supplementary mineral nutrition. Most commercial fertilizers used for houseplants are sold in liquid form or as powder that may be dissolved in water. Read label instructions carefully, then mix the fertilizer only 1/2 the label-recommended strength. If it says to use one teaspoon per quart of water, use only 1/2 teaspoon per quart. You can always fertilize again if needed, but symptoms of over-fertilization are irreversible.

Time-release products last for several months, releasing small amounts of fertilizer each time you water. Use these only when you would normally fertilize for that period of time anyway. Don't add them to the soil in fall as light levels are dropping, unless your plants grow actively all winter.

Organic fertilizers are mild and unlikely to burn because they're not immediately available in a form the plant can use. They must break down in the soil first. This is somewhat temperature dependent, occurring more slowly when soil is cooler.

Inorganic fertilizers are immediately available to the plant, but carry more risk of "burning" if you aren't careful when mixing and applying them.

Use fertilizer when plants are growing actively. Reduce or eliminate it at other times. Never use fertilizer to jolt a houseplant out of a slow growth period. If it's growing slowly, it is undoubtedly responding to environmental factors, primarily low light levels. Additional fertilizer will not be beneficial, and could prove harmful.

During the winter months you may not need to fertilize because reduced light and temperature result in slow growth for most houseplants. However, if plants grow under fluorescent lights, or are growing actively in a bright window, they may need regular amounts of fertilizer year-round. This is particularly true if they're growing in a "soilless" mix.

Never fertilize when soil is bone dry and the plant is moisture-stressed. Fertilize when soil is slightly moist, or water the plant first, then when water no longer comes through the drain holes, water a second time using fertilizer solution.

When applying liquid fertilizer in solution, make sure that some runs out the bottom of the pot to be discarded. This helps prevent a build-up of soluble salts or excess fertilizer part way down the root ball, and reduces the likelihood of damaging the roots or restricting most of the root growth to the upper portion of the soil.

Soluble Salts

Soluble salts refers primarily to fertilizer salts in the soil that will dissolve in water. They can accumulate on top of the soil, forming a yellow or white crust that can be scraped off. They may be present within the root area of the soil, as well. Salts can build up on the walls of containers. You may have seen the petioles of African violets that turn soft and rot where they contact the rim of a pot with crusty soluble salt build up.

High soluble salt levels damage roots directly. This weakens the plant, leaving it more susceptible to attack from root rot organisms as well as other diseases and insect pests. Signs of high soluble salt levels include brown leaf tips and margins, lower leaf loss, stunted new growth, dead roots and wilting.

The best way to prevent soluble salt injury is to **prevent salts from building up.** Fertilize only when the plant is growing actively, using a dilute fertilizer mixed half-strength.

Water correctly, as described above. **DO NOT ALLOW THE POT TO SIT IN WATER.** If you allow the soil to reabsorb drained water, any salts that were washed out will be pulled back into the soil. To leach built up salts from the soil, hold your container over the sink or laundry tub and water two or three times in rapid succession, using lukewarm water. If a layer of salts has formed a crust on top of the soil, scrape it off before you begin to leach. Try not to remove more than 1/4 inch of soil. After leaching, you can replace the soil you removed with fresh potting soil.

If the container has no drain holes, repot the plant, removing as much soil as is practical, replacing it with good potting soil. Put the plant into a container with drain holes, so leaching will be possible if necessary, and there will be less likelihood of soluble salt build-up.

Temperature

Most houseplants do well at the same temperatures that people find comfortable; 65 to 75 degrees F. daytime dropping 5 to 10 degrees at night. They can often withstand higher temperatures during the day, provided they receive plenty of light. And they can become accustomed to somewhat cooler day or night temperatures, provided the change occurs gradually over time.

Respiration, the process that allows plants to use food energy accumulated in photosynthesis, occurs 24 hours a day and is heavily influenced by temperature. The higher the temperature, the faster the rate of respiration and the more energy the plant burns. By reducing the temperature at night, houseplants expend less energy at a time when no photosynthesis is occurring.

Photosynthesis is primarily dependent on light; temperature will have less impact, at least in the range we keep our homes. Indoors, the brighter the light levels, the more photosynthesis; the lower the light, the less photosynthesis will occur.

The worst situation for a plants indoors -- and it's quite common in our heated homes in winter -- is a combination of relatively high temperatures and low light. Houseplants use their energy reserves rapidly through respiration, then deteriorate because there isn't enough light to replenish those energy supplies through photosynthesis.

Most flowering houseplants prefer the same daytime range but enjoy slightly cooler nighttime temperatures -- 55 degrees to 60 degrees F. Lower night temperatures intensify flower colors and help prolong flower life.

Cold temperatures can also be a problem in Minnesota homes. Because most houseplants originated in warmer climates, they can be damaged by chilly temperatures, even when those temperatures are above freezing. This is particularly true when changes in temperature are sudden.
If plants are too close to icy window panes in winter their leaves may cup and curl or develop water soaked areas. Parts that actually touch the glass may turn tan and papery. It's a good idea to pull plants back a bit from these windows in winter and lower shades or close drapes at night, if possible. Cold can also be transmitted to a container when it sits on a hard-surfaced floor, such as a tiled entryway. Get the pot up off the floor and away from outside doors or cold hallways.

Humidity

Most houseplants thrive in higher humidity than we are able to provide, but you can make up for lack of humidity with careful watering. Here are some additional strategies for improving humidity:

- Forget misting; it sets the stage for bacterial and fungal leafspot diseases, but increases humidity for only a brief period of time.
- Group plants together to take advantage of moisture lost through **transpiration.** (Sometimes referred to as "evapo-transpiration," it is the process of moisture evaporating from the leaves through their stomates or gas exchange openings.) Grouping plants together to improve humidity is only beneficial **if light levels are adequate.** Higher humidity does not in any way make up for low or inadequate light.
- Set plants on saucers over pebbles in trays of water, so the water can evaporate around them without wicking directly into the soil.
- Grow humidity-loving plants in terrariums, provided they don't need high light levels. Any sunlight shining through the glass would heat the contents of the terrarium, killing the plants.

Cleaning

Though misting can be harmful, it's important to **clean** houseplant leaves and stems regularly. They'll look better, they'll be less attractive to insects, and most important, the light they receive won't be filtered through a layer of dust and grime. This is especially critical in winter when light levels are already reduced.

Don't use plant shine products. They can build up to harmful levels, and the shiny, waxy surface may reflect light rather than allow it to penetrate to the chlorophyll in leaf tissue, which is the site of photosynthesis. This holds true for "home remedies," such as wiping the leaves with milk or mayonnaise, as well as for commercially manufactured products.

Ventilation

Houseplants, especially flowering varieties, may be sensitive to drafts from air conditioners or heat from registers. Forced air dries plants rapidly, and may cause developing flower buds to drop.

On the other hand, most plants grow best and have fewer problems with mildew when there's adequate ventilation present. Orchids, African violets, and ferns are among the many houseplants that thrive where there's good air movement. Ceiling fans are a big help in keeping air circulating, but it's also helpful to space plants so they're not crowded together too closely.

Houseplants are sensitive to natural or blended gas. Some plants refuse to flower, while others drop flower buds and leaves when exposed to gases. Foliage can also twist and cup from even slight exposure to the products of incomplete combustion. Though unlikely, keep these problems in mind if all your plants "go bad" at roughly the same time.

INSECT PESTS

There are many approaches to insect control, but all require early detection, and most require repeated treatments.

- Examine plants regularly, using a hand lens to check on anything unusual looking.
- Prune out heavy insect infestations, or at least the worst-looking parts of the plant.
- Eggs may remain even though you eliminate the adults; you'll need to check back and repeat the treatment until no live insects are present.
- Never spray a plant that's moisture-stressed regardless of whether you use a chemical insecticide, organic spray, or insecticidal soap. There is too much opportunity for phytotoxicity or plant damage.
- Keep newly sprayed plants out of direct sunlight for a day or two to minimize burning.

Read *Houseplant Insect Control,* Extension Folder FO 1031, carefully, for advice on controlling specific insect pests common to houseplants.

CONTAINERS

A good container for houseplants should:

- provide adequate room for soil and roots (but not too much)
- accommodate proper watering
- provide drain holes for excess moisture to escape (except for self-watering or sub-irrigated pots)
- look attractive without visually overpowering the plant

Clay and Ceramic Containers

Unglazed clay or **terra cotta** pots absorb and lose moisture through their walls. Although easily broken, clay pots provide excellent aeration for plant roots and are considered by some to be the healthiest type of container for houseplants. They can be a good choice for anyone who tends to over-water their houseplants. Their main drawbacks are that they are heavy, fragile, dry rapidly, and may lack aesthetic appeal. Ornate versions may be very costly.

Ceramic pots are usually glazed on the outside, and often on the inside as well, so soil retains moisture longer than in unglazed clay pots. Glazed ceramic containers may lack drain holes, rendering them unacceptable unless you use the double potting method.

These pots are also heavy and fragile; however many glazed ceramic pots are also quite attractive. Those designed specifically with houseplants in mind do have drain holes, and often come with a matching saucer to catch excess water and protect furniture surfaces.

Double Potting: A decorative ceramic pot without drainholes is called a "cachepot". A smaller, functional pot may be placed inside it on top of a few pebbles or potsherds, so when you water, the excess flows out of the inner pot and sits harmlessly on the bottom of the larger container. If you're concerned you may be overwatering, lift the inner pot every-so-often to make sure it's not sitting directly in trapped water.

(If you don't double pot, putting clay potsherds or gravel **inside** the bottom of a pot without drain holes will not improve soil drainage. It only provides a small space beneath the soil where some excess water can sit inside the pot before it wicks back up into the soil.)

Plastic Containers

Plastic containers are lightweight and easy to handle. They may be cleaned easily for reuse, and because they aren't porous, the soil in them dries more slowly

than it does in an unglazed clay pot. Plastic containers are also less likely to accumulate salt deposits on the container walls.

Plastic containers are available in many sizes, shapes and colors, but inexpensive ones are often rather brittle, and may not last long. Similarly, there's a huge variability in aesthetic appeal; some are quite attractive while others look cheap.

Self-watering containers

Some "self-watering" plastic or glazed ceramic containers feature a reservoir that allows moisture to wick back into the soil as needed (sub-irrigation.) In general, these containers work best with plants that don't need to get very dry between waterings. For success you need to become familiar with the peculiarities of the specific type of self-watering system you use.

The obvious benefit of self-watering containers is that you don't have to water houseplants as frequently. That can also be a drawback, as you are less likely to spot problems early, when they may be dealt with in a timely manner. Sub-irrigation containers are popular in commercial settings because they allow for reduced labor, which means money in the maintenance company's pocket.

TRAINING AND GROOMING

"Pinching" refers to the removal of an inch or less of new stem and leaf growth. Frequent pinching can help you keep some houseplants compact and well filled out. You may be destroying the plants' natural appearance, though.

When necessary, pinch right above a node, where a leaf joins the stem. This stimulates new growth and doesn't leave little stubs. You can pinch regularly or not at all, depending on how you want your plants to look. **Never pinch or prune a palm;** it won't regrow.

Pruning refers to removing more than just terminal shoot tips. Sometimes part of a branch or stem should be pruned for the sake of appearance. Or you might have to remove an entire section of a plant to aid in disease or insect control. Prune houseplants with woody stems and trunks as you would outdoor shrubs.

Remove any dying leaves, spent flowers or dead branches. You may trim off brown leaf tips and margins on individual leaves, but the brown area usually works its way back from the new edge before long. It's better to find out why leaf tips and margins are turning brown, then work to change those conditions rather than use a "band-aid" approach such as trimming off the dead tissue.

Washing: Keep leaves dust-free by washing plants with lukewarm water and mild soap. Small plants may be swished upside down in a sink or washtub of barely soapy water (cover the container and soil with a plastic bag or aluminum foil, secured snugly around the base of the plant). Wash larger plants outdoors or in the shower.

If plants have large leaves, you may prefer to clean each leaf individually, using a soft, damp rag. Remember to wash the undersides, petioles, and stems as well as the tops of leaves.

ACCLIMATIZING INDOOR PLANTS

Acclimatization: Definition: when an organism becomes adapted to a new environment. In this context it refers to a houseplant becoming adapted to growing conditions in homes, offices or other indoor spaces.

Research done in Florida in the late 1970's revealed interesting discoveries about how houseplants grow. Tropical houseplants grown in full sun have leaves called "sun leaves" that are structurally different from those of houseplants grown in shade ("shade leaves"). It's as if plants growing in high light conditions are trying to protect themselves from too much light, while those growing in shadier conditions are trying to gather as much light as they can, as efficiently as possible.

Sun leaves appear paler or more olive green and shade leaves appear darker green due to the location of their chloroplasts. The sun leaves have fewer chlorophyll-containing "chloroplasts" near cell surfaces. Their chloroplasts are located deep inside the leaves which are thick, waxy, smaller in size but numerous. Shade leaves have greater numbers of chloroplasts spread out closer to the cell surface. The leaves are thinner, larger and fewer in number.

When plants are grown in strong light they develop sun leaves which are photosynthetically very inefficient. If these same plants are placed in low light, they must either reorient existing sun leaves or drop their sun leaves and grow a new set of shade leaves that will be photosynthetically more efficient. In fact, only the youngest leaves appear to be capable of "re-orientation."

Conversely, plants growing in lower light will produce shade leaves that are thinner and more receptive to light, in an attempt to photosynthesize more efficiently. If you move them directly into a sunny location, those "shade leaves" will burn easily, then drop and be replaced by sturdier "sun leaves."

In order to grow large, robust houseplants as rapidly as possible, commercial growers expose them to intensely bright light outdoors, or more commonly, in sunny greenhouses. Then to reduce the shock that occurs when these plants with sun leaves are placed in shadier conditions indoors, they gradually reduce the light levels to which they're exposed. They also reduce fertilizer rates, watering frequency, and humidity levels as they prepare plants for shipment to retail outlets, and their ultimate placement in homes and offices across the country.

You could "acclimatize" plants when placing them outdoors in summer by starting in the shade, then gradually increasing light intensities and reversing the process before bringing them back indoors in autumn. But when you put houseplants outdoors, it's better to compromise by placing them under trees or on the north side of the house, where they're protected from midday sun. That way you won't have to spend half the summer getting them used to lots of sun and the other half accustoming them to shadier conditions prior to bringing them back into the house.

Help acclimatize newly purchased plants to the growing conditions in your home by placing them in a brightly lit area initially. Then move them to their permanent location several weeks later. Keep in mind that you cannot acclimatize a plant to thrive in light levels lower than what is generally recommended. When light levels are relatively low, you must choose low light plants and/or add supplementary lighting to keep them healthy.

SOLVING HOUSEPLANT PROBLEMS: A SERIES OF QUESTIONS TO CONSIDER

1) How long have you had the plant? (You can assume anyone who has had the plant for years knows how to grow it, but maybe they've moved recently and the plant has different growing conditions.)

- Was it healthy when you bought it? (Some people love the challenge of taking in a plant that doesn't look too good, then nursing it back to health.)
- How long have the symptoms been present?
- Has anyone else cared for the plant recently? (It could have been overwatered or ignored while you were on vacation.)
- Have you moved it from one location to another?

2) Where is the plant located?
   - Which exposure is the nearest window, N, S, E, or W? Are there large trees or other buildings that shade the window?
   - Is the plant directly in the window, or to the side?
   - Does it receive direct sunlight on the leaves?
   - Do sheer curtains or window shades filter the light?
   - Is the plant near a radiator or heat vent?
   - Is it chilled from leaky windows, cold floors, doors, or air conditioners?
   - Does it hang high in the room, where air is warmer and drier?

3) How often do you water the plant?
   - Does the pot have drainholes?
   - Do you water thoroughly, then discard the excess?
   - Do you use cold water or water from a softener?

4) How often do you fertilize the plant?
   - What do you use?
   - When was the last time?
   - Do you mix it full strength?

5) When did you last repot the plant into a larger container?
   - What kind of potting soil did you use?
   - Did you replace the soil? (Removing all the soil breaks off the tiny root hairs responsible for absorbing moisture and nutrients, often shocking the plant, sometimes irrevocably)

6) Do you mist, wash, or use leaf shine products on the foliage?

7) Could there be damaging fumes in your home?
   - Are all your plants in trouble?
   - Do you burn wood? (improper venting or incomplete combustion can cause distorted plant growth)
   - Do you store herbicide or weed & feed in the basement?
   - Do you spray with disinfectants, window cleaner, room deodorizer or other aerosol products close enough so they might settle on your plant?

RESOURCES

Minnesota Extension Service Publications

The most up-to-date listing of Minnesota Extension Service publications is available online at http://www.extension.umn.edu
Scroll down the left hand side of the page and click on gardening, then click again on flowers and houseplants. Read the following fact sheets and folders.

1031 House Plant Insect Control
1116 Forcing Bulbs for Indoor Beauty
1118 Outdoor-Indoor Geranium Culture
1127 Cacti & Succulents
1128 Keeping Cut Flowers & Flowering Plants Longer
1170 Bacterial Leaf Diseases of Foliage Plants
1130 Caring for Houseplants in Northern Climates

Yard & Garden Line Briefs

These sheets may also be accessed online at http://www.extension.umn.edu/projects/yardandgarden/ Scroll down the right hand side of the page and click on Yard & Garden Briefs, then Flowers & Houseplants. Read the following Briefs.

- Air-layering
- Care of Greenhouse (indoor) **Azaleas**
- Growing **Citrus** Indoors
- **Cyclamen** Care
- Growing Tropical **Ferns** Indoors
- Rubber Trees, Weeping Figs, and Other Friendly **Ficus**
- Hibiscus

- Houseplants Help Clean Indoor Air
- Oedema
- Growing **Palms** Indoors
- Care of **Poinsettia**
- Powdery Mildew on Indoor Plants
- Root Rot of Houseplants

Houseplant Books

Many excellent books have been written about houseplants. Here are a few interesting ones:

All About Houseplants, published by Ortho Books, Chevron Chemical Company, San Francisco, California. Good pictures and information.

Exotic Plant Manual by Alfred Byrd Graf, published by Roehrs Co., Rutherford, New Jersey. This is out of print, but definitely worth looking for in a used book store or through one of the online out-of-print book finders, if you'd like an authoritative and comprehensive reference for your collection.

How to Grow Fresh Air, by Dr. B.C. Wolverton, published by Penguin Books. Information on individual plants isn't great, but the book does cover the role of houseplants in cleansing indoor air.

Ortho's Houseplant Encyclopedia and Decorating With Houseplants (Ortho); may also be out of print, but can often be found at nurseries, hardware stores, or building supply stores that carry plants and related products.

Taylor's Guide to Houseplants, published by Houghton Mifflin Company; excellent photos for plant ID.

Suggested Websites to Visit:

In addition to the University of Minnesota Extension Service web page, there are many other sources of houseplant information online. The following site discusses houseplants and clean air: http://www.plants4cleanair.org/

The University of Illinois also has an interesting site. Go to: http://garden-gate.prairienet.org/ and click on *sunroom*.

For information on a large number of houseplants and greenhouse plants check out: http//www.plantcare.com

chapter 10

herbaceous

chapter 10

herbaceous

HERBACEOUS PLANTS

by Mary H. Meyer, Extension Horticulturist

INTRODUCTION

Herbaceous plants are non-woody plants that die back to the ground each year or, if evergreen, have non-woody stems. Most herbaceous plants are considered "flowers" by the general public. With thousands of flowers to choose from, this topic will be divided into four sections for Master Gardener training: annuals, bulbs, perennials, and ground covers. Herbs or culinary plants are a special sub-section of herbaceous plants which will not be covered in this course.

Flowers provide endless enjoyment from their showy flowers, diversity of plant form, texture, height, and color. The wide variation in flower color adds another design dimension which can alter a viewer's mood and reaction to a garden or planting. Entire books have been written on the subject of color in the garden and it is beyond the scope of this chapter. As a Master Gardener you may be called on to recommend plants for public plantings. Some ideas to keep in mind are selecting color combinations that vary from year to year, following themes, and using colors to direct or influence the viewer. Take note of favorite combinations or plants that work well together when you visit public and private gardens. Color themes used at the Minnesota Landscape Arboretum are listed below in the annuals section.

Flowers provide color against the predominant green of a landscape; they are the accent and contrast that make a landscape lively and interesting. They add depth and dimension, form and texture, and, as with all plants, they soften buildings and hardscapes.

Flowers also have specific uses beyond aesthetics, such as culinary herbs for the table; cut flowers for fresh and dried arrangements; and nectar to feed bees, butterflies, moths, and other insects.

LEARNING OBJECTIVES

Learning objectives of this section for Master Gardeners are to:

1. Explain several ways of using flowers in the home landscape.
2. Understand what the terms annual, perennial, and bulb refer to and give several examples.
3. Describe soil preparation for annuals, perennials, groundcovers, and bulbs.
4. Discuss selection of flowers for specific sites.
5. Discuss several aspects of cultural management for the flower garden including watering, weeding, and fertilization.
6. Understand preventive pest control for herbaceous plants.

ANNUALS

Annuals grow from seed to seed and complete their lifecycle in one year. The food reserves or carbohydrates of annuals are used to produce flowers and seeds. No carbohydrates in annuals go into storage structures such as roots, tubers, crown, or bulbs which would perpetuate the plant post-flowering. The life cycle of annuals is often short and, in fact, plant breeders have selected for those with even earlier flowering. In cold climates such as USDA Zone 4, annuals are very important for fast, dependable summer color. Many plants that cannot survive winter in Zone 4 and are grown as annuals are actually perennials in warmer climates. These plants are known as horticultural annuals. Examples of horticultural annuals are snapdragons, zonal geraniums, and crimson fountain grass.

It is important to realize the difference in physiology of annuals, and perennials, (plants survive and flower over multiple growing seasons). For annuals all carbohydrates are directed towards flowers and seeds and for perennials carbohydrates are apportioned between flowers AND storage organs to continue the plant in future growing seasons. In annuals, flower and seed production can actually signal the death of the plant or senescence and cessation of growth. Deadheading or removing flowers is a maintenance technique that delays death by encouraging new growth and new flower formation.

Annuals are further divided, or classified, by their length of growing season and cold tolerance. Hardy annuals are the most resistant to cold or frost. Some, such as calendula and sweet pea, can withstand light frosts and are not killed until temperatures are in the mid to low 20s F. Bachelor's button, sweet alyssum, and calendula are examples of hardy annuals that can be sown outdoors early in the spring and flower by midsummer. Cool nights in spring and fall are not harmful to hardy annuals. These are good choices for all of Minnesota and especially for northern Minnesota where the growing season is short.

Half-hardy annuals have less cold tolerance than hardy annuals, but more than tender annuals. This is a "gray" area of cold tolerance, and it is not as easy to separate half-hardy from hardy or tender annuals. These plants take longer to flower from seed and are more likely to be started indoors, although marigolds fall into this category and are easily direct-seeded in the garden. Other half-hardy annuals include cleome, dusty miller, nasturtium, petunia, and nicotiana.

Tender annuals are those with no cold tolerance that are easily killed by frost. This group usually needs to be started indoors and requires a longer growing season. Begonias, ageratum, bedding or annual dahlias, salvia, and heliotrope are examples of tender annuals. Tender annuals do not grow and develop in cool temperatures and planting them outside before nights are consistently above 45-50º F will not encourage development and can actually stunt them.

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Characteristics of Annuals

Annuals are grown for their showy, reliable flowers which last most of the summer. This long season of bloom (remember all carbohydrates go to the flowers) is the main advantage of growing annuals. In comparison to trees and shrubs, annuals are individually less expensive, fast growing, and make a major display. However, many plants are needed to make a showy display. One, two, or three petunias will not be enough for a display unless, of course, it is in one container or pot. Mass plantings of annuals are necessary for a showy display in the garden.

It is possible to landscape a home or building almost entirely with annuals. In addition to being relatively inexpensive, the design, color scheme, and appearance can be changed completely from one year to the next because annuals are temporary plants. Similarly if you make a mistake with annuals, it is short-lived and easily corrected the following year.

Annuals require work and effort in planting each year. Planning and plant or seed selection also takes time. Early spring bloom is lacking for annuals, since

they are typically small and often without flowers during May and early June. The annual flower display can remain relatively consistent over the season, and considerable maintenance including regular watering, deadheading, and fertilization is essential to keep annual flowers blooming prolifically.

Culture and Maintenance of Annuals

One key decision when growing annuals is whether to buy seed or plants. If you are an advanced gardener with time and a desire for specific cultivars, you may want to grow your own plants from seed. Starting plants from seed is covered in another chapter in this book (see index). Our homes are built for people, not plants, and not all homes have the special lighting and temperatures needed for success in starting seeds indoors.

Many plants, like begonias and impatiens, may not mature in the short season of Zone 4 and must be started indoors. These species are typically purchased as plants or grown from seed started indoors 6-8 weeks before the last expected frost.

Plants grown indoors must be hardened off, or acclimatized, to outdoor conditions before being planted in the garden. Greenhouse plants are usually hardened off before they are sold, with cool greenhouses or opened vents conditioning the plants to temperatures changes.

Planting a young seedling outdoors without hardening off is similar to a person going out for a suntan (after a Minnesota winter) and staying out all day. Plant cells formed in lower light have to adjust or acclimate to higher light gradually. Therefore, transplanting on cloudy days is a good practice because it gives plants a chance to acclimate.

Soil preparation for annual flowers involves determining if the pH is in the correct range, typcially between 6 and 7; adding organic matter to improve the soil structure; and adding fertilizer. Have the soil tested to determine pH and nutrient status. See the chapter on soils for detailed information on soil testing.

Most annual flowers grow best when the pH is between 6 and 7. Add organic matter such as compost, peat moss, shredded leaves, or grass clippings and work into the soil. Use 1-2” of organic matter if soil is medium in texture; add 2-4” if the soil is quite sandy or coarse in texture or quite heavy clay very fine in texture. Organic matter has several advantages: it improves the water-holding capacity, creating air spaces, and improves the soil structure. Depending on the type of organic matter, you may or may not be adding nutrients or fertilizer. A complete fertilizer such as 5-10-5 or 5-10-10 at the rate of 1-2 pounds per 100 square feet should be broadcast over the soil and worked in along with the organic matter. The complete chemical fertilizer may be eliminated if the source of organic matter has an equivalent amount of nutrients. Soil preparation should be done each year in the spring before planting. Even with fertilizer added in the spring prior to planting, many annuals require additional fertilizer. Liquid, water-soluble fertilizer is good for annuals since its nutrients are readily available. Fertilizer is often the limiting factor for annual growth, especially for plants in full sun and watered regularly. Weekly applications of liquid fertilizer for annuals will usually result in large plants with prolific flowers. Just remember to use a complete balanced fertilizer that is not high in nitrogen.

Most annual flowers prefer full sun, although many newer plants on the market grow well in shade. Select the correct plant for the site. Dry or moist conditions also require some thought; some newer annuals such as melampodium (butter daisy) are very drought tolerant. Selecting the correct plant will mean less maintenance and a better display of flowers.

If you are planting a public site and using many plants in a design, lay the design out using string or flour as guidelines for sections or planting areas. Time spent in planning will pay off in an attractive design pattern.

Water is a requirement for annual flowers. With shallow root systems, annuals often wilt and benefit from supplemental water. Container plants are very dependent on water and usually require a daily application.

Deadheading is the removal of dead or faded flowers. As discussed above, annuals invest all food reserves for flower production and this in turn can induce senescence or death of the plant once the goal of seed production is met. To encourage long flowering, remove flowers as they fade. Deadheading will also result in more food reserves going into flowers instead of seed production. As a rule of thumb, the largert he flower, the more the plant will benefit from deadheading. Fibrous begonias and impatiens grow just fine without deadheading, but petunias and zinnias bloom much better when faded flowers are removed.

Weeding is a much-lamented garden task. Weeds compete with plants for water, nutrients, and light. As annuals are planted, cover the exposed soil with mulch such as grass clippings, compost, pine bark, or peat moss to exclude light and prevent weeds from germinating.

Taller annuals, like cleome, may need staking, especially if plants are grown in partial shade. Many other annuals used to require staking, but the flower cultivars today are shorter and do well without staking.

Selecting Annual Plants

Visit public gardens to get ideas for using annuals. Some popular locations in Minnesota are the Minnesota Landscape Arboretum in Chanhassen, Noerenburg Gardens in Mound, and Munsinger and Clemens Gardens in St. Cloud. Since 1932, All-America Selections awards have been given to flowers and vegetables based on ratings from all over the US. In Minnesota there are five display gardens for the All-America Selections: the Minnesota Landscape Arboretum; the Northeast Experiment Station, Grand Rapids; Lyndale Park, Lake Harriet Parkway, Minneapolis; the West Central Experiment Station, Morris; and the University of Minnesota, 1970 Folwell Avenue, St. Paul.

Site and personal preference, of course, play a major role in plant selection.

Annual theme gardens

Each year the Minnesota Landscape Arboretum chooses a new theme for the annual beds containers, gatehouse, and main building beds. The following list may give you ideas for plantings in your community.

- Pinks and purples
- Primary colors: red, blue, and yellow
- Drifts of cool colors: blue and white
- Shades, tints, and tones of red in patchwork patterns
- Pastel colors in an English garden design
- Complementary colors of orange and blue with flowing lines
- Argyle design of purple, lavender, white, and silver
- Matisse cut-out designs: pinwheels and swirls
- Bright colors: red, yellow, and orange
- Plants with upright habits and flowers borne in spikes

Good Annuals for the Upper Midwest

Hardy withstand cold into the low 20's; sow directly outdoors; perennials in south

Antirrhinummajus -- snapdragon (origin: Mediterranean)
Brassicaoleracea -- flowering kale, cabbage (origin: Europe)
Calendulaofficinalis -- pot marigold (origin: Europe)
Centaureacyanus -- cornflower, bachelor's button (Eurasia)
Clarkiaamoena -- satinflower, godetia (origin: California)
Cleomehassleriana -- spider flower (origin: S. America)
Coreopsistinctoria -- annual coreopsis (Midwest and west)
Dianthuschinensis -- Chinese pink (origin: China)
Eschscholziacalifornica -- California poppy (California)
Gaillardiapulchella -- blanket flower (south and central US)
Iberisumbellata -- annual candytuft (Mediterranean)
Lathyrusodoratus -- sweet pea (origin: Italy)
Linumgrandiflorum -- annual flax (origin: north Africa)
Lobeliaxspeciosa -- cardinal flower, (Upper Midwest, SE US)
Lobulariamaritima -- sweet alyssum (origin: Europe)
Matthiolaincana -- stock (origin: Europe)
Nemesiastrumosa —nemesia (South Africa)
Phloxdrummondii -- annual phlox (origin: Texas)
Rudbeckiahirta -- black-eyed-Susan (origin:central US)
Salviaargentea – silver sage (southern Europe)
Salviafarinacea -- mealy-cup sage (origin: Texas)
Violatricolor -- Johnny-jump-up (origin: Europe)
Violaxwittrockiana -- pansy (origin: garden)

Half Hardy withstand a frost, killed at high 20 degrees; sow indoors or outside

Ageratumhoustonianum -- flossflower (C. America)
Calibrachoaxhybrida – trailing petunia (South America)
Diasciaspp. –twinspur (South Africa)
Eustomagrandiflorum -- lisianthus, (western Midwest)
Fuschiaspp. -- fuschia (garden hybrids)
Lantanacamara — lantana (tropics)
Limoniumsinuatum -- annual statice (Mediterranean)
Lobeliaerinus -- lobelia (origin: S. Africa)
Mirabilisjalapa – four o'clock (Peru)
Moluccellalaevis -- bells of Ireland (origin: Asia Minor)
Nicotianaxsanderae -- flowering tobacco (S. America)
Nicotianasylvestris – shooting stars (Argentina)
Nierembergiaspp. -- cupflower (origin: S. America)
Osteospermum hybrids – cape daisy (South Africa)
Pelargoniumxhortorum -- geranium (origin: S. Africa)
Petuniaxhybrida -- petunia (origin: S. America)
Plectranthusspp. – plectranthus (Australia, India)
Salviacoccinea 'Lady in Red' –bloody sage (tropical S.A.)
Seneciocineraria -- dusty miller (origin: Mediterranean)
Tagetesspp. -- marigold Includes ***T.erecta*** -- American marigold, African marigold; ***T.patula*** , French marigold; ***Tagetes erectaxpatula*** -- triploid marigold. (origin: Mexico,garden cultivars)
Toreniafournieri -- wishbone flower (origin: Vietnam)
Verbenaxhybrida -- verbena (origin: America)

Tender no cold tolerance, chilling injury at 50 degrees; long growing season, start indoors

Alternanthera several species, Joseph's coat (Mexico)

Angeloniaangustifolia **--summer snapdragon (C. America)**
Catharanthusroseus **-- vinca,periwinkle (Madagascar)**
Begoniaxsemperflorens-cultorum **-- wax begonia, fibrous begonia (origin: S. America)**
Begoniaxtuberhybrida **-- tuberous begonia (S. America)**
Browalliaamericana **-- bush violet (origin: S. America)**
Celosiaargentea **(Cristata group) -- crested cockscomb (origin: tropics)**
Celosiaargentea **(Plumosa group) -- plumed cockscomb (origin: tropics)**
Coleusxhybridus **see Solenostemon**
Cosmos **(several spp.) -- cosmos (origin: Mexico)**
Cupheahyssopifolia **– Mexican heather (Mexico)**
Gazaniassp. **(hybrids) -- gazania, (origin: S. Africa)**
Gomphrenaglobosa **-- globe amaranth (C. America)**
Helianthusannuus **-- annual sunflower (N. America)**
Helichrysumbracteatum**—strawflower, paper daisy (South Africa, Australia)**
Helichrysumpetiolare **—licorice plant (South Africa)**
Heliotropiumarborescens **-- heliotrope (origin: Peru)**
Impatiensssp.**, New Guinea hybrids -- New Guinea impatiens (origin: Australian Pacific islands)**
Impatienswalleriana **-- impatiens (origin: S. Africa)**
Ipomoeatricolor **-- morning glory (tropical America)**
Nigelladamascenea **--love-in-a-mist (s. Europe, N. Africa)**
Melampodiumpaludosum **-- butter daisy (C and S. Am)**
Pennisetumglaucum **– 'Purple Majesty' purple millet (garden hybrid)**
Pennisetumsetaceum **– fountaingrass (Ethiopia)**
'Rubrum' crimson fountaingrass
'Red Riding Hood' short crimson fountaingrass
Pennisetumvillosum **– feather top (tropical Africa)**
Pentalanceolata **– Egyptian star cluster (East Africa)**
Portulacagrandiflora **-- moss rose (origin: S. America)**
Salviasplendens **-- scarlet sage, salvia (origin: Brazil)**
Scavolaaemula **– fan flower (Australia)**
Solenostemonscutellariodes **[syn. Coleus xhybridus] -- coleus (origin: Old World tropics)**
Suterassp. **(Bacopa) – bacopa (South Africa)**
Thunbergiaalata **– blackeyed susan vine (tropical East Africa)**
Tithoniarotundifolia **– Mexican sunflower (C America)**
Tropaeolummajus **-- nasturtium (S. America)**
Zinniaelegans **-- zinnia (origin: Mexico)**
Zinniaangustifolia **—narrow leaf zinnia (SE US & Mexico)**

Disease Prevention for Annuals

The first step in disease prevention is to choose the correct plant for a given site, often referred to as the "right plant right place" concept. You will hear this many times as Master Gardeners. It is now known that a plant in the wrong site is predisposed to insect or disease problems. Because people are more conscious of pesticide use, prevention is the key to disease problems, instead of just control. Thus coleus in full sun will not be as lush and large as coleus in the shade; portulaca in wet, poorly drained soil will not be as healthy as plants in well-drained sites.

Additional disease prevention guidelines are:

1. Plant disease-resistant varieties or species. *Zinnia angustifolia* resists powdery mildew while common *Zinnia elegans* does not.
2. Clean up weeds. Weeds can harbor many of the same diseases that flowers get. Aster yellows is a common pathogen which is spread from weeds to desirable plants by leafhoppers. Removing weeds like dandelion and plantain lowers the chances of aster yellows affecting flowers.

3. Remove and discard infected plants, old plant parts, and debris. Diseases spread readily from one plant part to another through wind, rain, and insects. Sanitation makes good sense and is by far the most effective way to prevent disease.
4. Maintain good air circulation. Flowers tend to do well where there is good air movement and no stagnant air. While the wind blows often in the Midwest, planting close to buildings or in corners of two adjoining walls can lead to disease problems.

Common Questions about Annuals

Q: How can I overwinter my geraniums?
A: There are several ways to overwinter geraniums. The most successful is to bring the plants indoors and grow as houseplants over the winter. In late winter take cuttings and root new plants, or cut back the older stock plants and move outside again as the weather warms up. Another method is to take cuttings in the fall and root and grow these as houseplants over the winter. Another more severe and less successful method is to carefully dig up the plant and remove most of the soil from the roots, then hang the entire plant in a cool basement to be kept in a dormant state. The plant may be enclosed in a paper bag.

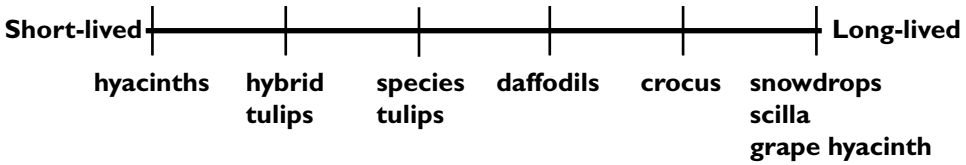
Q: Can I save seed from my favorite flowers?
A: Saving seed is fine from many annuals. Hybrids, plants grown from a cross between two carefully developed parents, will not come true from seed, and will probably result in inferior plants. Other flowers can be successfully saved. Collect seed when the flowers are mature and the seed falls out and is dry. Collect fresh seed each year.

Q: What plants can I grow in containers at my vacation home that will not always get additional water?
A: Use plants that like hot, dry conditions. Melampodium and portulaca are two good choices for dry spots. You may also want to place these pots where they will receive rainfall or overflow from spouting. Hydrogels are granular products that absorb water and can be mixed into potting soils to reduce the amount of water required; however, these gels have been shown to tie up nutrients and have other disadvantages that generally out weigh their advantages.

Q: What soil should I use in porch boxes and do I need to change it every year?
A: You can mix your own soil for containers. The traditional mix of one part garden soil, one part peat moss, and one part sand, perlite or vermiculite is still a good choice. You can also purchase synthetic soilless mixes which are very good for container plants. These are lightweight and hold water well and yet provide air spaces for good root growth. Ideally, you should use a new mix each year. You may be able to use a portion of the soil from the previous year and supplement it with, say, two-thirds or three-quarters new soil. Using supplemental fertilizer with soilless mixes is often essential; read the label to determine if fertilizer is included in the mix.

BULBS

This section will cover true bulbs, corms, and tubers as well as other modified stems and leaves which are commonly referred to as bulbs. The "Bulbs and Beyond" illustration which follows, shows the classification of bulbs and other modified storage structures. It is important to understand the origin of the plant tissue serving as a storage organ because that determines how each plant can be propagated or divided into more plants.



BULBS *and Beyond*

Three main vegetative plant parts

LEAVES (nodes at leaf base) | **STEMS** (many eyes/nodes) | **ROOTS** (rarely has eyes/nodes)

----------Modifications----------

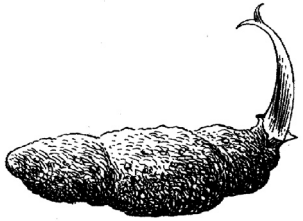
Leaf scales----**BULB**---basal plate
- lily: scaly bulb
- tulip
- hyacinth
- daffodil tunicate
- onion
- amaryllis

TUBER: potato
- caladium

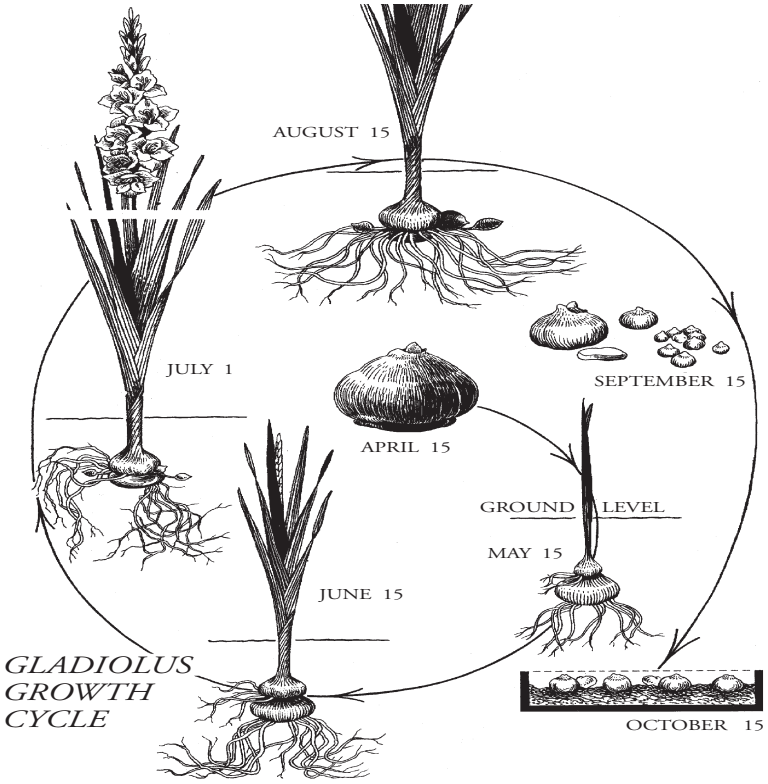
TUBEROUS STEM:
- begonia
- cyclamen

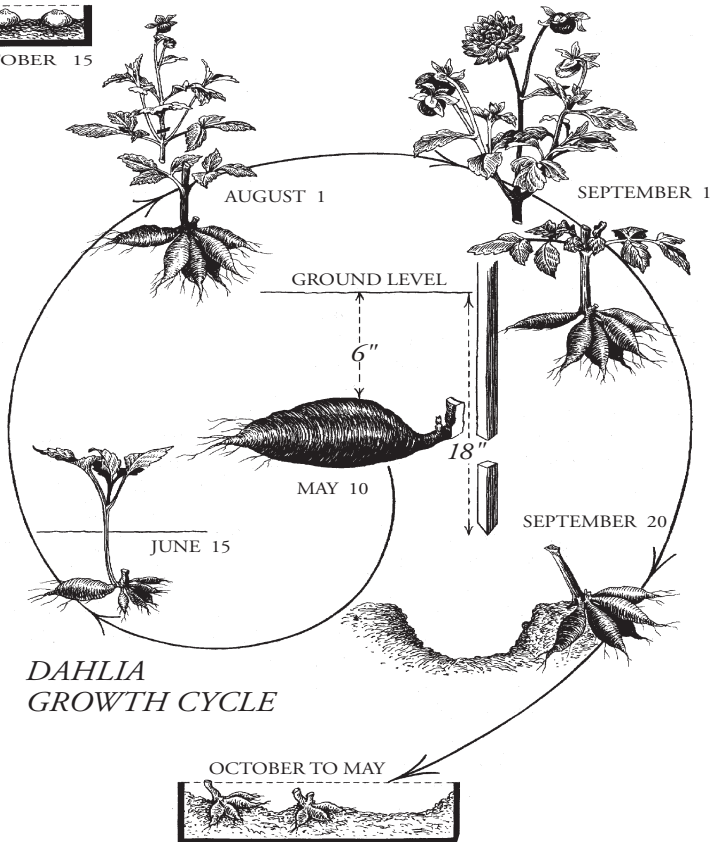
CORM: gladiolus
- crocus
- freesia
- autumn crocus

RHIZOME:
- canna
- calla lily
- lily of the valley

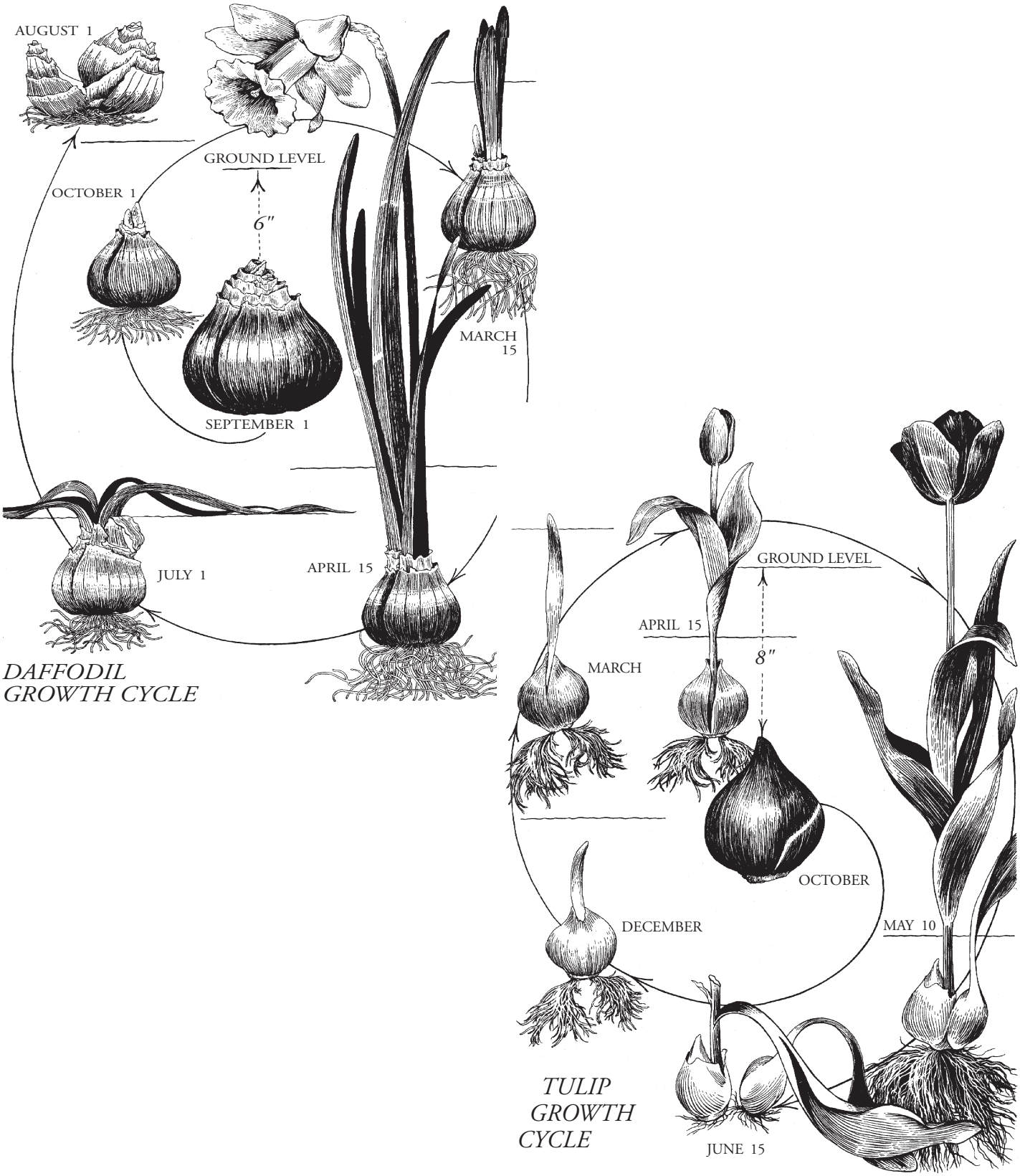


TUBEROUS ROOT:
- dahlia
- sweet potato





Life Cycles of Spring Flowering Bulbs, from The Complete Book of Bulbs. F. Rockwell and E. Grayson. 1953. American Garden Guild and Doubleday & Co. New York.



Life Cycles of Spring Flowering Bulbs, from The Complete Book of Bulbs. F. Rockwell and E. Grayson. 1953. American Garden Guild and Doubleday & Co. New York.

Spring Flowering Bulbs

Hardy spring flowering bulbs such as tulips and daffodils are easy to grow in cold climates. In fact, these bulbs require a chilling or cold treatment in order to flower. When you plant them in the fall, the winter fulfills the cold requirement and the plants flower the following spring. While many people think all spring flowering bulbs are perennials, some survive much longer than others. The scale on page 7 ranks spring flowering bulbs from short- to long-lived.

Note that the largest bulbs tend to be the shortest lived. This is because the larger bulbs need to store the greatest amount of plant food or carbohydrates to flower the following year. Smaller bulbs, however, do not have to store as much food. This chart is offered as a guideline only—it is possible to have hyacinths perenniate for several years if conditions are optimum.

Culture and maintenance

Spring flowering bulbs require a well-drained site and do not do well in wet soils. After flowering in the spring, they store energy and go dormant. They are adapted to climates where the summers are dry and arid. If annuals are planted with bulbs and summer watering continues, this will shorten the life of the bulbs. Dry sites where nothing is planted with the bulbs are actually preferable; they are, however, often impractical.

Plant spring flowering bulbs at the recommended depth early in the fall; the longer time the bulbs have to develop roots, the better they will grow. More roots means better survival and more flowers. A rule of thumb for planting depth is 2 ½ times the size of the bulb. So a 2“ bulb would be planted about 5” deep.

Fertilize bulbs at the time of planting and again in the spring during flowering. Use 2 pounds per 100 square feet of a complete fertilizer such as 5-10-5 or 5-10-10. Bulb fertilizer is usually high in phosphorus which promotes root growth and flowering. Bulbs will benefit from annual fertilization; fertilizer deficiency, can result in a lack of flowers.

The most important cultural practice in growing bulbs is to leave the foliage on after flowering. The foliage produces the carbohydrates that will be stored for next year’s flower. If the foliage is removed prematurely, less food will be stored, and the bulb will be small and may not flower. Do not remove spring flowering bulb foliage until it is completely brown or yellow.

Reasons for lack of flowers

A common gardening question is “Why didn’t my bulbs flower?“ There are several reasons for this, the first being the short-lived nature of many bulbs as referenced in the chart above.

Other reasons may be lack of fertilizer, wet soil in the summer, planting too late in the fall, bulb is too small to flower, deer or rodents ate bulbs or plants or ethylene gas killed the flower bud. Ethylene gas is given off by ripening fruit and vegetables, so bulbs stored near these may be affected by the gas. Bulbs stored in the refrigerator (to meet the chilling requirement) should be isolated from fruits and vegetables.

Summer Flowering Bulbs

Although there are many summer flowering bulbs, we will discuss only the most popular, such as gladiolus, dahlias, tuberous begonias, cannas, and caladiums.

Gladiolus are a favorite cut flower, have good frost tolerance, and can be planted in early May in Zone 4. Plant in full sun and hill up the plants or stake them to prevent lodging or falling over. Thrips are a common insect problem on glads and cause yellow streaking on the foliage and flowers. Insecticidal soaps and good sanitation in corm storage can provide control of thrips. Glads will rarely overwinter when left outdoors in Zone 4. Store gladiolus corms dry at 40º F.

Dahlias are large showy plants which produce tuberous root storage structures. Very cold-sensitive, dahlias should not be planted outdoors until late May in Zone 4. As the Bulbs and Beyond chart shows, dahlias are not true tubers. They are actually a type of root and as such have no growing points on the root. The only growing points or "eyes" are at the stem end of the tuber. The stem end or a visible bud must be attached to the root for the plant to grow. (The potato tuber is a true stem and has many growing points that can be sectioned, but dahlias are quite different.) Dahlias require full sun and well-drained soil. They do best with supplemental fertilizer and compost or manure applied to the hole before planting. Dahlia roots require protection from winter desiccation. Overwinter dahlia tubers in a slightly moist medium, such as peat moss or mulch at 35-45º F.

Tuberous begonias require a long growing season to develop and are usually started indoors in Zone 4. As the buds begin to grow on the flattened enlarged stems or tubers, they can be planted in pots and grown by windows or under lights. Known for beautiful large flowers in shady conditions, tuberous begonias will bloom all summer long. Winter storage is difficult, as the tubers like moist conditions with good ventilation to avoid mold. Store tuberous begonia bulbs in a slightly moist medium at 50º F.

Cannas are large-flowering, old-fashioned plants that are propagated by rhizomes. They love warm conditions and full sun. The foliage is large and showy, and cannas are relatively pest free. Store canna rhizomes in a slightly moist medium at 55º F.

Caladiums are another plant for shade. Their multi-colored foliage provides a bright accent to dark corners. As a container plant or in the garden, caladiums like warm temperatures and do not grow well below 65º F. Store caladiums in a slightly moist medium at 50º F.

PERENNIALS

Perennials are plants that survive more than two years from a crown or other over wintering plant part. Woody plants are also perennial, but "perennials" commonly referrs to herbaceous perennials. The top of perennials die back to ground level but the roots, crown, or other storage structure continues to live year after year. Some perennials are very long lived such as peonies, iris, or daylilies, while others, including columbine, lupine, and delphinium, are often short lived. Perennials have been popular fo centuries but have seen renewed interest recently in the U.S. The wide variety of plants available, a diversity of plant forms, textures, and flowering times, and a change through the seasons have made perennials a popular choice for many home gardeners.

This section will cover definitions, culture, and maintenance and suggest a list of perennials that are easy to grow in the north central states.

Tender perennials are plants that would be perennials in their native climate, but cannot survive hard northern frosts and winters. Many of these plants are also referred to as horticultural annuals, because they are grown as annuals in colder climates. Examples are pansies, geraniums, and mealycup salvia.

Biennials complete their life cycle in two years and then die. The first year the plant is usually a basal rosette. During the second year a flowering stalk develops, after which the plant dies. Many biennials self-seed and appear to perenniate. Occasionally a biennial such as 'Foxy' foxglove will flower the first year. Hollyhocks and dame's rocket are typical biennials. Fall planted pansies are grown as biennials. Care for biennials is similar to annuals or perennials.

A crown is the junction of the root and shoot of a plant where many buds, nodes, or growing points exist. Propagation of many perennials is done by division of the crown of the plants.

Characteristics of Perennials

Perennials are relatively permanent in the landscape. The majority are long lived and require less yearly work than annuals. Over time, the plants increase and can be divided at little expense or time. The large variety of flowers, foliage texture, and color among perennials makes them seem unlimited in kinds to grow. The biggest disadvantage of perennials is that they typically have a short bloom period. They also cost more individually than annuals and can require yearly work in weeding, staking, or pest control.

Culture of Perennials

Many of the same aspects discussed under annuals apply to perennials also. Consider the site, slope, soil type, and the role the plants will play in the garden. This becomes even more important with perennials since they will stay in the site for many years. Soil preparation is key because of the permanent nature of the plants. In general it is best to plant groups of perennials rather than one plant. Island beds, where taller perennials make a background, or borders in front of a fence or hedge are both attractive.

Few perennials will perform well if the soil is not properly prepared. For new beds, fall preparation can be beneficial. Have the soil tested to adjust the pH if necessary. Check the soil for drainage by digging a hole 10" deep and filling it with water. The next day fill the hole with water again and see how long it remains (it should not stay longer than 8 hours). If drainage is poor, consider using raised beds or use only plants that do well in wet sites. Incorporate 2-4" of organic matter into the soil. In the spring spade again and add fertilizer based on the soil test. Most perennials need 1-2 pounds/100 sq. ft. of complete fertilizer such as
5-10-5 applied annually. Rake the soil surface smooth.

It is best to select plants with a purpose in mind, such as edging, background, or time of bloom. With specific purposes in mind you can choose plants by considering their characteristics and deciding which meet your requirements. Named varieties have been selected due to having some unique or improved characteristic and are often superior ornamentally to the straight species. Visit public gardens to observe mature perennials and get ideas of appropriate combinations for your garden. Local garden centers and nurserymen are good sources of perennials.

Many perennials do not come true from seed and saving seed may result in off-types of color, flower form, and plant habit. Exceptions are native species and unnamed cultivars, which are relatively uniform from seed. Perennials can be planted in fall or spring if healthy, hardy container plants are used. Allow sufficient time for root establishment before the onset of cold weather.

Liquid fertilizer (such as 20-20-20) may be used at planting time to stimulate root growth. Be sure the soil is moist and water well if the soil is dry.

Weed control in perennials can be very tedious. Few herbicides are appropriate for home use. Organic mulches provide good weed control and improve the soil. Bark, pine needles, compost, and shredded leaves are common organic mulches. Summer mulches are applied at the beginning of the growing season and have the following advantages:

- Discourage weeds
- Keep the soil moist
- Conserve water
- Add organic matter to the soil
- Keep soil temperatures low
- Provide an attractive appearance, a finished look

Winter mulches are applied after the ground freezes (usually in November) and are used to prevent temperature extremes and repeated freezing and thawing which can heave up the crown or roots of perennials. W inter mulches may also help to collect snow and provide additional cover. Some years, a snow cover will come before the ground freezes. This "poor man's mulch" will provide the

necessary protection for perennials. The problem arises when the snow melts in mid-winter; then the plants will need supplemental protection. Snow is a good, but unreliable, mulch. Remove excess winter mulch in the spring when growth starts (usually in late March or early April).

Just as with annuals, perennials benefit from removal of faded flowers, thus putting more energy into new flowers or leaves, or storage for next year's flowers. Perennials such as monarda or salvia can be sheared off after flowering, removing the top leaves as well, which may encourage rebloom. Disbudding is the removal of buds before they open. Chrysanthemums are often disbudded in the spring, usually until early July, to encourage late summer flowering. Peonies may be disbudded to encourage one large flower per stem, rather than multiple small flowers.

While many newer cultivars are shorter, some tall plants need to be staked due to weak stems or heavy flowers. Some plants such as ornamental grasses may lodge or fall over if grown in the shade. Metal, wood, or bamboo stakes are suitable. Stiff-branched stalks of perennials from last year may also be used.

Maintenance of Perennials

Division

Divide perennials when they are dormant. Vigorous, stress-tolerant perennials like hosta and daylilies may be divided almost anytime. If plants are flowering well with no dead sections, division may not be necessary. If the center of the plant is dead, or flowers are few, divide the plant. Select only vigorous side shoots to replant and discard the older center of the clump. A good rule of thumb is to divide perennials in the opposite season from when they flower. Thus for peonies, fall division is good; for fall blooming asters and mums, spring is good. If you are unsure, spring is the fall back time for all perennials in general for our cold climate. Allow at least one month for plants to develop roots and adjust to division before the winter. How often? Every 5 years is a good rule of thumb, more for bearded iris, less for ornamental grasses, and not at all for some, see below. Mike Heger's and John Whitman's book Growing Perennials in Cold Climates is a good resource that lists how often to divide many common perennials.

There are several methods to divide perennials. Simple crown division, digging the clump and dividing with a knife or sharp spade, is fine for most perennials, especially the fine, fibrous rooted plants like grasses, monarda, phlox, nepeta, aster, etc. If the relatively large, fleshy-rooted perennials like daylilies and hosta, can actually be divided by division, but if the roots are carefully pulled apart, you can actually increase these plants without cutting and damaging the roots. The older and larger the clump, the more you may need a cutting tool. But if you can work these fleshy roots apartwithout cutting, you will see much less transplant shock and wilting.

Some perennials do not like to be divided and actually decline, especially if planted too deep or too shallow. Peonies are an example of a perennial that is best not divided and when planted, the eyes or growing points must be planted at 1-1½" deep. Aquilegia, Baptisia, Platycodon and Asclepias are other perennials that often do not grow well after division. Either tip or root cuttings can be used to propagate perennials. Select 3-6" long tips of new growth. Treat the base of the cutting with a root stimulant. Insert cutting into a lightweight potting soil or moist peat moss. Cover with clear plastic, keep out of direct sunlight, and supply moisture as necessary. Phlox, candytuft, and dianthus can be rooted from stem or tip cuttings. For root cuttings, cut pencil-sized roots into 4" sections: butterfly weed, phlox, and baby's breath can be grown from root cuttings.

Pinching, Pruning, Thinning, Cutting Back Perennials

Pinching refers to a small, usually less than 1-2", amount of growth removed from the tip of the shoot. Annuals are often pinched to improve branching and induce multiple stems. Pinching produces a fuller plant. Most tall or thin plant can benefit from pinching. Some plants have preset flowers and do not initiate new flowers in response to pinching like tulips and peonies, but most other herbaceous plants benefit from pinching.

Chrysanthemums have traditionally been pinched to delay flowering and induce compact, fuller plants. The rule of thumb has been to periodically pinch off the flower buds until July 4, after which one allows the buds to develop and open. Many people no longer do this and at the University of Minnesota, none of the mums in the breeding program are pinched.

Pruning herbaceous plants refers to cutting off a large amount of stem and foliage, from 2" to 8 or 10" when the plants are actively growing. This differs from cutting back, in that the plants have not flowered and you are pruning foliage or very small, usually not visible flower buds. Pruning vigorous perennials, such as aster, monarda, nepeta, phlox and salvia can alter the flowering time and the height of the plant. Flowering can be delayed by several weeks and the height shortened to almost half the normal size. This "controlling" or pruning can weaken flowering perennials and should only be done on vigorous plants. Tracy Disabato-Aust's book "The Well-Tended Perennial Garden," gives in- depth directions about this type of pruning. Try it on plants that are tall and gangly and tend to flop.

Thinning is another type of pruning where selected, entire stems are removed from a perennial. This improves air circulation and can reduce some diseases such as powdery mildew.

Cutting back. Removing flowers after they have bloomed, usually several inches to 2' of the plant is referred to as cutting back perennials. Some vigorous plants such as nepeta and salvia may re-bloom again after being cut back during the summer. Other plants will not rebloom and invest most of their food reserves in overwintering structures. Appearance, disease problems, and winter injury, are important factors to consider before you cut back perennials.

If at any time during the growing season, the plants are covered with disease, such as leaf spots or botrytis blight, it is a good idea to remove such foliage. Powdery mildew, although unattractive to look at, is not so fatal and if you repeatedly cut back mildew-covered foliage, you may kill the plant. Purchase resistant varieties for the best control of powdery mildew. Before winter, remove any diseased foliage including mildew, to decrease the over wintering fungal spores in your garden. Remove all diseased foliage and dispose of it, usually not in your compost pile, but in an off site location. Plants that are not diseased do not need to be cut back, unless you find them unattractive. Many plants are attractive in the winter, such as astilbe, rudbeckia, coneflower, and ornamental grasses. In fact, many grasses will be harmed in the winter if they are cut back in the fall, so leave their stems standing to catch snow and other leaves to protect them during the winter.

In early spring, usually in April for us, you can cut back all perennials and remove any leaves or mulch. An electric string trimmer works well for cutting back herbaceous perennials in the spring.

Why Didn't my Perennials Bloom?

A common question with perennials is "Why didn't my plant bloom?" Many factors, internal and external, contribute to flowering in perennials.

Internal factors are within the plant and are not as apparent. These include:

- The age or maturity of the plant
- Internal hormonal changes which may be a function of age or exposure to light or temperature
- Indeterminate (non-flowering) versus determinate stems

External factors include:

- Temperature—extremes can inhibit flowers
- Daylength—poinsettias and mums are known for being short-day plants
- Planting depth—peonies will not flower if planted too shallowly or too deeply
- Too little light—sun-loving plants will not bloom in the shade
- Winter injury—a late freeze (below 20º F) can damage spring flowering bulbs
- Improper pruning—small flower buds may be removed by pruning at the wrong time
- Lack of fertilizer—most perennials need yearly fertilization.

Insect & Disease Prevention for Perennials

Review the section on disease prevention under annuals. The same information is applicable to perennials. There are many disease- resistant perennials to choose from and more species of perennials to try for insect resistance. Sanitation is critical to pest prevention. Planting a wide range of perennials from different plant families can encourage a diversity of beneficial insects and help prevent a major buildup of pest problems.

In all cases, determine what the pest is and its life cycle before deciding if chemical controls are appropriate.

Perennials are especially sensitive to poor air circulation and grow best with wide spacing between the plants, although aesthetically this may not look as good. Pruning and thinning plants can also improve air circulation. Consider major pruning or thinning after flowering.

Good Perennials for the North Central US

The following table lists easy-to-grow, showy perennials. With hundreds of perennials to choose from, this list is by no means all inclusive.

Perennials for Shade

Botanical name	Common name	Comments
Anemone xhybrida	windflower	fall blooming, tall hybrids, maybe short-lived
Aquilegia canadensis	wild columbine	showy native
Aquilegia xhybrids	columbine	showy, self-seed, and short-lived
Arisaema triphyllum	Jack-in-the-pulpit	tough native; likes wet soil
Aruncus dioicus	goat's beard	large plant 4-6', best in moist soil
Asarum canadense	wild ginger	native; good ground cover
Astilbe x arendsii	false spirea	good for moist to wet-sites; many cultivars
Aster divaricatus *A. macrophylla*	wood and bigleaf aster	native to woods, maybe floppy
Bergenia spp.	bergenia	showy large leaves; shade tolerant
Brunnera macrophylla	Siberian bugloss	showy blue flowers; tough
Chelone spp.	turtlehead	native; tolerates moist soil; showy flowers
Cimicifuga racemosa	black snakeroot	native to edge of woods; sun or light shade

Cypripedium reginae	showy lady slipper	requires acidic woodland soil
Cypripedium calceolus	yellow lady slipper	easier than C. raginae
Dicentra spectabilis	bleeding heart	grows best in rich soil; dies back in summer
Digitalis purpurea	foxglove	biennial, allow to self-seed
Dodecatheon meadia	shooting star	prairie native, spring fls
Geranium maculatum	wild geranium	native to woods; easily spreads; many hybrids
Hakonechloa macra 'Aureola'	hakone grass	golden "waterfall" grass, likes acidic moist soil
Helleborus hybrids	lenten rose	partial shade and well drained soil
Hosta spp.	hosta	can compete with tree roots
Ligularia spp.	ragwort	great for moist or wet sites; coarse texture
Lysimachia punctata	yellow loosestrife	aggressive rhizomes
Mertensia virginiana	Virginia bluebells	showy native; foliage dies in summer
Phlox divaricata	woodland phlox	good ground cover for moist, woodland soils
Polemonium caeruleum	Jacob's ladder	prefers moist soil; tolerates shade; attractive foliage
Pulmonaria saccharata	lungwort	attractive foliage, many cultivars
Sanguinaria canadensis	bloodroot	spring wildflower, foliage dies after flowering
Thalictrum spp.	meadowrue	tolerates shade; moist soils; native
Tiarella cordifolia	foamflower	native woodland ground cover for moist soils
Perennials for Sun		
Achillea filipendulina	fernleaf yarrow	showy cultivars, usually no seedlings
Achillea millefolium	common yarrow	native; self-seeds and can be invasive; tolerates dry, poor soil.
Alchemilla mollis	lady's mantle	edging; easy to grow and divide, will tolerate some shade
Amsonia tabernaemontana	blue stars	native; tough; yellow fall color
Asclepias incarnata	swamp milkweed	native; good for wet sites.
Asclepias tuberosa	butterfly weed	native; usually best in dry sites; transplants poorly.
Aster novae-angliae	New England aster	native; many cultivars
Baptisia australis	wild indigo	native; attractive flowers and seed-pods
Belamcanda chinensis	blackberry lily	showy seeds throughout winter; Iris family
Boltonia asteroides	boltonia	may need staking; may winter kill
Calamagrostis x*acutiflora* 'Karl Forester'	feather reedgrass	bunchgrass;winter interest
Campanula carpatica 'Blue Clips'	bellflower	tiny plant with large flow ers; easy to grow
Centurea montana	mountain bluet	tolerates poor soil; can self-seed
Coreopsis verticillata 'Zagreb'; 'Moonbeam'	threadleaf coreopsis	native to Appalc. Mts; needs good drainage
Delphinium spp.	delphinium	requires cool, moist sum mers and staking
Chrysanthemum grandiflora		selections from North Central states are hardiest

Dictamnus albus	gas plant	showy foliage; may cause dermatitis
Echinacea purpurea	purple coneflower	native; self-seeds; several named cultivars self-seed.
Eupatorium maculatum	Joe-Pye weed	native to wet sites
Filipendula rubra	Queen-of-the-prairie	likes moist to wet soils, tolerates part shade
Heliopsis helianthoides	oxeye	native; showy yellow flow ers; long lived
Hemerocallis spp.	daylily	tough for many sites; long lived
Heuchera micrantha	'Palace Purple'	good for shade; many cultivars
Hibiscus moscheutos	rose mallow	varies in height and flower size with cultivar
Iberis sempervirens	candytuft	early flowering; very showy; may need winter mulch
Iris hybrids	bearded iris	easy and dependable; needs sun and regular division
Iris sibirica	siberian iris	resistant to iris borer
Liatris spp.	gayfeather,	native; many species; butterfly favorite
Lilium spp.	Asiatic & oriental lilies	wide variety of cultivars; many good for cold climates
Lupinus hybrids	lupine	short-lived; likes cool, moist summers and sandy soils
Lysimachia clethroides	gooseneck loosestrife	aggressive rhizomes, tolerates some shade
Monarda didyma	beebalm	mildew resistant:'Marshall's Delight'butterfly and bee favorite
Opuntia humifusa	prickly pear	native to dry soils; showy yellow flowers
Paeonia hybrids	peony	picky on planting depth but outlives many owners
Penstemon digitalis 'Husker Red'	beard-tongue	native; easy to grow but short lived
Perovskia atriplicifolia	Russian sage	subshrub; clouds of blue flowers for most of sum mer
Phlox paniculata	garden phlox	mildew prone; but still one of the showiest perennials
Physostegia virginiana	obedient plant	can be invasive; tolerates a wide variety of soil types
Platycodon grandiflorus	balloon flower	late to emerge in spring; showy buds and flowers
Rudbeckia fulgida	rudbeckia	long flowering cultivar; 'Goldsturm'self-seeds to other forms
Salvia 'May Night'	perennial sage	fragrant foliage; self-seeds; sheer flowers for rebloom
Schizachryium scoparium	little bluestem native;	3' bunch-grass, red-purple fall color
Sedum spp.	stonecrop	many species and cultivars for dry sunny sites
Sporobolus heterolepis	prairie dropseed	soft cloud-like flowers smell like hot-buttered pop corn

Stachys byzantina	lamb's ear	drought tolerant
Thermopsis caroliniana	carolina lupine	yellow spikes in spring
Trillium grandiflorium	trillium	showy spring wildflower
Verbena hastata	blue vervain	native to moist or wet sites
Veronica spicata 'Sunny Border Blue'	speedwell	deadhead for rebloom;
Yucca filamentosa	Adam's needle	drought tolerant

GROUND COVERS

In a general sense, a ground cover can be any plant that covers the ground surface. This can include a wide variety of plants such as:

- Grasses
- Broad-leaved evergreens
- Annuals
- Narrow-leaved evergreens
- Perennials
- Deciduous woody plants

When ground covers are chosen carefully and placed correctly, they greatly enhance the beauty of the landscape. In addition to their aesthetic value, they fulfill a number of other important functions, such as:

- Controlling erosion on slopes
- Obstructing traffic without impeding view
- Conserving soil moisture
- Reducing soil temperature
- Reducing lawn maintenance
- Filling narrow, odd-shaped areas where mowing and edging might be difficult
- Providing vegetative growth where grass is difficult to maintain
- Producing interesting variation in height, texture, and color to tie the landscape together
- Covering bare areas

Ground covers are usually easily-propagated, vigorous, and hardy. One problem that limits the use of ground covers is the cost of installation since many small, individual plants are required. In addition, a well-prepared planting bed is essential to the establishment of ground covers, which can be costly and time consuming. Wherever paving, lawn, or cultivated beds are not desirable, ground covers may be a good option. Newly cut banks, and any slopes greater than 12 percent, are best treated with ground covers. Around buildings, ground covers are superior to paving or structural controls for reducing heat, glare, noise, and dust.

Additional descriptive information can be found in FS 1114 Ground Covers for Rough Sites and North Central Region Publication 400 Ground Covers for the Midwest.

Considerations in Choosing Ground Covers

Several factors are important in selecting a ground cover, especially hardiness and availability. Plants must be well-adapted to the climate. Since ground covers are often used on very difficult sites, such as slopes or poor soils, they must be hardy enough to withstand such conditions throughout the seasons. Availability of plants or seed is of major concern also. Although sources may list common ground covers as being available from seed, most herbaceous plants used as ground covers are available only as plants, and large quantities may be available only in the spring. Cost is indeed a factor to consider since sufficient plants to cover a large area may be quite expensive. Ease of establishment and vigor will determine how well the ground cover gets going the first few years. Plants that require hand weeding or extra care need to be selected with this in mind. Most ground covers have few maintenance requirements once established. Pest control, pruning, or other maintenance should be considered. Longevity of the

plants is also of interest; for example, junipers have a long life expectancy, except in years of winter desiccation. Most ground covers will tolerate little foot traffic, except of course the universal ground cover of turfgrass which has a low growing point. Most ground covers will die if they are repeatedly walked on.

Culture and Maintenance of Ground Covers

Significant maintenance is necessary for up to three years or until the ground cover becomes established. Cultivation is necessary to control weeds and other undesirable plants; fertilization is important to encourage fast, vigorous growth; irrigation may be necessary in times of drought; and disease and pest control are also important. When this maintenance is done and the proper site is selected, the progress toward achieving a good ground cover planting is usually excellent.

Good Ground Covers for the North Central States

Botanical name	*Common name*
Aegopodium podagraria 'Variegata'	goutweed, bishop's weed
Ajuga reptans	bugleweed
Asarum europaeum	European wild ginger
Berberis koreana	Korean barberry
Convallaria majalis	lily of the valley
Coronilla varia	crown vetch
Dianthus deltoides	maiden pink
Diervilla lonicera	bush honeysuckle
Epimedium x rubrum	barrenwort
Euonymus fortunei 'Gracilis'	variegated wintercreeper
Fragaria spp.	strawberry
Galium odoratum	sweet woodruff
Glechoma hederacea	creeping charlie, ground ivy
Hemerocallis spp.	daylily
Herniaria glabra	rupturewort
Hosta lancifolia	narrowleaf hosta
Hosta undulata, Hosta 'Krossa Regal'	hybrid hostas
Juniperus horizontalis 'Bar Harbor'	Bar Harbor creeping juniper
Lamium maculatum 'White Nancy'	spotted dead nettle
Lotus corniculatus	birdsfoot trefoil
Lysimachia nummularia	moneywort
Lysimachia vulgare	loosestrife
Pachysandra terminalis	Japanese spurge
Phlox borealis	arctic phlox
Polygonum affine 'Border Jewel'	Border Jewel Himalayan fleece-flower
Polygonum cuspidatum compactum	compact Japanese fleeceflower
Potentilla tridentata	creeping cinquefoil
Rhus glabra	smooth sumac
Rhus trilobata	skunkbush
Sorbaria sorbifolia	ural false spirea
Salix x simulatrix	creeping willow
Sedum spp.	sedum
Stachys byzantina	lamb's ear
Symphoricarpos orbiculatus	coralberry
Thymus serphyllum	thyme
Tiarella cordifolia	Allegheny foamflower
Vinca herbacea	periwinkle
Viola spp.	violet

RESOURCES

University of Minnesota Extension Service Publications

Master Gardeners receive many of these publications as a part of their training or Core Course. New publications are continually added to the Distribution Center. The most up-to-date listing is available online at http://www.extension.umn.edu. Click on Publications, or search the site for publications of interest. Many of these fact sheets can be read online and are also available from county extension offices. Longer publications or those containing many photographs or illustrations may not be available online. Master Gardeners should order publications through their home county extension office. Public orders may be placed by calling 1-800-876-8636 (outstate) or 612-624-4900 (local).

FS 1105	Culture of Garden Roses
FS 1106	Growing Daylilies
FS 1112	Selecting Lilies for Your Garden
FS 1113	Iris for Northern Gardens
FS 1115	Growing Dahlias
FS 1116	Forcing Bulbs for Indoor Beauty
FS 1117	Storing Tender Bulbs and Bulblike Structures
FS 1118	Outdoor-Indoor Geranium Culture
FS 1119	Tall Garden Phlox for Minnesota Gardens
FS 1120	Growing Petunias
FS 1153	Diseases of Peony
FS 1154	Gladiolus Diseases
FS 1163	Rose Diseases
FS 1167	Damping Off of Seedlings
FS 1428	Gardening in the Shade
MR 2126	MinnQueen & Royal Knight—New Mums
MR 2148	Gold Country & Mellow Moon—New Mums for 1983
MR 2479	Centennial Sun—Garden Chrysanthemum Introduction
MR 3160	Rosy Glow Mum
FO 3238	Plants in Prairie Communities
MR 3318	Three New Golden Mums for 1988
MR 3764	New Mums for 1990
MI 3821	Fertilizing Garden & Landscape Plants & Lawns
MI 6992	Minnesota Gardening Calendar 1999
FS 6065	Native Plants: Common Questions about Wildflowers and Native Plants
MI 6076	Growing and Using Annuals and Bulbs
MR 6336	Rose Blush Chrysanthemum
BU 6411	Ornamental Grasses for Cold Climates
FS 6422	Ornamental Grasses for Minnesota
MR6432	Cultivar Trials of Bedding Plants—1994 Edition
BU 6521	Growing Perennials

Videos of Minnesota Gardening TV Programs

These are 30-minute videos developed as a series of programs aired in the Twin Cities for the general public. They are available from the University of Minnesota Extension Service Distribution Center :call 612-624-4900 (local) or 1-800-876-8636 (outstate).

VH 5981	Starting Seeds
VH 5982	Lilies
VH 5984	Roses
VH 5986	Perennials
VH 5988	Gardening on a Slope
VH 5989	Arranging Summer Flowers
VH 5996	Hardy Bulbs
VH 6007	New Annuals and Vegetables
VH 6010	Spring Wildflowers
VH 6013	Iris
VH 6014	Pesky Plants
VH 6015	Season Extenders
VH 6016	Minnesota Prairies
VH 6018	Dahlias

VH 6022 Putting Roses to Bed
VH 6025 Gifts from the Garden
VH 6028 Como Conservatory
VH 6029 Flower Breeding
VH 6030 Contemporary Flower Arranging, Part I
VH 6032 Planting From Seeds
VH 6033 Contemporary Flower Arranging, Part II
VH 6241 Flowering Annuals at the Arboretum
VH 6242 Reducing Pesticide Use
VH 6243 Daylilies
VH 6244 Breeding Hardy Plants for Northern Climates
VH 6246 Minnesota Mums
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Perennials for Moist Soils
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Stem Rot of Clematis
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chapter 11

Pesticides

PESTICIDE USE AND SAFETY: A GUIDE FOR GARDENERS AND HOMEOWNERS*

chapter 11

Pesticides

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INTRODUCTION

Pesticide use is a controversial topic in the home landscape. Master Gardeners need to be informed of all aspects of the topic to be able to give unbiased, correct information. Extension recommendations start with least toxic alternatives first. This section follows the same philosophy. The individual sections discuss pesticides, both organic and non-organic; regulatory information; environmental and health issues; and risk management.

LEARNING OBJECTIVES

Learning objectives of this section for Master Gardeners are to:

1. Learn the definition of the term pesticide.
2. Learn about pesticide types, formulations, and additives.
3. Understand the purpose and use of pesticide labels.
4. Learn about pesticide application and equipment.
5. Learn about pesticide storage and disposal.
6. Understand pesticide toxicity.
7. Learn about potential environmental hazards.
8. Learn about pesticides and the law.
9. Answer the question "Do you really need a pesticide?"

TOPICAL OUTLINE:

- Types of pesticides
- Pesticide formulations and additives
- Pesticide labels
- Pesticide application equipment
- Calibrating pesticide application equipment
- Applying pesticides safely
- Pesticide storage and disposal
- Pesticide toxicity
- Pesticide safety and poisoning symptoms
- Potential environmental hazards
- Home yard and garden vs. commercial pesticides
- Pesticides and the law

*** Note:** The information in this section of the Master Gardener Core Course Textbook applies to the use of pesticides in the home yard and garden environment. Commercial pesticide applicators have additional regulations to follow and may have increased health and environmental hazards associated with the use of commercial pesticides.

PESTICIDE ALTERNATIVES

- Select plants resistant to insects and diseases.
- Remove dead plant material that could harbor insects or diseases.
- Pull weeds before they bloom.
- To keep insects away without pesticides, try physical barriers such as cheesecloth, netting and row covers. Surround developing plants with tin can collars to protect against insects that feed or lay their eggs at a plant's base.
- Try removing pests with a forceful jet of water.
- Spray plants with insecticidal soaps to kill soft-bodied insects such as aphids and grubs.
- Try a natural insecticide such as *Bacillus thuringiensis* (Bt), which has been shown to be effective against caterpillars and beetles without harming humans or wildlife.
- Spread boric acid liberally in areas where insects typically enter houses to kill ants and roaches. Boric acid should not be used where children or animals may encounter it.
- Plant a variety of crops that flower throughout the season (such as marigolds) to deter some pests.
- Remove sources of food, water and cover for pests.

What Exactly are Pesticides?

The word **pesticide** is a general term used to describe any natural or man-made substance or mixture of substances that is used to destroy a pest, control its activity, or prevent or reduce the damage they cause. The suffix "cide" (derived from the Latin word "cida") literally means, "kill." The term pesticide refers most often to a chemical substance that kills pests. Combining the name of the pest (e.g. insect or mite) with the suffix "cide" describes what type of pest a pesticide kills. It is incorrect to assume that the term pesticide refers only to insecticides. Pesticides include many different types of products with different functions.

Not all pesticides kill pests. **Plant growth regulators** stop or control how plants develop; **sterilants** keep pests from reproducing; **repellents** ward off insects, birds, pets, or other animals. Although these chemicals or substances are not pesticides in the true sense of the word, the same laws affecting pesticides regulate them.

Many chemicals or substances used as pesticides have other uses as well. Boric acid, used as an insecticide to control cockroaches, can also be used as a disinfectant in eyewash solutions, and act as a flame retardant when applied to clothing. Common table salt has been used as an herbicide to control cactus in the Southwest United States. Ordinary beer has been used to control garden slugs.

Common examples of pesticides in and around the home include:

Insecticides and **Miticides** (kill or repel insects, ticks, and mites)
- Garden dusts and sprays
- Horticultural soaps and oils
- Mosquito and tick repellents
- Bug sprays
- Ant and roach baits
- Flea shampoos, flea and tick collars
- Mothballs

Herbicides (kill weeds or unwanted plants)
- Weed killers
- Weed-and-Feed lawn care products
- Brush killers

Fungicides (kill mold, mildew and other fungi)
- Rose and flower sprays
- Treated seeds
- Paint additives to prevent mildew growth

Rodenticides (kill rodents such as mice and rats)
- Mouse and rat bait stations

Disinfectants (kill bacteria, mold and mildew)
- Bleach
- Ammonia
- Disinfectant aerosols
- Kitchen and bathroom cleaners
- Tub and tile cleaners
- Pool and spa cleaners

Wood preservatives (protect wood from insects and fungi)
- Chemicals for pressure-treating wood

Before deciding to use a pesticide, determine what the problem is and the best way to treat it. Use non-chemical control (biological control, cultural control, mechanical control, sanitation) as the first line of defense, and consider pesticides only when the problem cannot be controlled by other means. If damage is only cosmetic and not a health risk to the plant, control may not be necessary.

If you do decide a pesticide is necessary, be sure to use the right product, the right timing, and the right formulation/application method. Remember, each pesticide is limited in what it can control. Insecticides will not control plant diseases, nor will they correct the damage from an insect that has come and gone. In addition, few plant diseases are cured by fungicides, which generally provide only preventative control. Using the right product, at the right time, in the right way will help you solve the problem safely and effectively without causing unnecessary environmental harm.

When purchasing pesticides, select the smallest container that will still provide the coverage you need. Few homeowners have proper storage conditions to keep pesticides from year to year. Many pesticides require winter protection from freezing temperatures and some require protection from moisture.

TYPES OF PESTICIDES

The chemical names of pesticide active ingredients are usually so long and complex that they are generally used only in the active ingredient statement on the pesticide label and in scientific or technical publications. The common name of a pesticide active ingredient is one that is commonly used and has usually been approved by an appropriate scientific group. The trade name of a pesticide active ingredient is a copyrighted name used by its producer. A pesticide active ingredient will usually have only one common name but it may have several trade names. For example, glyphosphate is the common name for the chemical isopropylamine salt of N-(phosphonomethyl) glycine, the active ingredient in Roundup®. These trade names should not be confused with the brand names used by formulators and distributors of pesticide products (for example, Ortho). Pesticides can be grouped according to how they work. Many work in more than one way. For example:

- **Contact pesticides** must make direct contact with a pest to kill it.
- **Stomach poisons** kill when swallowed.
- **Systemics** function by entering and becoming distributed within a pest or within plants on which the pest feeds.
- **Translocated herbicides** move from the point of initial application to circulate throughout the plant. Circulation ensures death of the entire plant including the root system.
- **Fumigants** are gasses that kill when they are inhaled or otherwise absorbed by pests.

Pesticides can also be divided into two categories based on the range of pests they affect:

- **Selective pesticides** kill only certain kinds of plants or organisms; for example, 2,4-D kills broadleaf lawn weeds but does not harm most grasses.
- **Nonselective pesticides** kill most plants or organisms. Roundup® and Kleenup® area good examples of a nonselective post emergence herbicides because they kill all vegetation in the target area.

Pesticides can also be classified on the basis of their chemical structure or origin. The **inorganic pesticides** are those which contain no carbon in their chemical structure. The **organic pesticides**, those that contain carbon, are usually synthetic but some are obtained from natural sources such as plants or microorganisms. Some synthetic organic pesticides such as the pyrethroids, or synthetic pyrethrins, are based on naturally occurring chemicals.

Finally, pesticides can be classified for **"general use"** or **"restricted use"**. Pesticides with high potential for health or environmental risks are classified as **"Restricted Use,"** requiring licensing (training) for purchase and application. Restricted Use pesticides are not for use by home gardeners.

In 1996, the Environmental Protection Agency (EPA) de-regulated many common household products (such as alcohol, soaps, oils, and herbal treatments) as pesticides for home yard and garden use. This allows non-commercial, home gardeners to legally use these products for pest control. No endorsement of effectiveness is implied, The de-regulation does not extend to commercial applications.

PESTICIDE FORMULATIONS AND ADDITIVES

The **formulation** describes the physical state of a pesticide and determines how it is applied. The chemical in the pesticide that actually kills is termed the **active ingredient.** Other components, which improve efficacy or make the product easier to mix or apply, are termed **inert ingredients.**

Gardeners often attempt to compare a spray with a dust. Note that a dust is a type of formulation, but a spray is not; sprays are one means of applying several different formulations (such as wettable powders or emulsifiable concentrates) mixed with water.

Common pesticide formulations are discussed below.

Aerosols (A) - These products are very low-concentrate solutions, usually applied as a fine spray or mist. They generally are sold in aerosol cans and are a convenient, but expensive, way to apply a pesticide. Some aerosols are dissolved in petroleum distillates and thus are flammable.

Baits (B) - A bait formulation is made by adding the active ingredient to an edible or attractive substance. Baits often are used to control slugs, snails, small ground insects, and rodents.

Dusts (D) - Dust formulations are made by adding the active ingredient to a fine, inert powder or talc. They generally are used dry. Dusts are more likely to drift than liquid formulations because of their light weight and poor adhering qualities.

Emulsifiable concentrates (EC or E) - In these formulations, the active ingredient is mixed with an organic solvent (often a petroleum derivative) and an emulsifying agent. These materials form an emulsion when mixed with water for application (i.e., droplets are dispersed throughout the water). ECs are common because they are easy to mix and use. Protect them from freezing temperatures, which can break down the emulsifier. One characteristic of many ECs is that they turn water white. They also can cause minor surface bronzing of light-colored fruit. Because ECs are oil-soluble, they penetrate skin more readily than most formulations. Take extra precautions to avoid skin contact with ECs.

Flowables (F or L) - These formulations consist of very finely ground solid materials (an active ingredient and a carrier) suspended in a liquid. A flowable formulation is mixed with water to form a suspension in a spray tank.

Granules (G) - Granular formulations are made by adding the active ingredient to coarse particles (granules) of inert material such as fired clay. They are used dry.

Soluble powders (SP) - A soluble powder formulation contains an active ingredient in powder form that dissolves in water.

Solutions (S) - Solutions are preparations made by dissolving a solid, liquid, or gaseous active ingredient into another substance (usually a liquid) without a chemical change taking place. (Sugar dissolved in water is an example of a solution.). These formulations often are premixed (ready to use directly from the container); others must be mixed with water.

Wettable powders (WP or W) - Wettable powder formulations are made by combining the active ingredient with a fine, inert carrier such as talc or silicone. They look like dusts, but they are made to be mixed with water. These formulations are difficult to use because they need continuous agitation to maintain a suspension. When mixing a WP, first mix the measured quantity with a small amount of water to form a

slurry. A paper cup and Popsicle© stick make good disposable mixing tools. Then add this mixture and the proper amount of additional water to the spray tank. Shake the spray tank frequently to maintain the suspension.

Pesticide formulations and additives

Surfactants (also known as **additives** or **adjuvants**) improve pesticide coverage, thus reducing the amount needed and the risk of spray drift. When added to a pesticide, a surfactant reduces the surface tension between two unlike materials. For example, it may help oil and water mix to form a spray or may help spray droplets stick to a leaf.

Many pesticide products contain surfactants. In other cases, the product label suggests adding a surfactant when you mix the pesticide for spraying. Be aware that in some cases surfactants can increase the toxic effects of pesticides. Thus, if the label does not recommend addition of a surfactant, do not add one.

Surfactants include **activators; compatibility agents; deflocculators; detergents; dispersants; emulsifiers; foam** and **drift suppressants;** and **spreading, sticking,** and **wetting agents**. Each of these materials has a different purpose. For example:

- **Suspension agents** help keep a pesticide in suspension reducing the need for agitation.
- **Dispersants** reduce the attraction between like particles, thus enhancing dispersion of the spray.
- **Spreading and sticking agents** increase wetting (or coverage) of leaves, fruits, and stems. These materials are some of the most common types of surfactants.

When added to a pesticide mix, **spreaders** (also known as **wetting agents**) increase the area that a given volume of spray will cover. They also improve contact between the pesticide and the plant surface by reducing the surface tension of spray droplets. Most wettable powder insecticides benefit from the addition of a spreader. Overuse of spreaders, however, may cause runoff rather than better coverage.

Stickers (or **adhesives**) are added to a spray mix to improve the material's adherence (tenacity) to a plant surface. Sticking agents are oily in consistency and increase the amount of suspended solids retained on plant surfaces. Some stickers also protect spray from the effects of wind and rain, thus extending their usefulness. Most fungicides, especially wettable powders, benefit greatly from the addition of a sticker.

Whether a spray rolls off or sticks to a plant surface depends on the physical and chemical properties of the spray mixture and the physical properties of the surface itself. For example, if the plant surface is waxy, spray droplets roll off. Thus, spreading and sticking agents are most useful when spraying the hard-to-wet foliage of plants such as azalea, boxwood, camellia, carnation, conifers, euonymus, gardenia, gladiolus, holly, iris, narcissus, peony, roses, and yews.

Pesticide formulations and the application method

The pesticide formulation and application method, in combination, impact potential risks to the environment and human health. The following summarizes the pros and cons of common pesticide formulations and typical application methods used by gardeners and homeowners:

Sprays (applied with a tank sprayer)

Advantages:

- Resist washing or wearing off, once dried
- Provide superior control with small amounts of pesticides through better control of mixing and directing the spray
- Create less drift onto non-target areas and the person doing the application

Disadvantages:
- Involve a time-consuming process
- Cannot reach into taller trees and shrubs
- Require high equipment and maintenance costs

Sprays (applied with a hose-end sprayer)

Advantages:
- Resists washing or wearing off, once dried
- Cover large areas quickly
- Require no premixing (some brands of sprayers)
- Allow easy clean-up
- Are inexpensive
- May reach into medium size trees and most shrubs

Disadvantages:
- Provide poor calibration of product, reducing effectiveness
- Cause much of the pesticide to fall to the ground when applied to trees, shrubs, flowers, and vegetables
- Have a high potential for drift onto non-treatment areas and onto the person doing the application
- Uses 10 to 25 times more pesticide than tank sprayers for equivalent coverage

Ready-to-Use products (RTUs)

Advantages:
- Require no mixing
- Requires no additional equipment

Disadvantages:
- Expensive because of low percentage of active ingredient
- In the case of insecticides, typically require frequent reapplication

Dusts

Advantages:
- Are quick and easy to apply
- Usually ready to use; require no mixing or additional equipment
- Effective where moisture from a spray might cause damage
- Effective in hard-to-reach indoor areas

Disadvantages:
- Expensive because of low percentage of active ingredient
- Can easily blow or wash off treated plants; drift hazard high
- Can be picked up by bees and other pollen-gathering insects
- Are difficult to spread evenly
- Are difficult to direct to target area such as the underside of leaves
- Sometimes leave an obvious surface residue

Granules

Advantages:
- Ready to use; no mixing
- Drift hazard is low - particles settle quickly
- Low hazard to applicator - no spray, little dust
- Are preferred for soil applications - weight carries the formulation through foliage to soil target
- Simple application equipment - often seeders or fertilizer spreaders
- May be more persistent than wettable powders or emulsifiable concentrates

Disadvantages:
- More expensive than wettable powders or emulsifiable concentrates
- Must be watered or cultivated into the soil
- Can be used only for soil applications
- May need moisture to activate pesticidal action

Baits

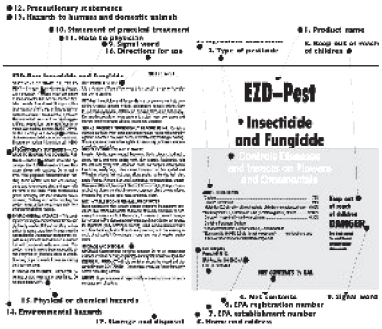
Advantages:

- Ready to use
- Entire area need not be covered, since pest goes to bait
- Controls pests which move in and out of an area

Disadvantages:

- Can attract and harm children, pets, and wildlife
- Pest may prefer the crop or other food to bait
- Dead pests may cause odor problem
- Other animals feeding on the poisoned pests may also be poisoned
- Can lose effectiveness if exposed to rain or irrigation
- Application costs are high

PESTICIDE LABELS



All of the printed information on or with a pesticide, including the label, brochures, and promotional fliers from the manufacturer or its agent, is called **labeling.** The actual **label** is a legal document designed to protect your health, crops and the environment. It is usually printed on or attached to a pesticide container. It tells how to use the product correctly and what special safety measures are needed. Specific parts of the label include the following:

- **Brand name (product name, trade name)** - Each company that manufactures pesticides uses brand names to identify its products. The brand name shows up plainly on the front of the label. Examples of some common product brand names include Deep Woods Off Insect Repellent®, Black Flag® Ant & Roach Killer, Lysol® Brand Disinfectant & Deordorizing Cleaner, Roundup® Herbicide, and Hi-lex® Bleach.
- **Type of formulation** - A description of the physical state of the pesticide that determines how it is applied. Be aware that the same pesticide may be available in more than one type of formulation. For example, Sevin® (carbaryl) can be purchased as a 4-5% dust, a 5% granular bait, a 50-80% wettable powder, or an 80% emulsifiable concentrate.
- **Ingredient statement** - Each pesticide label must list the names and amounts of active ingredients and the amount of inert ingredients in the product. The ingredient statement must list the official chemical names and/or common names for the active ingredients but the inert ingredients need not be named; the label must simply show what percent of the total contents inert ingredients comprise.
- **Common name and chemical name** - Pesticides have complex chemical names derived from their chemical composition. Some also are given a shorter name, or common name, to make them easier to identify. The same common name or chemical name may be sold under several brand names. When comparing two or more different products with the same active ingredient, be sure to compare the amount of active ingredient in each product. Often products will contain the same active ingredient, but in different concentrations. Make comparisons based on use rates that contain the same amount of active ingredient.
- **Net contents** - This statement tells how much product is in the container. Contents can be expressed in gallons, pints, pounds, quarts, or other units of measure.
- **Name and address of manufacturer** - The producer's or registrant's name and address must be displayed on the label.
- **EPA Registration number** - The pesticide industry is the most highly regulated industry in the world. A registration number must be on every pesticide label. It shows that the product has been approved by the Environmental Protection Agency (EPA) for the uses listed on the label.

The EPA registration number is not a guarantee of safety in all situations. The EPA registration number usually has two parts. The first number identifies the company and the second number identifies the product.

- **EPA Establishment number** - The establishment number tells which factory made the pesticide. The first number indicates the company and the second the location.
- **Precautionary statements** - A section with a title such as "Hazards to Humans and Domestic Animals," tells the ways in which the product may harm humans and other animals. It also describes any special steps necessary to reduce hazards, such as using protective equipment.
- **Environmental hazards** - The label tells how to avoid damage to wildlife, birds, fish, and bees or to the environment. Some examples are: "This product is highly toxic to bees exposed to direct treatment or residues on crop," "Do not contaminate water when cleaning equipment or when disposing of wastes," and "Do not apply where runoff is likely to occur."
- **Physical and chemical hazards** - The label lists specific fire, explosion, or chemical hazards. Examples are: "Do not puncture" and "Do not store near heat or open flame."
- **Signal words and symbols** - Some pesticides may be hazardous to people. Signal words give the user an idea of the relative toxicity of a pesticide. (Signal words and toxicity are discussed later in the chapter.).
- **Statement of practical treatment** - If swallowing or inhaling the product or getting it in the eyes or on the skin would be harmful, the label contains emergency first-aid measures and a statement of treatment for medical personnel.
- **Note to physicians** - The note to physicians provides emergency medical personnel with poison treatment information and antidotes. It often provides an emergency phone number to contact for further information. The pesticide label is the most important information to take to a physician when a pesticide poisons someone. Without the label, it is very difficult for a physician to help.
- **Directions for use** - This section lists the crops, animals, or sites on which the product legally can be used, as well as many of the pests the product will control. It also tells how to apply the product, how much to use, and where and when to apply the material.
- **Preharvest interval** - When a pesticide is used on fruits, vegetables, or other food crops, a certain period of time must pass from the time of application until the crop is safe to pick and use. Known as the preharvest interval and expressed as "days to harvest," this is the time required for the residue to degrade to safe levels. It often is listed as a number in parentheses following the crop name. Do not assume that the residue can be removed by washing. Tables for the minimum days from the last application to harvest for fruits and vegetables are provided in Appendix B.
- **Misuse statement** - This section is a reminder that it is a violation of federal law to use a product in a manner inconsistent with its labeling.
- **Storage and disposal directions** - Every pesticide should be stored and disposed of correctly. This section tells how to store and dispose of left over product and its container.

Always read the label before buying the product, before using, before storing and before disposal! Buy only as much pesticide as you will use during the year. Mix only the amount needed for each application.

Before you buy a pesticide, read the label to determine:

- If the pesticide will control the pest or pests.
- If the pesticide can be applied safely and legally under the application conditions.
- Where the pesticide can and cannot be applied.
- Necessary application and safety equipment.
- The amount of pesticide needed for the application (buy only the amount needed).

Compare different pesticide labels, because often several different products will control the same pest. A comparison of the labels and product prices will help select the product that controls the pest and is less toxic and/or less expensive.

Before you mix the pesticide, read the label to determine:

- Protective equipment you should use.
- Compatibility of the pesticide with other products or additives.
- Amount of the pesticide to use.
- Mixing procedure.

Before you apply the pesticide, read the label to determine:

- Safety measures you should follow.
- Procedures to follow to minimize potential harm to people, animals, plants or the environment.
- How to apply the pesticide.
- When to apply the pesticide (including the limitations about re-entering a treated area and the minimum number of days that must elapse after the application before fruits, vegetables, or other edible crops can be harvested - see Appendix B).

Before you store or dispose of the pesticide or pesticide container, read the label to determine:

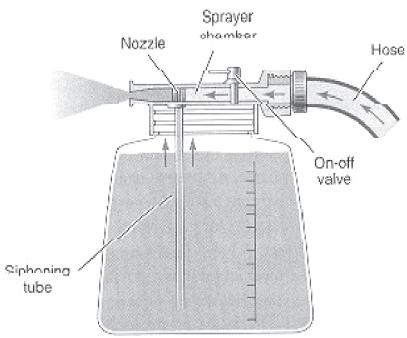
- Where and how to store the pesticide.
- How to decontaminate and dispose of the pesticide container.
- Where and how to dispose of surplus pesticides.

PESTICIDE APPLICATION EQUIPMENT

Pesticide application equipment for homeowners and gardeners comes in all shapes, sizes, types and prices. Select equipment that best meets your needs.

Special Note: Using the same application equipment for weed control and other pest control is neither safe nor desirable. No matter how well you rinse a tank or sprayer after using an herbicide, residue may be left in the tank or hoses, and on gaskets and other parts. If you use the same equipment to spray a plant with insecticide or fungicide, the herbicide residue may harm the plant. The wisest policy is to maintain two sprayers - one for herbicides and another for insecticides and fungicides. **Label them clearly according to use**. And, always triple rinse sprayers after each use.

Some common types of pesticide application equipment are discussed on the following page.



Proportioners (hose-end sprayers)

These inexpensive, small sprayers are designed to be attached to a garden hose. A small amount of pesticide is mixed with water and placed in the receptacle. A tube connects this concentrate to the opening of the hose. When you turn on the water, the suction created by the water passing over the top of the tube pulls the pesticide concentrate up and into the stream of hose water. The stream can reach into a tree canopy if water pressure is high.

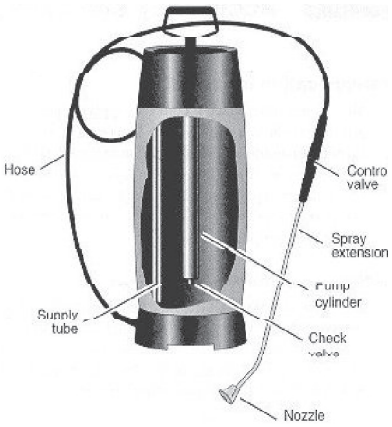
Some hose-end sprayers control spraying by means of a thumb hole. When the hole is uncovered, the sprayer stops spraying. Others use a trigger device to control spraying.

These sprayers are popular because of their low cost, but they have several potential problems:

- They may distribute spray unevenly.
- They may dispense too much spray for many needs and may use excessive amounts of pesticides. Their low price is quickly negated if excessive pesticide is used. However, these sprayers can be appropriate for soil application of pesticides, where you need a high volume of water to move the chemical into the soil.
- Nozzles may clog.
- The metering of concentrate into the stream of water can be inaccurate because it is determined partially by water pressure.

If you use a hose-end sprayer, make sure the sprayer or your water spigot is equipped with an anti-siphon (anti-backflow) device to prevent back siphoning of toxic chemicals into your water system.

Compression sprayers (knapsack or tank sprayers)



With these sprayers, the spray solution is mixed in a small tank (generally 1 to 5 gallons). A hand-operated pump supplies pressure during application. Because water weighs approximately 8 pounds per gallon, small tanks are easier to use than large ones. A uniform concentration is maintained because the pesticide is mixed with a known quantity of water. However, although these sprayers meter out pesticide more evenly than hose-end sprayers, they do not maintain pressure as evenly unless pumped frequently. Also, frequent agitation of the mixture is necessary when using a wettable powder formulation. With practice, you can achieve excellent coverage with these sprayers, making them a good choice for treating small trees, ornamentals, and vegetables. The spray will not reach into tall trees, however.

Spreaders (drop and rotary)

Two basic types of spreaders are available for home yard and garden use: drop and rotary. Drop spreaders have a full-width agitator over a row of metering ports and granules are dropped straight down. The width of the swath of a drop spreader is equal to the width of the hopper. Drop spreaders generally give a more uniform distribution pattern, if used correctly, but are sensitive to correct swath width. On each pass, the wheels must be overlapped inside the previous wheel tracks to avoid turf stripes. Rotary (sometimes called broadcast) spreaders typically have one to three metering ports that drop the granules onto a spinning impeller. The swath width varies with product but is wider than the spreader hopper. Rotary spreaders have wider patterns so the product can be spread over a lawn faster than with a drop spreader. Rotary spreaders are more forgiving of swath width errors, but their spreader pattern may not be as uniform. More care is needed with rotary spreaders to avoid throwing granules into non-target areas.

Hand dusters

A duster may consist of a squeeze tube or shaker, a plunger that slides through a tube, or a fan powered by a hand crank. Uniform coverage of foliage is difficult to achieve with many dusters.

All pesticide application equipment has some limitations, making it necessary to have access to several types. The situation and specific pest problems often dictate which type of application equipment to use. Unless specifically prohibited on the label, any application method is allowed when applying pesticides. For example, a liquid lawn weed control product can be applied with a hand pump sprayer, a sprinkling can, a bottle with a trigger sprayer or a paint brush.

The chemical may also indicate the type of equipment to use. For example, most formulations of benomyl (a fungicide) are wettable powders. A wettable powder is generally incompatible with a hose-end sprayer, so benomyl should be applied with a pressure tank sprayer.

CALIBRATING PESTICIDE APPLICATION EQUIPMENT

Before mixing or loading pesticides, calibrate the equipment. **Calibration** means adjusting the equipment so that it applies the right amount of pesticide in the right place. It should be done every time you switch chemicals or change application rates.

There are several reasons for calibrating equipment:

- **The settings given on pesticide labels are only a guide.** Actual settings needed to deliver the recommended rate may differ.
- **All applicators are not identical.** Small differences in equipment may cause changes in the application rate.
- **Equipment wear may increase the application rate and change application patterns.** For this reason, spot-check the calibration rate before each season, even if the pesticide or the application rate has not changed.
- Even though pesticide granules seem similar, they are not. **Each pesticide has its own flow characteristics,** which can change with moisture and temperature changes. You must calibrate your applicator when these conditions change as well as when you switch pesticides.

There are many ways to calibrate pesticide application equipment (Specific methods of calibrating application equipment are beyond the scope of this chapter.). The important thing is to select a method you understand and perform it faithfully.

APPLYING PESTICIDES SAFELY

Pesticides can increase the quality and quantity of our food supply, prevent disease and improve the comfort and aesthetics of our environment. The use of pesticides, however, is not without risks. It is the responsibility of every pesticide applicator to prevent harm from occurring to humans, pets, livestock, wildlife or the environment.

Did you know?

- Deaths from occupational exposure to pesticides are unusual.
- Children under 10 years old represent 50% of the accidental death by pesticides!
- Eating or drinking the product causes nearly all pesticide deaths!
- About 90% of the exposure that a pesticide user receives is dermal! Thoughtfulness and use of appropriate clothing will reduce pesticide exposure.

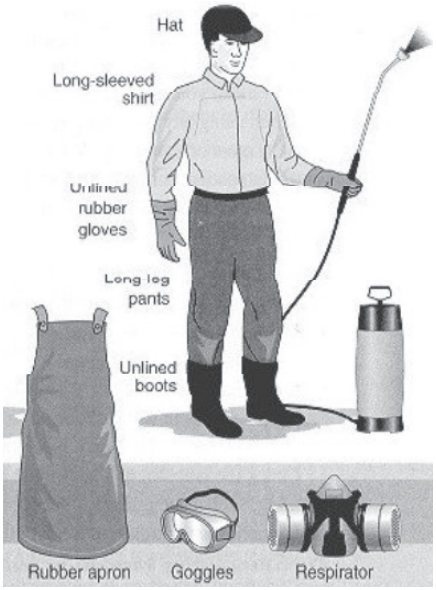
Handle pesticides safely!

From purchase to disposal, pesticides demand cautious handling. Follow these guidelines when you use a chemical pesticide:

- Read the label before you buy the product to be sure it is registered for the pest and site you wish to treat. Choose the lowest toxicity pesticide that can be used legally on the target area, crop or plant and that will safely and effectively control the pest. Remember, plan ahead and buy no more pesticide than you need. Avoid bulk purchasing. When it comes to pesticides, small potential savings in purchase price is greatly offset with the high cost of disposal.
- Keep pesticides separate from other items in a shopping cart, and make sure they are wrapped in a separate bag at the checkout counter.
- Transport pesticides in the trunk of the car instead of the backseat to avoid contaminating the car interior in case of breakage.
- Read the entire label before using the pesticide even if you have used the same product before. Follow all instructions exactly.
- Observe all safety precautions on the label, such as "Keep out of reach of children" and "Do not use near fire, sparks, or flame."
- Wear protective clothing, especially items specified on the label. Always wear liquid-proof gloves (unlined; at least 12 inches long of neoprene, Nitrible, butyl rubber or other materials approved for pesticides. Latex gloves designed for household cleaning and dish washing are not adequate. Never use leather or cloth gloves that could absorb chemicals.); chemical-resistant shoes, a long-sleeved shirt, long-legged pants or coverall-type garment and a wide-brimmed hat that covers the back of the neck. A respirator that is approved for pesticides may be needed for some pesticides that pose a risk from inhalation.

- Avoid wearing soft contact lenses when dealing with pesticides. Soft contact lenses may absorb pesticide vapors from the air and hold them against your eyes. Wear a face shield or safety goggles over regular glasses.
- Never eat, drink, smoke or go to the bathroom while handling pesticides; wash your hands thoroughly with soap and water after handling pesticides.
- If you mix or dilute the pesticide, do so only in well-ventilated areas. Mix only the amount you need; do not mix a large batch and store for later use.

- Remove pets and toys from areas to be treated. Keep them out of the area until the spray thoroughly dries or dust settles. For kitchen cabinets, remove food, dishes, pots and pans before you treat the shelves. Wait until shelves are dry before returning utensils. Observe the re-entry period according to the signal word on the label (i.e., Caution - 4 to 12 hours; Warning - 24 hours; Danger - 48 hours).
- Provide good ventilation while you are applying pesticide indoors. If you are applying pesticide outdoors, close the windows of your house.
- Avoid mixing or applying pesticide near wells or open water.
- Do not apply pesticide to blooming plants, especially if honeybees or other pollinating insects are visiting them. If you must treat blooming plants, do so in the early evening and use a non-dust formulation. Do not spray near or on bird's nests.
- To minimize drift, apply pesticides only when there is a breeze of less than 5 miles per hour. If even moderate winds come up while you are spraying, stop immediately. Reduce drift by spraying at low pressure (do not pump the spray tank to maximum pressure) or by using a nozzle with a larger orifice. Generally, drift is least likely to occur in early morning or late evening.
- Choose pesticide formulations that do not evaporate easily (Vaporization is the evaporation of an active ingredient during or after applica tion.). Pesticide vapors can injure non-target plants. Since high temperatures increase vaporization of many chemicals, do not spray when temperatures will exceed 85° F following application.
- Evaluate your control effort. If it is unsatisfactory, consider these possibilities:



  - Did you correctly identify the pest and use the correct pesticide?
  - If you used a wettable powder, did you shake the tank frequently? If not, the pesticide may have settled to the bottom of the tank, so that you sprayed only water!
  - Did you apply pesticide to the correct site? For example, you must spray for spider mites and aphids on the undersides of leaves, not the tops.
  - Did you time your treatment correctly? For example, it is more effective to treat pests when their populations are low than to wait until populations are high.
  - Rainfall shortly after your treatment may reduce its effective ness. Even in this case, you must still follow re-treatment intervals stated on the label.
  - Old product (generally over two years) may have lost its effectiveness.
  - The pests may be resistant to the pesticide - but this is usually not the case in around-the-home pest control.

Clothing clean-up

When you are finished using pesticides, **wash yourself and your clothes.** Showering is better than bathing because pesticide lingers in bath water. Clothing should be cleaned using the following guidelines:

- Read the pesticide label for special cleaning information.
- Pre-rinse contaminated clothing by pre-soaking in a suitable container, agitating in an automatic washing machine, and/or spraying/hosing the garment(s) outdoors.
- Keep clothing used during pesticide application separate from family laundry.
- Always pre-treat using a suitable pre-wash product.
- Launder clothing using hot water (140° F/ 60° C), full water level, and normal wash cycle (12 minutes).
- Re-wash the contaminated clothing two to three times if necessary.
- Use more detergent than recommended by the product label.
- Wash only a few contaminated garments at a time, using lots of water.
- Launder clothing daily when applying pesticide daily.
- Clean washing machine after use by running it without clothing through a normal wash cycle.
- Line-dry clothing (sun's rays break down some pesticides).

If you are sprayed by accident, change clothes and shower immediately. Use first-aid procedures if necessary.

Application equipment and clean-up

Do not store mixed pesticides. Spray leftover mixed pesticide over an area that it will not harm. Check the pesticide label to determine safe areas that may be legally treated. **Never rinse pesticides down the drain!**

Thoroughly clean all pesticide application equipment, including mixing tools, inside and out with clean water immediately after use. If a sprayer was used, rinse it with a small amount of water and spray over an area that may be legally treated. Be careful not to let the cleaning water damage crops and do not dump it all in one place where it will be concentrated and may become a pollutant. Clean the sprayer, including hoses and nozzles, with water or as directed on the label. Triple rinse with clean water and allow to dry.

PESTICIDES STORAGE AND DISPOSAL

Store pesticides properly

- Store pesticides out of reach of children and pets. Federal and state laws require that all pesticides must be stored out of the reach of children. Courts have interpreted this as a locked cabinet or storage unit.
- Protect the pesticide from temperature extremes (some can be damaged by freezing or excessive heat) and direct sunlight.
- Store pesticides only in their original container with labels visible and intact. Transferring a pesticide to another storage container greatly enhances the potential for accidental poisoning or misapplication. Never store pesticide in an old food or drink container because children may mistake it for something edible. Transferring a pesticide to another container is also a violation of federal law, with penalties of heavy fines and imprisonment.
- Store all pesticides away from food, feed, seed, fertilizer, and water or flammable materials. Store pesticides only in a well-ventilated building. Never store pesticides in the living area of a home.
- Seal containers tightly after using and check containers often for corrosion and possible leakage.

- Mark the date on containers that are put into storage with a permanent marker and keep an up-to-date list of products and purchase dates near the storage area. Use oldest products first. Do not store pesticide for more than two years; many break down after that time (Three notable exceptions include Diazinon®, Malathion® and Sevin® that have a typical shelf life of 5 years).

Dispose of excess pesticide properly

If you have pesticide that you no longer need:

- Never put potentially hazardous waste, such as pesticides, directly in the garbage.
- Do not pour remaining chemicals down the drain. Bathroom cleaners and drain cleaners, however, can be flushed down the drain with plenty of water.
- Evaporate solvent-containing pesticides in an area where they will not be disturbed by children or pets. Check the label for the presence of solvents such as carbon tetrachloride, chlorinated solvents, petroleum distillates, toluene or trichloroethane.
- Share remaining pesticides with someone who can use them as intended on the label.
- Check if your community has a household hazardous waste collection program. If you have questions about disposal, look in the yellow pages of the phone directory under "Waste Disposal - Hazardous" or contact your local county solid waste office, or call the office of Environmental Assistance at 1-800-657-3843.

Dispose of containers properly

Empty pesticide containers are considered hazardous waste unless they are properly processed. Follow these guidelines:

- Triple rinse empty glass, plastic and metal pesticide containers by filling the containers ¼ full of water, covering tightly and shaking. Triple rinsing will remove more than 99% of the pesticide residue remaining in an empty container. Apply the rinse water on the original target area.
- Do not re-use empty pesticide containers and never allow children to play with them.
- Punch holes in metal, plastic, or cardboard containers, crush them, wrap them in newspaper and put them in the trashcan for collection.
- Wrap aerosol containers in several layers of newspaper and put them in the trashcan for collection.
- For glass containers, break the container if possible. Otherwise, replace the lid, wrap the container in newspaper, and place it in the trashcan for collection.
- Use up, share or wrap the following in newspaper and save for a house hold hazardous waste collection site: pest strips, pet collars, pet shampoos and pet dusting powders.

Handle spills correctly
Accidental pesticide spills require special handling. Follow these guidelines:

- Do not leave the spill unattended. Send someone else for help.
- Keep people, especially children and pets, upwind and away from the spill until it is cleaned up.

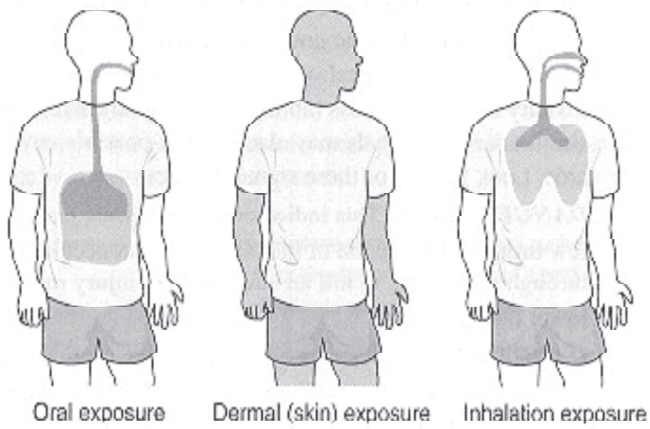
- If pesticide was spilled on someone, wash it off immediately and give the correct first aid as indicated on the label.
- Protect yourself during cleanup by wearing the protective clothing and equipment listed on the pesticide label.
- If the spill occurs indoors, ventilate the area with fans, and open windows and doors.
- Do **not** hose down the area. This only spreads the pesticide.
- Try to confine the area of the spill. Use a non-flammable absorbent material such as cat litter, sand, sawdust, or soil.
- Put the absorbed material in a non-corroding container such as a plastic bucket with a tight-fitting lid.
- Seal the container and label it with the product name, amount and absorbent material used. In some communities, the material will need to be safely stored until the community holds a household hazardous waste collection.

PESTICIDE TOXICITY

Although pesticides are designed to control pest problems, they can be toxic to desirable plants and animals, including humans. It is important for anyone using a pesticide to understand how pesticides may affect them.

How pesticides enter the body

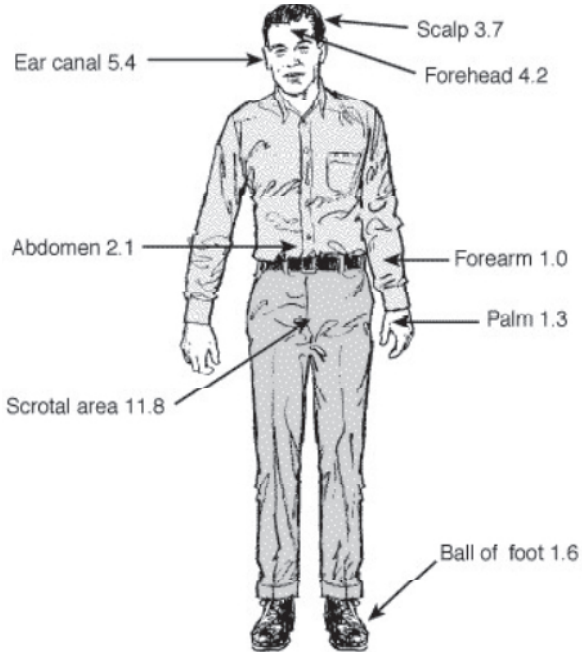
There are three major routes of entry for pesticides into the body:



- **Oral Exposure** - Oral exposure refers to the intake or absorption of a pesticide through the mouth or digestive system. Generally, the oral intake of a pesticide is due to an accident such as trying to blow a plugged spray nozzle clean; drinking from a container (such as a pop bottle) which should never be used even temporarily to store a pesticide; or failing to wash after handling a pesticide and this contaminates the food being eaten.

- **Dermal Exposure** - Dermal or skin exposure accounts for about 90 percent of the exposure a pesticide user receives. It may occur any time a pesticide is mixed, applied or handled, and is often undetected. Dry materials such as dusts, wettable powders, and granules, as well as liquid pesticides, can be absorbed through the skin. The seriousness of dermal exposure depends on (1) the dermal toxicity of the pesticide, (2) rate of absorption through the skin, (3) the amount of pesticide on the skin, (4) the size of the skin area contaminated, and (5) the length of time the pesticide is in contact with the skin.

  Rates of absorption through the skin are different for different parts of the body as shown in the figure below. Compared to the dermal absorption rate through the forearm (absorption rate of 1), absorption through the lower groin area would be more than 11 times faster.



Absorption continues to take place on all of the affected skin area as long as the pesticide is in contact with the skin. The seriousness of the exposure is increased if the contaminated area is large or if the material remains on the skin long enough to allow for absorption.

- **Inhalation Exposure** - Inhalation exposure results from breathing in pesticide vapors, dust, or spray particles. As in the previous types of exposure, inhalation exposure is more serious with some pesticides than with others, particularly fumigant pesticides.

  Inhalation exposure can occur when protective equipment is not worn and a person breathes in the vapors or spray mist while mixing and/or applying pesticides. Exposure can also occur from breathing in smoke from burning pesticide containers or the smoke from pesticide contaminated smoking materials (cigarette, cigars, etc.).

Toxicity defined

Toxicity can be simply defined as any adverse effect resulting from exposure to a chemical. The toxicity of a pesticide is usually one of two types: **acute** or **chronic**, based on the number of exposures to the pesticide and the time it takes for symptoms of poisoning to occur or develop. The adverse effects produced by chemicals range from slight symptoms (acute) such as headaches, nausea, or dizziness to more severe symptoms like convulsions, coma, or even death. Most acute toxic symptoms are reversible and do not cause permanent damage if there is prompt medical treatment. The chronic toxicity of a pesticide, however, can cause irreversible (permanent) damage.

Acute Toxicity

The **acute toxicity** of a chemical refers to its ability to do damage (internal, external or both) as a result of a **one-time** or **short-term exposure** to a relatively **large amount** of the chemical. The acute toxicity of a pesticide is expressed by its **median lethal dose** or **LD_{50} level.** The LD_{50} level is the milligrams of active ingredient per kilogram of body weight that will kill 50 percent of the test population of animals (usually rats and rabbits). This means that the lower the LD_{50} value the greater its toxicity and the higher the LD_{50} value the less toxic the pesticide. However, a pesticide with a high LD_{50} can be toxic even if only a very small amount is absorbed.

The **signal word** on a pesticide label is based on the acute toxicity of the pesticide. Acute toxicity may be measured as acute oral (through the mouth), acute dermal (through the skin), and acute inhalation (through the lungs). The LD_{50} values for each of these categories of acute pesticide toxicity are shown later in this section.

Chronic Toxicity

Chronic toxicity refers to harmful effects produced by **long-term, low-level exposure** to pesticides. Less is known about the chronic toxicity of pesticides, not because it is of less importance, but because chronic toxicity is much more complex and subtle in how it presents itself. In the past greater emphasis was placed on the acute rather than the chronic, toxic effects of pesticides. While situations resulting in acute exposure (a single large exposure) do occur, they are usually the result of an accident or careless handling. On the other hand, persons may be routinely exposed to small amounts of pesticides while handling, mixing, loading, and applying pesticides or while working in areas where pesticides have been applied.

It is not possible to assess chronic toxicity of a pesticide in the same way as an LD_{50} level is used to determine acute toxicity. Instead, a number of different tests are performed on animals, which help to predict whether a pesticide will cause a number of possible long-term effects. Test animals are exposed to sub-lethal levels of pesticides for periods ranging from about 90 days to several years. They are examined for a wide variety of toxic effects from dermal, oral and respiratory exposure. Such effects include:

Carcinogenicity - ability to produce cancer or to assist carcinogenic chemicals.

Mutagenicity - ability to cause genetic changes.

Teratogenicity - ability to cause birth defects.

Oncongenicity - to induce tumor growth (not necessarily cancers).

Liver damage - death of liver cells, jaundice (yellowing of the skin), fibrosis and cirrhosis.

Reproductive disorders - such as reduced sperm count, sterility, and miscarriage.

Nerve damage - including accumulative effects on cholinesterase depression associated with organophosphate insecticides.

Allergenic sensitization - development of allergies to pesticides or chemicals used in formulation of pesticides.

Label Identification of Acute and Chronic Toxicity

To alert pesticide users to risks associated with the acute toxicity of a pesticide, a signal word must appear on the label. Signal words alert the user as to whether the chemical is highly toxic, moderately toxic or slightly toxic. These signal words are usually based on the acute toxicity of the active ingredient(s). The signal word is used to represent the greatest risk category for that chemical. For example, if a pesticide has an acute oral toxicity level that would place it in the slightly toxic category, but its dermal toxicity is highly toxic, then the signal word on the label would reflect the toxicity risk posed by dermal exposure. Skin and eye irritation can also influence the signal word on a pesticide label. The table below describes the three signal words in layman's terms:

TOXICITY CATEGORY	SIGNAL WORDS REQUIRED ON LABEL BY EPA	ORAL LD_{50} (MG/KG)	DERMAL LD_{50} (MG/KG) 24-HR EXPOSURE	ORAL DOSAGE TO KILL AN ADULT (Less for children)
Hightly toxic	DANGER<POISON, Plus Skull and Crossbones Symbol	0 to 50	0 to 200	A few drops to 1 tsp.
Moderatel Toxic	WARNING	50 to 500	200 to 2000	1 tsp. To 2 tsp.
Slightly Toxic	CAUTION	500 to 5000	2000 to 20000	1 oz. To 1 pt. (1 lb.)
Low Toxicity	CAUTION	>5000	>20000	1 pt. (1 lb.) or more

Unlike the signal words used to express the acute toxicity of a pesticide, there are no signal words to express the chronic toxicity of that chemical. Instead, the label will state the specific chronic toxicity problem. Such a statement might read, "This product contains (name of chemical) which has been determined to cause tumors or birth defects in laboratory animals."

The recommendation to wear protective clothing together with a description of the type of protective clothing to be worn is based on both the acute and chronic toxicity of the pesticide. Exposure to the pesticide can be minimized, if not eliminated, by following the protective clothing recommendations.

The Risk Formula

Certain risks are inherent in life. Some are more acceptable than others. The risk in handling and using pesticides can be manageable. The risk is a function of product toxicity and the potential for personal exposure. The Risk Formula is:

Risk = Toxicity x Exposure

Knowledge of a pesticide's toxicity and the potential for personal exposure allows a user to manage the risk. If exposure is low enough, risk can be acceptable. Note that toxicity alone does not determine the risk of using a product. The application of the Risk Formula to gasoline is an example. Gasoline is very toxic when ingested, but can be handled safely. The product's toxicity is not changed, but the risk in handling it can be managed. No matter how toxic a substance may be, if the degree of exposure is kept low enough, risk can be managed.

PESTICIDE SAFETY AND POISONING SYMPTOMS

Awareness of the early symptoms and signs of pesticide poisoning is important. Unfortunately, **all pesticide-poisoning symptoms are not the same.** Each chemical family (organophosphates, carbamates, chlorinated hydrocarbons, etc.) affects the human body in a unique way.

Fumigants and solvents, for example, can make a person seem drunk. Symptoms include poor coordination, slurring of speech, confusion, and sleepiness.

Common pesticides such as carbamates and organophosphates injure the nervous system. Symptoms develop in stages, usually occurring in this order:

Mild poisoning or early symptoms of severe poisoning - Fatigue, headache, dizziness, blurred vision, excessive sweating and salivation, nausea and vomiting, stomach cramps, or diarrhea.

Moderate poisoning or early symptoms of severe poisoning - Inability to walk, weakness, chest discomfort, muscle twitches, constriction of pupils; earlier symptoms become more severe.

Severe poisoning - Unconsciousness, severe constriction of pupils, muscle twitches, convulsions, secretions from mouth and nose, breathing difficulty, death if not treated.

Illness may occur a few hours after exposure. **If symptoms start more than 12 hours after exposure to a pesticide, some other illness probably is responsible.** Check with your physician to be sure.

First aid is the help you can provide a victim while medical help is on its way. First, remove the victim from exposure; make sure the victim is still breathing, then call a physician, Poison Information Center, or police emergency number (911). Proper first aid depends somewhat on the way the pesticide entered the body. While you are waiting for help to arrive, do the following:

For skin exposure

- Remove clothing.
- Drench skin with water.
- Clean skin, hair and fingernails thoroughly with detergent and water. Detergents work better than soap for removing pesticides.
- Dry victim and wrap in a blanket.

For eye exposure

- Hold eyelids open and gently wash with running water for at least 15 minutes.
- Do not use chemicals or drugs in the water.

For inhaled exposure

- Carry victim (do not let them walk) to fresh air. Open all doors and windows.
- Loosen all tight clothing.
- Give artificial respiration if breathing has stopped (Do **not** administer **direct** mouth-to-mouth resuscitation if the victim has swallowed a pesticide.) and cardio-pulmonary resuscitation if heart has stopped.
- Keep victim quiet.

For swallowed exposure

- Quickly determine from the label (Read the "Statement of Practical Treatment") if you should induce vomiting. This is often the correct action, but there are important exceptions. When vomiting is recommended, make the victim sit up and drink large amounts of water or milk, then put your finger on the back of the victim's throat.
- Never induce vomiting if the victim is unconscious or convulsing.

Poison Information Center

Minnesota has a Poison Information Center that provides round-the-clock information on toxic substances. It is a valuable resource during emergencies involving poisons.

Have this information ready when you call:

- Your name, address, and telephone number.
- Brand name of suspected toxin and its label.
- How did the victim take in the toxin (swallowed, on skin, inhaled)?
- How long ago did exposure occur?
- What are the symptoms of the victim?
- If the victim is a child, what is the child's weight?
- What is the health history of the victim?

What the Poison Information Center can do for you:

- Evaluate the seriousness of the problem. Many types of exposure can be treated at home; others are truly life threatening and demand immediate medical attention.
- Advise first aid treatment.
- Refer you to experts if needed.

Telephone numbers of Poison Information Center:

o HCMC Hennepin Regional Poison Center at 1-800-222-1222 .

National Pesticide Telecommunications Network (NPTN)

The National Pesticide Telecommunications Network (NPTN) is a toll-free telephone service that provides information on pesticides and how to recognize and respond to pesticide poisonings. If necessary, staff at NPTN can transfer your call directly to a local poison information center. The service operates Monday through Friday, from 9:30 a.m. to 7:30 p.m., eastern time. Call NPTN toll free at 1-800-858-7378.

POTENTIAL ENVIRONMENTAL HAZARDS

There are several ways that pesticides can harm the environment or beneficial organisms.

Direct kill

Fine mists of herbicides can drift to nearby crops or landscape plants and kill them. Bees and other pollinators can be killed if a crop is treated with a pesticide when they are in the field. Pesticides also can kill the natural enemies of pest insects. Accidental spraying of ditches and waterways, careless container disposal, and leaching of harmful chemicals through the soil can harm plants and animals in streams or ponds.

Give special consideration to protecting insect pollinators such as honeybees and bumblebees. Apply insecticides that are highly toxic to bees only when bees are not active, i.e., in late evening and early morning ***(This applies only to products like Malathion®, Thiodan®, Bacillus thuringiensis, Kelthane®, methoxychlor, pyrethrin, resmethrin, rotenone, and sabadilla; all other insecticides are highly toxic to bees exposed to direct treatment or residues on plants).*** **Do not apply insecticides that affect bees when plants (crops or weeds) are blooming.**

Persistence and accumulation

Although most pesticides break down quickly into harmless products, some break down slowly and stay in the environment for a long time. These pesticides are called **persistent**. Some persistent pesticides can build up in the bodies of animals, including humans. These pesticides are called **accumulative**. Most persistent pesticides, for example DDT, have very limited usage or no longer are available.

Compatibility and synergism

Compatibility occurs when two or more pesticides can be mixed together without reducing their effectiveness or harming the plant to which they are applied. For instance, carbaryl (Sevin®) often is combined with a miticide such as Kelthane® in order to kill both insects and mites at one time.

Synergism is the action of two materials that, when used together, produce a greater effect than the sum of the materials when used alone. Each of the materials used alone may have a limited effect, but the total effect is greatly increased when the two are used together. For example, chemical X kills 60 percent of a pest population and chemical Y kills 20 percent, but chemicals X and Y together kill 98 percent of the pests. Synergism may increase control or allow you to use less chemical, but it also may make pesticides more harmful to non-target organisms. A synergistic effect also may kill or damage the plant being protected.

Protect the environment!

Our **environment** is our surroundings: air, water, soil, plants and animals. All pesticide users have the responsibility to use pesticides correctly and safely. Pesticides can be a tool to protect the environment when used carefully, wisely, and judiciously. Consider the following environmental factors when using pesticides:

Temperature. Volatility, a change in the physical state such as from liquid to gas, is influenced by temperature. It increases with increasing temperatures. Liquid lawn weed control products applied at ambient temperature above 85° F have a greater chance of volatilization, which can cause injury to nearby susceptible plants. Apply these products in the morning when air temperatures tend to be cooler, relative humidity higher, and winds lighter.

Rain or Irrigation. Pesticides applied to a lawn right before substantial rain or irrigation may not be effective in controlling the target pest. As an example, an herbicide that controls growing broadleaf weeds on a lawn needs to stay in contact with the weed's leaves after application. Rain or irrigation too soon after the herbicide application removes the product from the weed surface and greatly reduces its effectiveness. Do **not** apply pesticides if a rain is forecast within 24 hours of application. This is especially important when spraying fungicides on fruit trees or herbicides on growing lawn weeds.

Wind. Wind can drift pesticides to non-target sites. An example is a lawn herbicide that blows onto a neighbor's fruit or vegetable garden. The amount of pesticide lost from the target area and the distance it moves both increase as wind velocity increases. A general rule of thumb is: **do not spray a pesticide when wind velocities are greater than 5 miles per hour.** Such wind is a gentle breeze that produces constant but light motion of twigs and leaves. Also, keep in mind the wind direction. Select a time when there is little wind (usually early morning) or the wind blows gently away from susceptible plants.

Water Resources. Once applied, a pesticide may move off the intended site if good management practices are not followed. Run-off can be caused by excessive irrigation or rain upon an area that has just received a pesticide application. A balance is often required. Some pesticides require a certain amount of water after application to move the product into the soil where it will be effective against the pest. Run-off water (because of excess rain or irrigation) away from the application site can contaminate surface water resources. Pesticides can be moved off-site in the water solution or while attached to soil particles during soil erosion (Some pesticides chemically bind to the soil particles in a process called **adsorption**. Soils high in organic matter or clay are more adsorptive than sandy soils.). If the soil is coarse or sandy, excess water also can move pesticides downward through the soil profile (leaching). **Never apply garden pesticides directly into lakes, streams, ponds, or wetlands.** Avoid using the following products near lakes, streams, ponds, or wetlands:

- ***Insecticides***: Cygon® (dimethoate), diazinon, dormant oil, Dursban® (chlorpyrifos), Imidan® (phosmet), Kelthane® (dicofol), Malathion®, Neem® (azadirachtin), nicotine sulfate, pyrethrum, pyrethrins,

resmethrin, rotenone, Sevin®, sulfur, and Thiodan® (endosulfan).

- ***Fungicides***: Benlate® (Benomyl), Bordeaux (copper sprays), captan, Daconil® (chlorothalonil), lime sulfur, Mancozeb® (Fore), Maneb®, sulfur, and Thiram®.
- ***Herbicides***: Amitrol T® (amitrole), Atrazine®, Balan®, Dacthal® (DCPA), Pramitol® (prometon), Treflan®/Preen® (trifluralin), all broadleaf lawn weed killers (2,4-D; MCPP, MCPA, Banvel®/dicamba).

HOME GARDEN VS COMMERCIAL PESTICIDES

Some pesticides are packaged specifically for home yard and garden use. These products are packaged in small quantities, for example, pints, quarts, ounces, or pounds. They seldom are highly toxic and usually are in low concentrations. The label rate is usually given on a per-gallon or per-square-foot basis.

Because of the limited label size on small containers, home yard and garden products may **not** list all of the plants and/or pests for which a product is registered. For example, one manufacturer sells Diazinon® 25 percent emulsifiable concentrate as both Fruit and Vegetable Insect Control and Diazinon® Insect Spray. They are basically the same product, but plants and pests listed vary greatly. This situation causes confusion for the consumer and stimulates the purchase of excessive amounts of pesticides.

Products packaged for commercial growers may seem less expensive, but do **not** be tempted to use them. They generally are more toxic than those for home use and require special protective clothing and equipment. These products are more concentrated and are sold in larger containers than homeowners can use or store safely. They also are much more difficult to calibrate and mix correctly since rates usually are based on a per-acre system.

The EPA classifies a few products that are extremely toxic to humans or the environment as “restricted-use” pesticides. Labels on these products state "Restricted-use pesticide for retail sale to and application only by certified applicators, or person under their direct supervision." A license from the Minnesota Department of Agriculture (MDA) is required for purchase and use of restricted-use pesticides. This license is intended for commercial growers and applicators and does **not** automatically authorize them to use these products in home gardens, even their own.

Protect yourself, your family, and the environment. **Do not use pesticides from the commercial trade.**

PESTICIDES AND THE LAW

The Environmental Protection Agency (EPA) and state departments of agriculture govern the registration and use of pesticides. Under the amended Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and Federal Environmental Pesticide Control Act of 1972 (FEPCA) and other amendments, **it is illegal to use a pesticide on a food crop unless the crop is listed on the label.** The rate of application on the label may not be exceeded. Fines and other penalties vary.

Property owners are legally liable for misuse of pesticides on their property. Recent court rulings extend that liability to include misuse by hired commercial applicators. Serious misuse by gardeners can result in treatment of a plant by the wrong pesticide or drift of a pesticide onto non-target plants and organisms. **Any use of a pesticide outside of label direction is a violation of federal and state laws punishable by fines and imprisonment.** Civil fines of up to $5,000 and criminal penalties of fines up to $25,000 and/or 1 year in prison apply.

Often, people ask whether it is safe to eat vegetables or fruits that have been sprayed with a pesticide. **The truth is that foodborne illnesses due to bacteria, molds, and yeasts pose a greater health risk than exposure to pesticide residues.** Fear among the public that pesticide residues in fruits and vegetables are linked to cancer rates is not scientifically based.

The Environmental Protection Agency (EPA) under the Food Quality Protection Act of 1996 sets the legal levels of pesticide residues that may remain on food sold to supermarkets or food processors. The Food and Drug Administration (FDA) tests food samples for pesticide residues and inspects them to make sure that only legally registered pesticides are used. The United States Department of Agriculture (USDA) tests meat, poultry and egg products for pesticide residues. If illegal pesticides or improper amounts are detected, the food is to be removed from the marketplace. Sometimes, however, fresh produce from your garden or from the grocery store may contain traces of pesticides. The following guidelines will minimize your exposure to pesticide residues:

- Choose foods carefully. Examine food for dirt, cuts, decay and mold.
- Eat a variety of foods every day to minimize your exposure to any one pesticide.
- Wash fruits and vegetables thoroughly under running water. Do **not** use household detergents or bleach on fruits and vegetables because the FDA does **not** recommend these for use with food.
- Peel fruits and vegetables to remove residues from the surface. If you want to eat the fiber-rich peelings, scrub the produce well. Peel away and discard outer leaves from cabbage and lettuce.
- To avoid pesticide residues in animal products, trim fat and skin from fish, poultry and meat, and discard pan drippings and broths.

DO YOU REALLY NEED A PESTICIDE?

Make sure you can answer **yes** to these questions before applying any pesticide.

- ***Have you identified the insect or disease causing the problem?***
- ***Is the level of damage substantial enough to warrant control?***
- ***Is the problem unlikely to go away if you do not take action?***
- ***Have you tried other cultural, biological, or mechanical control methods?***
- ***Is the pest present and in a vulnerable stage at the time you are planning to apply the pesticide?***
- ***Is the pesticide you've chosen registered for use on the plant or site you plan to treat?***
- ***Is the pest or disease you are spraying for listed on the pesticide label?***
- ***Have you chosen the least toxic pesticide registered for use on the pest and crop?***

GLOSSARY

Abiotic: Nonliving; also refers to plant problems caused by nonliving agents, such as drought, lawn mowers, string-trimmers, and so forth.

Abrasion: The process of wearing away by rubbing.

Abscisic Acid: A growth-regulating chemical found in plants that causes the stomata to close during drought stress.

Abscission: The separation of fruit, leaves, or stems from a plant.

Absorbent: The ability to soak up liquids.

Absorption: The process by which a chemical is taken into plants, animals, or minerals. Compare with adsorption.

Acid: A chemical compound that, when mixed with water, produces a solution with pH less than 7.0.

Acid Equivalent: The amount of active ingredient in a pesticide formulation given in terms of the acid from which it was made.

Active Ingredient: The chemical in a pesticide formulation primarily responsible for phytotoxicity to its target and which is identified as the active ingredient on the product label.

Activation: The process by which a surface-applied herbicide is moved into the soil, where emerging seedlings can absorb it.

Activator: A chemical added to a pesticide to increase its activity.

Acute Exposure: A single exposure to a pesticide, usually with a larger dose.

Acute Toxicity: The measure of the capacity of a pesticide to cause injury as a result of a single exposure.

Additive: A chemical added to a pesticide formulation to increase its effectiveness or safety.

Adherence: Sticking to a surface.

Adjuvant: Any non-pesticide material in a pesticide formulation or added to the spray tank to modify pesticidal activity or application characteristics.

Adsorption: The process by which chemicals are held on the surface of a mineral or soil particle. Compare with absorption.

Adulterated: Any pesticide whose strength or purity falls below the quality stated on its label. Also, a food, feed, or product that contains illegal pesticide residues.

Aerobic: Living in the air; the opposite of anaerobic.

Aerosol: An extremely fine mist or fog consisting of solid or liquid particles suspended in air. Also, certain formulations used to produce a fine mist or smoke.

Agitation: The stirring or mixing of a spray solution in a sprayer.

Algicide: Controls algae in swimming pools, lakes, canals, and water used industrially or stored.

Alkali: A chemical compound that, when mixed with water, produces a solution with a pH greater than 7.0. Alkali and acids can be used to neutralize each other.

Alkaloids: Chemicals present in some plants. Some are used as pesticides.

Allelochemicals: Chemical substances produced by plants that protect them from their natural enemies and environmental stress. Examples of allelochemicals include tannins and other phenolic compounds (such as tannic acid), terpenes (such as pine resins and fragrant chemicals in herbs and spices) and alkaloids (such as nicotine and morphine).

Allelopathy: The production of compounds by one plant which retard or inhibit the growth of another plant.

Anaerobic: Living in the absence of air; the opposite of aerobic.

Animal Sign: The evidences of an animal's presence in an area.

Annuals: Plants that live 12 months or less.

Antagonism: An effect that occurs when two or more pesticides are mixed together and their combined activity is less than if they were used separately.

Antibiotics: Chemical compounds, produced by microorganisms that are toxic to other microorganisms.

Anticoagulant: A rodenticide that kills the mammal by reducing its ability to froorm blood clots. Poisoned animals usually die by internal bleeding through leakage in capillaries and other blood vessels.

Antidote: A practical treatment for poisoning, including first aid.

Application Rate: The amount of pesticide applied to a site; usually expressed as the amount of liquid or dry material to apply per acre, square foot, animal, etc.

Aqueous: A term used to indicate the presence of water in a solution.

Aracnicide: Kills mites (See miticide).

Area Repellent: A chemical that causes a pest to leave once the chemical is smelled.

Arsenicals: Pesticides containing arsenic.

Artificial Respiration: Making someone breathe by mechanically forcing air into and out of the lungs.

Aseptic: Free of disease-causing organisms.

Attractant: Attracts pests (for example, lure an insect or rodent to a trap). Pheromones are chemical sex attractants often used to confuse mating behavior of insects.

Avoidance: A disease-management strategy in which using disease-free plants or planting in sites unfavorable for disease development keeps disease problems from occurring.

***Bacillus thuringiensis* (Bt)**: A bacterium that produces a poison that kills certain insects.

Backsiphon: A reverse flow that can draw a spray mixture from the tank into the water supply.

Bactericide: A chemical used to control bacteria.

Bacterium (bacteria): Microscopic, single-celled microorganisms, some of which can cause disease in plants and animals.

Bait Shyness: The tendency for rodents, birds, or other pests to avoid poisoned bait.

Band Application: The placement of a pesticide in a narrow row either over or alongside the crop row.

Basal Treatment: The application of a pesticide to encircle the stem of a plant just above the soil surface such that foliage contact is minimal. A term used mostly to describe treatment of woody plants.

Beneficial Insects: Those insects that are useful or helpful to humans, for example, insects that feed on or become parasites of pests.

Biennials: Plants that live for two years, typically producing a small rosette plant the first year and flowering the second year.

Biocide: Kills any organism.

Biological Control: The control or suppression of pests by action of one or more organisms through natural means or by manipulation of the pest, organism, or environment.

Biological Degradation: The breakdown of a pesticide in the soil due to the activities of living organisms such as bacteria and fungi.

Biotic: Alive; caused by living agents. Usually a reference to disease caused by living microorganisms.

Biotype: A population within a species that has a distinct genetic variation.

Bipyridyliums: A group of synthetic organic pesticides, which includes the herbicide paraquat.

Blight: A symptom or disease in which plant parts such as leaves, flowers, and stems are rapidly killed.

Blotch (leaf): Areas of dead tissue, randomly dispersed on a leaf.

Blotch Mine: An irregularly shaped discoloration in a leaf caused by the excavation of tissue between upper and lower leaf surfaces.

Botanical Pesticide: A pesticide made from plants. Also called plant-derived pesticides.

Broadcast Application: The uniform application of a pesticide to an entire area or field.

Broadcast Rate Equivalent: For band treatments, the amount of pesticide applied per unit area when only the band area is considered. All rates for band treatment should be expressed as the broadcast rate equivalent.

Broadleaf Weeds: Plants with broad, rounded, or flattened leaves.

Bronze: A brown discoloration of many small, light, or tan spots caused by spider mite feeding.

Brush Control: Control of woody plants such as brambles, sprout clumps, shrubs, trees, and vines.

Buffer: An adjuvant that lowers and stablizes the pH of alkaline water.

Calculate: To determine application rates, sprayer calibration, and other amounts by using mathematics.

Calibrate (calibration): To measure and adjust pesticide application equipment to the proper pesticide delivery rate.

Canister: A container used in respirators to absorb fumes and vapors from the air before you breathe them; provides more protection than a cartridge.

Canker: A localized dead area on woody tissue, often sunken, on a twig, branch, or stem that can enlarge over time.

Carbamate: A synthetic organic pesticide containing carbon, hydrogen, nitrogen, and sulfur.

Carcinogen: A substance that can cause cancer.

Carrier: The inert liquid or solid material added to an active ingredient to prepare a pesticide formulation.

Causal Agent: Either a biotic or an abiotic agent that causes a disruption of a plant's normal growth or physical properties.

Chemosterilant: A chemical that can prevent reproduction.

Chlorinated Hydrocarbon: A synthetic organic pesticide that contains chlorine, carbon, and hydrogen.

Chlorosis: Whitish or yellowish discoloration of normally green plant material due to the lack of chlorophyll.

Chlorotic: Plant tissues that appear pale-green to yellow.

Cholinesterase: A chemical catalyst (enzyme) found in animals that helps regulate the activity of nerve impulses.
Chronic: A condition or situation that occurs a regular or frequent basis.

Compatible: Describes the ability of two or more chemicals to be mixed without affecting each other's properties.

Compatibility Agent: An adjuvant that facilitates more uniform mixing of liquid fertilizer and pesticides, or mixing of two or more pesticides in a tank mix with any liquid carrier.

Competition: The active acquisition of limited resources by an organism that results in a reduced supply and consequently reduced growth of other organisms in a common environment.

Complex: A variety of symptoms expressed as the result of different causal agents.

Concentration: The amount of active ingredient in a given volume or weight of a pesticide formulation.

Contact Herbicide: An herbicide that causes injury to only the plant tissue to which it is applied, or an herbicide that is not appreciably translocated within plants.

Contact Repellent: A chemical that causes a pest to leave once the chemical is tasted or touched.

Contaminate: To make impure or to pollute.

Copper Compounds: Pesticides containing copper that are used to manage fungal and bacterial diseases.

Corrosion: The process of wearing away by chemical means.

Crop Oil: A petroleum- or vegetable-based product generally containing 2 percent emulsifier and 98 percent oil.

Crop Oil Concentrate: A petroleum-based product generally containing 15 to 20 percent surfactant/emulsifier and 80 to 85 percent oil.

Crucifers: Plants belonging to the mustard family, such as mustard, cabbage, turnip, and radish.

Cucurbits: Plants belonging to the gourd family, such as pumpkin, cucumber, and squash.

Cultural Control: Control of pests with plant cultural practices.

Cumulative: Increasing in quantity or strength because of additions, such as the buildup of pesticides in the body or the soil.

Curl: A leaf or shoot distortion associated with lack of water or sucking injury.

Damage: An injury that is extensive enough to cause economic loss.

Deciduous Plants: Perennial plants that lose their leaves during the winter.

Decontaminate: To remove harmful chemicals or materials.

Deflocculating Agent: A material added to a suspension to prevent settling.

Defoaming Agent: An adjuvant used for suppressing both surface foam and trapped air in the spray mixture.

Defoliant: Causes leaves or foliage to drop from a plant, usually to facilitate harvest.

Degradation: The process by which a chemical is reduced to a less complex form.

Depletion: Removal or loss.

Dermal: Of the skin, through or by the skin.

Dermal Toxicity: A measure of the capacity of a pesticide to cause injury when absorbed through the skin.

Desiccant: Promotes drying of living tissue - unwanted plant tops or insects, for example.

Desiccation: Drying out.

Device: A thing made for a special purpose, such as a respiratory protective device.

Diagnosis: The process of determining the cause of a disorder.

Dieback: The gradual death of tissues beginning at the tips of branches that can kill part of or entire branches or groups of branches.

Diffusion: The gradual mixing of two substances by passive means.

Dilute: To make thinner by adding water, another liquid, or a solid.

Dilutent: Any liquid or solid material used to dilute or carry an active ingredient.

Directed Application: Precise application to a specific area or plant organ, such as to a row or bed or to the leaves or stem of a plant.

Disease: Any disturbance of a plant over some period of time that interferes with its normal structure, function, or economic value and that induces symptoms.

Disinfectants and Sanitizers: Kill or inactivate disease-producing microorganisms (bacteria, viruses, etc.) on inanimate objects.

Disorder: Any disease caused by a noninfectious (nonliving) agent.

Dispersible Granule: A dry granular formulation that will separate or disperse to form a suspension when added to water.

Dispersing Agent: A material that reduces the attraction between particles.

Dispose: To get rid of.
Distortion: Abnormal shape.

Dormant: State in which growth of seeds or other plant organs stops temporarily.

Dose, Dosage: Quantity of a pesticide applied.

Drift Retardant: An adjuvant used in spray mixtures to reduce drift.

Economic Damage: The value of preventable crop damage, which exceeds the cost of control.

Economic Injury Level: The lowest pest population density at which economic damage occurs.

Economic Threshold: The population density of a pest at which control measures should be started to prevent the increasing pest population from reaching the economic injury level.

Emulsifiable: A chemical property that allows you to mix two liquids, which normally do not mix, such as oil and water.

Emulsifier: A chemical, which aids in suspending one liquid in another.

Emulsion: A mixture in which one liquid is suspended as tiny drops in another liquid, such as oil in water.

Entomologist: An expert on insects.

Enzyme: Proteins that increase the rate of specific chemical reactions.

Eradication: Removal and destruction of diseased plants or plant parts.

Exclusion: The erection of barriers or sealing of openings so that pests are unable to enter an area.

Exoskeleton: The rigid external covering of insects.

Exposure: To be brought into contact with a pesticide.

Extender: See surfactant.

Fatty Acid: Long-chain carbon molecules commonly used in soaps and similar products.

FIFRA: The Federal Insecticide, Fungicide, and Rodenticide Act - the federal law regulating most pesticides and their uses.

Flagging: A disease or disorder symptom manifested by the leaves on a branch wilting, turning brown, and clinging to the branch for an extended period instead of falling off immediately.

Flammable: Able to burn easily.

Flowable: A two-phase formulation containing solid pesticide suspended in a liquid which forms a suspension when added to water.

Foliar Application: Application of a pesticide to the aboveground portions of a plant.

Formulation: The pesticide product as purchased, usually consisting of a mixture of active ingredients, inert ingredients, adjuvants, and carriers.

Fumigant: A pesticide gas that is able to penetrate pest hiding places through very small spaces. Many fumigants are general poisons that kill animals or plants that they contact. They are often used to disinfest interiors of buildings as well as soil before planting.

Fumigation: Application of pesticides in the form of vapors or fumes.

Fungicide: A chemical compound that is toxic to fungi.

Fungistat: A chemical that keeps fungi from growing.

Fungus (fungi): A small, sometimes microscopic organism that lives on organic matter or as a parasite.

Gall: An abnormal swelling or growth of plant tissue that is initiated by a pathogen, insect, or mite.

GPA: Gallons per acre.

GPM: Gallons per minute.

Genetic: Influenced by inherited traits.

Genus: A group of species having similar fundamental traits.

Hard (water): Water containing soluble salts of calcium and magnesium and sometimes iron.

Hazard: A possible source of danger or injury.

Herbaceous Plant: A vascular plant that does not develop woody tissue above ground.

Herbicide: A chemical substance or cultured biological organism used to kill or suppress the growth of weeds or other plants that grow where they are not wanted.

Herbicide Resistance: The trait or quality of a population of plants within a species that have a tolerance for a particular herbicide that is substantially greater than the average for the species. Herbicide resistance develops through selection for naturally occurring tolerance by exposing the weed to the same herbicide for several reproductive cycles.

Horticultural Oil: Highly refined petroleum oil with an ability to kill insects by smothering them and disrupting membranes.

Hydraulic: Moved or operated by the use of pressurized fluids.

Hydrogen-Ion Concentration: A measure of acidity or alkalinity, expressed in terms of the pH of the solution. For example, a pH of 7 is neutral, from 1 to 7 is acid, and from 7 to 14 is alkaline.
Immune: Not susceptible to a disease or poison.

Impermeable: Not permitting fluids to pass through. Semi-permeable means that some substances can pass through and others cannot.

Incompatible: Unable to mix or combine with.

Incorporate: To mix or blend, for example, when pesticides are mixed into the soil.

Induce: To cause.

Inert: Not active.

Infectious: Able to spread from plant to plant. For example, disease caused by living pathogenic microorganisms is infectious.

Ingest: To swallow.

Inhale: To breathe in.

Injury: Physical removal, discoloration, or distortion of a plant part.

Inoculum: The part of a pathogen, or collection of individual pathogens, which are capable of initiating disease.

Insect Growth Regulator: Disrupts the action of insect hormones controlling molting, maturity from pupal stage to adult, or other life processes.

Insecticide: Kills insects.

Instars. The stage in the development of an insect between two successive molts.

Integrated Pest Management (IPM): A systematic plan, which brings together different pest control strategies into one program that is economically sound and that minimizes environmental problems.

Invert emulsion: A mixture in which water is dispersed in oil rather than oil dispersed in water; invert emulsions are normally quite thick and thus less susceptible to drift.

Lateral Movement: Movement of a pesticide through soil, generally in a horizontal plane, from the original site of application.

LC_{50}: The concentration of an active ingredient in air, which is expected to cause death in 50 percent of the test animals treated. A means of expressing the toxicity of a compound present in air as dust, mist, gas, or vapor. It is generally expressed as micrograms per liter as a dust or mist but in the case of a gas or vapor as parts per million (ppm).

LD_{50} : The dose of an active ingredient taken by mouth or absorbed by the skin which is expected to cause death in 50 percent of the test animals treated. If a chemical has an LD_{50} of 10 milligrams per kilogram (mg/kg) it is more toxic than one having an LD_{50} of 100 mg/kg.

Leaching: Movement of a substance downward or out of the soil as the result of water movement.

Leaf Scorch: Leaf browning associated with rapid water loss.

Leaf Spot: A discrete dead area on a leaf.

Lethal: Deadly.

Live Trap: A trap that captures an animal but doesn't harm it. This allows the animal to be released unharmed in an area where its presence will not be a problem or to be killed in a humane manner.

Mammals: Warm-blooded animals that nourish their young with milk. Their skin is more or less covered with hair.

Marginal Necrosis: Browning (death) of green tissue around the outer edge of a leaf.

Mechanical control: Pest control measures using physical means.

Metamorphosis: The process by which insects change their body structures as they develop.

Microbe: Microorganisms that kill, inhibit, or out-compete pests, including insects or other microorganisms.

Microclimate: Environmental conditions of a specific limited area.

Mildew: A plant disease in which white mycelium and spores of the causal fungus are visible on the plant surface.

Miscible Liquids: Two or more liquids that can be mixed and will remain mixed under normal conditions.

Miticide: Also called aracnicides; kills mites that feed on plants and animals.

Molluscicide: Kills snails and slugs.

Monitor: To keep track of.

Mosaic: A pattern of yellow-and-green intermingled on a leaf; typical of many virus diseases.

Mutagenic: Can produce genetic change.

Necrosis: Localized death of living tissue such as the death of a certain area of a leaf.

Necrotic: Showing varying degrees of dead areas or spots.

Nematicide: Kills nematodes.

Nematode: A microscopic, wormlike organism that lives in the soil or water as a parasite of plants, animals, or fungi.

Neoprene: A synthetic rubber characterized by high resistance to oils, heat, or other substances.
Neurological: Having to do with the nervous system of animals.

Nitrophenols: Synthetic organic pesticides containing carbon, hydrogen, nitrogen, and oxygen.

Noninfectious: Unable to spread from plant to plant. For example, nutritional disorders are noninfectious.

Nonselective Herbicide: An herbicide that affects all or most plants.

Nontarget Species: Species not intentionally affected by a pesticide.

Noxious Weed: A plant defined by law as being especially undesirable or troublesome.

Oral: Of the mouth, through or by the mouth.

Oral Toxicity: Ability of a pesticide to cause injury when taken by mouth.

Organic Compounds: Chemicals that contain carbon.

Organochlorine: Same as chlorinated hydrocarbon.

Organophosphate: A synthetic organic pesticide containing carbon, hydrogen, and phosphorus.

Ovicide: A chemical that destroys eggs.

Oxidizer: A substance that provides oxygen in a chemical reaction; can be a fire hazard when combined with combustible materials.

Parasite: A living organism that obtains all or part of its food while living on or in another living organism.

Pathologist: An expert on diseases.

PPB: Parts per billion. A way to express the concentration of chemicals in foods, plants, and animals. One part per billion equals 1 pound in 500,000 tons.

PPM: Parts per million. A way to express the concentration of chemicals in foods, plants, and animals. One part per million equals 1 pound in 500 tons.

Pathogen: Any disease-producing organism.

Penetration: The act of entering or ability to enter.

Permeable: Allowing substances, such as liquid pesticides, to pass through a membrane.

Persist: To remain in the soil or environment for a long period of time.

pH: A logarithmic measure of the hydrogen-ion activity of a soil. The degree of acidity (or alkalinity) of a soil.

Pheromone: A hormone secreted by an animal, including insects, that stimulates others of the same species.

Phytoplasma: A microorganism without cell walls or organized nucleus that causes yellows diseases in plants.

Phytotoxic: Harmful to plants.

Plant Growth Regulator: A substance used for controlling or modifying plant growth processes without severe phytotoxicity.

Plant Penetrant: An adjuvant that enhances a liquid's ability to penetrate plant roots, leaves, and stems.

Pollutant: An agent or chemical that makes something impure or dirty.

Postemergence: Refers to pesticides or herbicides aplied after energence of the specified crop or weed.

PSI: Pounds per square inch.

Porous: Full of pores or small holes through which substances can pass.

Prebaiting: The practice of placing food or other attractant in areas where pests will find it and get used to it before mixing it with a pesticide or placing it in a set trap.

Precaution: Safety measures taken in advance; a warning.

Predator: Any animal that destroys or eats other animals.

Preemergence: Refers to pesticides or herbicides applied before emergence of the specified crop or weed.

Propellant: Liquid in self-pressurized pesticide products that forces the active ingredient from the container.

Re-entry Interval: The period of time following a pesticide application before people can enter a treated site without personal protective devices.

Registration: The process by which a pesticide becomes labeled for use by the EPA.

Relocation: The release of a live animal in an area other than its home area.

Repellent: A pesticide that does not kill the pest but, rather, causes it to leave the area.

Residual Toxicity: The amount of time after pesticide application when the material is toxic to the pest.

Residual Herbicide: An herbicide that persists in the soil and injures or kills germinating weed seedlings for a relatively short period of time after application.

Residue: Any pesticide remaining in or on raw farm products or processed foods.

Resistance: The ability to overcome or to slow the development of disease.

Respirator: A device that covers the nose and mouth to protect one from breathing in poisonous gases and particles.

Respiratory Tract: The parts of the body that are involved with breathing.

Restricted Use: A classification by the Environmental Protection Agency of pesticides that are subject to special rules governing their purchase and use.

Resuscitate: To restore consciousness.

Ringspot: A circular area of chlorosis or necrosis with a green, healthy-appearing center.

Rodent: A small mammal with two front teeth which are suited for gnawing and continue to grow throughout the animal's life.

Rodenticide: A pesticide used to kill mice, rats, and other rodents.

Rot: Tissue breakdown.

Safener: A chemical added to a pesticide to keep it from injuring plants.

Sanitation: Removal or destruction of plants or other materials that may attract or harbor pests and diseases.

Scorch (leaf): Dead (necrotic) tissues on the margins of leaves or between veins that results in browning and shriveling of foliage.

Seed Protectant: A chemical applied to seed before planting to protect seeds and new seedlings from disease and insects.

Selective: A pesticide that is effective only against certain species and that can control unwanted pests without serious injury to desirable species.

Sign: The physical evidence of a causal agent.

Siphon: To draw a liquid from a higher level to a lower level through a pipe or tube.

Slurry: A watery mixture.

Soil Sterilant: A chemical that prevents the growth of all plants and animals in the soil. Soil sterilization may be temporary or permanent, depending on the chemical.

Solubility: The ability to dissolve in water or other liquids.

Soluble: Will dissolve in a liquid.

Solution: Mixture of one or more substances in another in which all ingredients are completely dissolved.

Solvent: A liquid which will dissolve a substance to form a solution.

Spot Treatment: Application of pesticide to restricted area or areas of a whole unit. For example, the treatment of spots or patches within a larger field.

Spray Drift: The movement of airborne spray from the intended area of application.

Spreader: A chemical which increases the area that a given volume of liquid will cover on a solid or on another liquid. See surfactant.
Sticker: An adjuvant that increases the adhesiveness of finely divided solids to solid surfaces.

Stipple: White flecks on green leaves caused when a sucking insect removes chlorophyll. Common for lacebugs.

Stunt: To abnormally reduce growth of stems, branches, leaves, flowers, fruit, or roots of plants.

Stunting: Abnormally small size, dwarfing.

Surfactant: A chemical which increases the emulsifying, dispersing, spreading and wetting properties of a pesticide product.

Susceptible: Capable of being diseased or poisoned; not immune.

Susceptible Species: A plant or animal that is poisoned by moderate amounts of a pesticide.

Suspension: Finely divided solid particles mixed in a liquid.

Symptom: An outward signal of a disease or poisoning in a plant or animal.

Synergism: The joint action of two or more pesticides that is greater than the sum of their activity when used alone.

Systemic: Describes the property of insecticides or fungicides that penetrate and disperse throughout a plant; synonymous with translocated herbicide.

Target Pest: The pest at which a particular pesticide or other control method is directed.

Thickener: An adjuvant that increases the viscosity of a spray mixture.

Tolerance: (1) The ability of a living thing to withstand adverse conditions, such as pest attacks, weather extremes, or pesticides. (2) The amount of pesticide that may safely remain in or on raw farm products at time of sale.

Toxic: Poisonous at certain doses.

Toxicant: A poisonous chemical.

Trade Name: Same as brand name.

Translocated Herbicide: An herbicide that is moved within the plant. Translocated herbicides can be either phloem-mobile or xylem-mobile, but the term is frequently used in a more restrictive sense to refer to herbicides that are applied to the foliage and move downward through the phloem to underground parts of the plant.

Triple-rinse: Washing procedure required before properly disposing of plastic and metal pesticide containers.

Turbulent: Agitated or stormy.

Vapor Drift: The movement of pesticides as vapor from the area of application after the spray droplets have impinged on the target.

Vapor Pressure: The property which causes a chemical to evaporate. The lower the vapor pressure, the more easily it will evaporate.

Variety: A subdivision of a species having a distinct difference and breeding true to that difference.

Vector: A carrier, such as an insect, that transmits a pathogen.

Vertebrate: An animal that has a backbone.

Virus: A submicroscopic pathogen consisting of a nucleic acid surrounded by a protein coat.

Viscosity: A property of liquids that determines whether they flow readily. Viscosity usually increases when temperature decreases.

Vitality: The relative health of a plant, usually a function of the growing environment.

Volatile: The ability of a solid or a liquid to turn to a gas (or vapor) under ordinary temperatures when exposed to air.

Weed: Any plant that is objectionable or interferes with the activities or welfare of humans.

Weed Control: The process of reducing weed growth or infestation to an acceptable level.

Wetting Agent: A chemical, which causes a liquid to contact surfaces more thoroughly. See surfactant.

Wilt: The loss of water turgor pressure in a leaf, causing it to droop or curl or to lose a degree of its normal color.

Yellows: A plant disease caused by a phytoplasma that results in chlorosis and stunting of the affected plant.

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Internet Resources

American Association of Pesticide Safety Educators: http://aapse.ext.vt.edu/aapse.html
AAPSE maintains a list of Web resources by state, with links to program information, newsletters, journals, and other resources for pesticide educators, including guidebooks for evaluating pesticide applicator training programs and guides to EPA regulations.

Clemson University Pesticide Information Program: http://entweb.clemson.edu/pesticid/index2.htm
An excellent Web site for a multitude of information regarding pesticide use and safety publications and training resources. Their Pesticide Safety for Homeowner Information Sheets are excellent.

Cornell University Pesticide Management Education Program: http://pmep.cce.cornell.edu/
A good Web site that promotes the safe use of pesticides for the user, the consumer, and the environment. PMEP serves as a pesticide information center for college and field extension staff, as well as growers, commercial applicators, pesticide formulations/distributors, environmental and conservation groups, and private citizens.

EPA Office of Pesticide Programs: http://www.epa.gov/pesticides/
Responsible for overall pesticide regulation with special programs on agricultural workers, and pesticide applicators. Specific programs include the promotion of the reduction of pesticide use, establishment of tolerance levels fro food, and investigation of pesticide releases and exposure events.

EPA Office of Prevention, Pesticides, and Toxic Substances: http://www.epa.gov/opptsfrs/home/opptsim.htm
A program that promotes pollution prevention and the public's right to know about chemical risks.

EXTONET: Extension Toxicology Network: http://ace.orst.edu/info/extonet/
A source of objective, science-based information about pesticides written for the non-expert.
National Antimicrobial Information Network: http://ace.orst.edu/info/nain/
A toll-free telephone service (1-800-447-6349) that provides objective, science-based information about a wide variety of antimicrobial products: sanitizers, disinfectants, and sterilants; toxicology; environmental chemistry; regulations; and registration.

National Center for Environmental Health, Centers for Disease Control (NCEH): http://www.cdc.gov/ncehhome.htm
NCEH provides environmental pesticide case surveillance and disease outbreak investigations.

National Pest Management Association: http://www.pestworld.org/
This site allows you to post a question about pest problems and receive a reply from a NPMA staff member or a professional pest control operator. Also, if you need professional pest control help, they suggest guidelines and list NPCA-member pest control firms in your area.

National Pesticide Telecommunications Network: http://ace.orst.edu/info/nptn/
A toll-free telephone service (1-800-858-7378) that provides objective, science-based information about a wide variety of pesticide-related subjects including pesticide products, recognition and management of pesticide poisoning, toxicology, and environmental chemistry.

Penn State University Pesticide Education Program: http://www.pested.psu.edu/
This Web site includes fact sheets, newsletters, articles, regulatory updates, pesticide-related Web sites, and much more.

University of Minnesota Extension Service Pesticide Resources: http://www.extension.umn.edu/pesticides/pesticides/pesticideresources.html
A good local Web site that provides a lot of information about pesticide information on the Web, access to major pesticide/chemical health and safety databases, links to pesticide information about health, toxicology, use, and reviews of pesticide laws and regulations at the federal and state level.

University on Nebraska Pesticide Education Resources: http://pested.unl.edu/
This Web site provides access to one of the best University Extension sites dealing with pesticide use and safety. Their NebGuides on pesticides are very useful fact sheets.

USDA Office of Pest Management Policy and Pesticide Impact Assessment Program: http://ipmwww.ncsu.edu:8150/opmppiap/
The Office of Pest Management Policy provides coordination to pest management programs across several USDA agencies, and oversees administration of the Pesticide Impact Assessment Program. The Pesticide Impact Assessment Program is a multi-agency program jointly administered by the USDA's Cooperative State Research, Education and Extension Service (CSREES) and the state land-grant universities. The PIAP site has a great pesticide database.

APPENDIX A

Oral LD_{50} values of common garden pesticides (active ingredient amounts) compared to other household products (mg pesticide per kg of body weight)

Di-Syston® (i) 2-12
Silica Gel 5
Thiodan® (endosulfan) (i) 18-110
Kerosene 50
Nicotine 50
Rotenone (i) 50-75
Dursban® (i) 82-276
Baygon® (propoxur) (i) 83-104
Nicotine Sulfate (i) 83
Gasoline 150
Caffeine 192
Cygon® (dimethoate) (i) 215-380
Betasan® (bensulide) 270-1470
4300-5400
Bordeaux, coppers and 300-1000
Lime sulfur (f)
Diazinon® (i) 300
2,4-D (h) 375-805
Sevin® (carbaryl) (i) 500-850
MCPA (h) 550-1160
Thiram® (f) 620-780
Pyrethrin (i) 820-1870
Orthene® (acephate) (i) 866
MCPP (h) 930
Karathane® (dinocap) (f) 980
Aspirin 1000
Basic copper 1000
Malathion® (i) 1000-1375
Metaldehyde 1000
Kelthane® (dicofol) (i) 1000

Banvel® (dicamba) (h) 1040-1700
Vitamin A 2000
Trimec® (h) 2380
***Borax* 2660-5190**
Prometon® (Pramitol) (h) 2980
Table Salt 3000
Dacthal® (DCPA) (h) >3000
Casoron® (dichlobenil) (h) 3160
Ammonium sulfamate (h) 3900
Sabadilla Dust 4000
Resmethrin (i) 4230
Zineb® (f) 5200
Roundup® (glyphosate) (h)

Maneb® (Manzate) (f) 6750
Mancozeb® (Fore) (f) 7500
Bacillus thuringiensis (i) 8500
Streptomycin (b) 9000
Captan® (f) 9000-15000
Balan® (benefin) (h) 10000
Benomyl® (Benlate) (f) >10000
Daconil® 2787 >10000
(chlorothalonil) (f)
Phaltan® (folpet) (f) >10000
Treflan® (Preen®, trifuralin) >10000
Amitrol T® (amitrole) (h) 11000
Ethyl Alcohol 14000
Funginex® (f) 16000+
Sucrose (table sugar) 29700

Italics signify products certified for organic farming

b = bactericide
f = fungicide
h = herbicide
i = insecticide

Appendix B

Minimum Days from the Last Application to Harvest -- Vegetables

(Provided only as a guide - read and follow the label directions!)

Vegetable	Bt	Cygon (dimethoate)	Diazinon	Malathion	Methoxychlor	Pyrethrin	Rotenone	Sevin (carbaryl)	Thiodan (endosulfan)	Daconil (chlorothalonil)	Mancozeb
Asparagus			no		3	0	1	1			120
Beans	0	0	7	1	3	0	1	0	3	7	
Beets, roots	0		14		7		1	3	no		
Beets, tops	0		14		14		1	14	no		
Broccoli	0	7	5		14	0	1	3	7	0	
Brussel sprouts	0		7		14	0	1	3	14	0	
Cabbage	0	7	7		3	0	1	3	7	0	
Carrots	0		10		7			0	7	0	
Cailiflower	0	7	5		7	0	1	3	14	0	
Celery	0		10			0			4	7	
Corn, sweet	0		1	5	7	0	1	0		14	7
Cucumbers	0		7	1	1	0	1	0	0	0	5
Eggplant	0		no		7	0	1	0	14		
Kohlrabi			no		1		1	3	no		
Lettuce, head	0	7	10	7	14	0	1	3	14		
Lettuce, leaf	0	14	10	14	14	0	1	14	14		
Melons	0	3	3		7	0	1	o	0	0	5
Onions	0		10	3	no				no	14	7
Parsnips	0		10					3			
Peas	0	0	0		7		1	1	0		
Peppers	0	0	5	3	1	0	1	0	4		
Potatoes	0	0	35	0	1	0	1	0	0	0	14
Pumpkins	0		no		1			0	0	0	
Radishes	0		10		7	0	1	3			
Rutabaga	0		no		7			1	3		
Spinich	0	14	10		14	0	1	14	21		
Squash, summer	0		7		1	0	1	0	0	0	5
Squash, winter	0		3		1	0	1	0	0	0	
Swiss chard	0	14	12				1	14	no		
Tomatoes	0	7	1	1	1	0	1	0	1	0	5
Turnips, roots	0	14	10		7	0	1	3	21		
Turnip, tops	0	14	10		14	0	1	14	21		

Minimum Days from the Last Application to Harvest -- Fruits
(Provided only as a guide - read and follow the label directions!)

Fruit	Diazinon (phosmet)	Imidan	Malathion	Methoxychlor	Sevin (carbaryl)	Benomyl (benlate)	Captan	Lime Sulfur	Sulfur
Apples	14	7	3	7	1	0	0	0	0
Apricots	10	pb*	7	21	3	0	0		
Cherry	10	7	3	7	1	0	0	0	0
Grapes	18	7	3	14	0	7		0	
Pears	14	7	1	7	1		0		0
Plums	10	7	3	7	1	0	0	0	
Raspberries	7		1	14	7	3	0	0	
Strawberries	5		3		1	0	0		

*pb -- pre-bloom

chapter 12

wildlife

chapter 12

LIVING WITH WILDLIFE

by James Kitts, Extension Specialist
Wildlife and Fisheries

wildlife

INTRODUCTION

The title of this section of your training reflects an attitude about life which, if commonly held, could benefit humans as well as wild animals. As Master Gardeners you will have occasions to councel clients in ways of attracting certain wild species. You might also be the source of information about controlling damage from wildlife to crops, to plantings, to dwellings, to pets, etc.

In this chapter you will receive information about basic wildlife management and a challenge to think critically about each situation where your assistance is requested. Some of your clients will need more than a simple prescription to correct a certain condition. Be prepared to help them set goals as well.

When dealing with wildlife management, always remember that the key to the presence or absence of wildlife is plants. All animal life is dependent on plants—specific sets of plants for specific animal species. We, humans as well as wild animals, are habitat specific. Of course, some animals have broader requirements and are said to be more adaptive than others. Pigeons, starlings, crows, Canada geese, gray squirrels, house mice, cottontail rabbits, white-tailed deer, and raccoon are a few examples of very adaptive wildlife. Even so, these species can be managed by altering their habitats. The only long-term, enduring, successful wildlife management practice is habitat alteration. It can be used to encourage or discourage production of various species.

LEARNING OBJECTIVES

Learning objectives of this section for Master Gardeners are to:

1. Understand the biology and habitat requirements of urban wildlife.
2. Recognize various types of wildlife and their damage.
3. Become aware of solutions that may help to prevent or reduce wildlife damage.
4. Help others deal effectively with animal-related problems.

MANAGEMENT CONCEPTS

Understanding the concepts discussed here is basic to your success in assisting your clients. There is considerable scientific literature to support the points presented; however, this chapter will only summarize the concepts and the science behind them.

Succession

Succession is a natural, ecological process—the replacement of one species

by another through a reasonably predictable sequence. Animal succession is directly linked to plant succession. Consequently, as the set of plant species on any piece of land changes, so does the species of animals that depend on those plants for part of their *habitat*. As people garden and landscape they alter the set(s) of plants on their properties. To wildlife, this artificial succession of plants produces the same result as natural succession, except that it occurs over a shorter time. The changes may have a positive, negative, or neutral (a rare occurrence) impact on animal production.

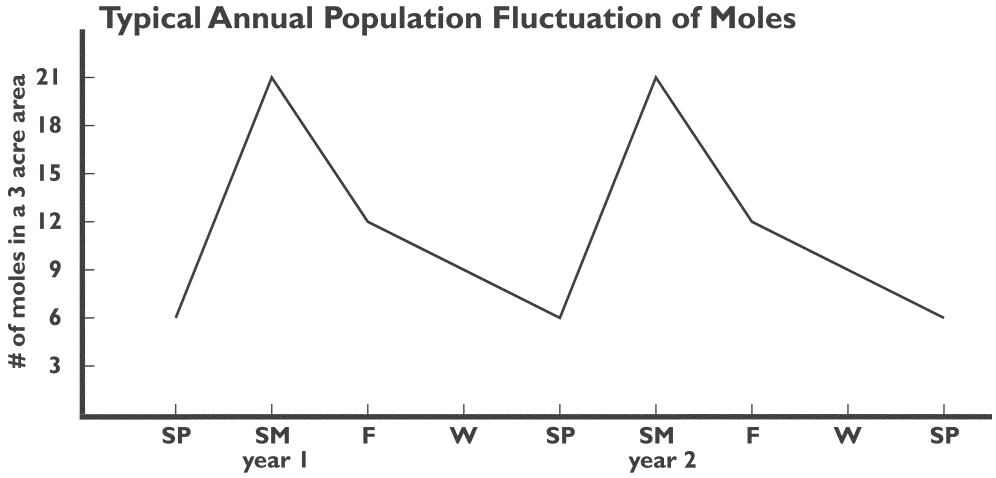
Population Dynamics

Sex is a powerful tool of nature. It is the means by which populations and species remain viable. However, animal populations (all individuals of a particular species inhabiting a given area) fluctuate as animals respond to their habitats and external environmental conditions.

Although each animal pair deals with reproduction individually, it is the collective result of these births and deaths that determines the fate of their species. The population is the fundamental unit for species survival and is the focus of wildlife management. In every wildlife population there is an annual production of young (*natality*). There is also an annual loss (*mortality*). The difference between these determines the population density. The following graph is based on a hypothetical mole population but illustrates how annual population fluctuates.

Notice several things about the graph.

- Population low point always occurs in the spring because of deaths over the winter.
- Population high point always occurs in summer because of births.



- Population high points and low points are about the same level each year in a stable population.
- Each year there is a high point and a low point.

Reproduction is timed to correspond to periods favorable to survival of young. In temperate regions of the world this is usually spring and summer. Hence the population low occurs in late winter or early spring just prior to the birth of the first young. The high point occurs in late summer at the time of the birth of the final young of the year. In some cases there might be a second high point as animals from other populations move about searching for available habitat.

Populations in which high and low points are statistically equal year after year are said to be *stable*. They are, in essence, in balance with the quality and quantity of their habitat. *Carrying capacity* has been reached.

The result of natality is production of excess animals (more than needed to replace dead and more than can survive in the habitat). If they remain, their impact reduces the habitat quality and the entire population suffers. If they leave, they are at extra risk from a host of mortality factors, but the original population does not suffer. Many of these excess animals fall prey to natural predators.

Suppose you have a stable population of moles in your yard. The carrying capacity of the habitat is 6 moles. If the population consists of 4 females and 2 males, and the females have one litter each of 4 young, the spring population is 6 moles. The summer population high (with no mortality) will be 2+4+16=22 moles. What is the number of excess moles? That is, how many moles must be removed in order to keep lawn damage to a level no greater than the previous year? How many moles must be removed to eliminate 100 percent of the damage? How likely is this to be accomplished by the average homeowner? What happens to the excess moles in your neighbors' yards?

The point of this exercise is to demonstrate that simply destroying lots of animals is no guarantee the problem is solved. Killing animals might work in the short term, but it isn't efficient or cost-effective. There are better ways to reduce wildlife populations.

Damage Control

Habitat is the unique combination of food, water, cover, and space required by a population for its survival. Reduction in quality or quantity of any one component will reduce or eliminate the dependent wildlife population(s). Habitat management is the most effective method for increasing or decreasing densities of wildlife.

Because of the abundance of water throughout Minnesota, this is usually the least effective component of habitat with which to work. Managing the availability of food or cover frequently works better. *Controlling the availability* of plants, seeds, pet food, brush piles, firewood, etc. is controlling wildlife food and cover.

Another option is *restricting access* of wild animals to food and cover. Often this means installing a fence around plantings so animals cannot get to food or cover. This technique can be very effective, but it requires considerable thought, maintenance, and monetary investment. And, in general, fences still look like fences!

Under certain conditions, *repelling* wild animals can be successful. However, success with repellents is highly variable and is not recommended in situations involving protection of valuable plants or with dangerous animals. Repellents are audibly or visually frightening, or they taste or smell bad. Repellents do not work well after animals have established undesirable behavior patterns.

Finally, *removing* selected individual animals can reduce damage. This technique will not, in most situations, reduce or prevent future damage. It is not for chronic situations. It does not work well when large numbers of animals are concerned or when endangered or other sensitive species are involved, and it does not alter the habitat. Individuals can be removed alive or they can be

killed. Either way there could be legal ramifications. Always check with your local Minnesota Department of Natural Resources conservation officer before attempting to remove protected species (all migratory birds, all game animals and furbearers, all raptors, all threatened and endangered species, or species of special concern).

Legal Considerations

Most wildlife is protected, either by state or federal law. Some migratory birds are protected by international treaty. As a general rule, refer bird control problems to local representatives of the Minnesota Department of Natural Resources, Law Enforcement Division (conservation officers). Large-scale bird damage should be reported to the state office of the U.S. Department of Agriculture—Animal Damage Control (612-296-3157).

Strictly speaking, it is not legal to live-trap wild animals, transport them to distant locations, and then release them. It might be legal if they are released on land where the property owner has given prior permission. This also applies to lands known as "public property" such as state parks, state forests, game reserve areas, waterfowl production areas, and other federally controlled lands.

When using pesticides *ALWAYS* follow the label instructions. Deviation from these instructions can result in serious legal consequences, health compromises, and inefficient use of the products. These materials are designed to kill living things. The suffix *icide* means "killer of," thus rodenticide means "killer of rodents." If pesticides are handled and used strictly according to label instructions they can be effective.

SPECIFIC CONTROL

Moles and Shrews

These critters are close relatives and are predators. Moles feed mostly on soil invertebrates (worms and soil insects and their larvae) which the moles encounter as they burrow through the soil. Shrews also consume invertebrates, but they also feed on small vertebrates such as mice, frogs, and snakes. Shrews forage widely on the surface while moles seldom venture out of their burrows.

Neither moles nor shrews consume more than 5 to 8 percent vegetative matter as a regular part of their diets. It is, therefore, inefficient to attempt to control them with poison grain products. Control the food and you control the animals. This is easier said than done. For mole control you must reduce the populations of soil invertebrates. Establish a program of monitoring which will lead to the identification and timely reduction of soil-borne pests such as white grubs.

Special crops raised in small areas might be protected by the use of wire barriers buried around the perimeter of the plot(s). Sometimes raised planting beds will provide some protection if they are built over a base of coarse gravel or commercial landscape cloth.

As a final option moles can be killed with any modern design mole trap. Perhaps the easiest to use is the harpoon trap. This particular design rests mostly on the soil surface so you need not disturb the soil to set it. In areas where there are curious pets or small children, put the traps out at night and remove them during the day.

Shrews are valuable predators of small rodents. Like moles the damage they do is mostly aesthetic while the service they provide in mouse control usually compensates for the flower bulbs they might damage. Occasionally they will invade a house, where they can be controlled easily with mouse traps. Use live-traps if possible and release the animal outside near compost, brush, or wood piles. If the animal must be killed, use mouse traps baited with peanut butter or small pieces of raw meat.

Mice and Voles

These are small rodents commonly found in woods and meadows. Voles seldom enter our dwellings but might be found in pole barns, storage sheds, and places where hay and grains are stored. Voles are not climbers and usually are found in or under hay bales, stored lumber, firewood, etc.

Wild mice, especially those in the genus *Peromyscus* (deer mice, white-footed mice) frequently enter dwellings in the late summer and early fall. They are strong climbers and can be found at all levels from basement to attic.

Vole damage can be controlled by containing their movements. Maintain lawns and ground covers at under 3” height. Do not fall fertilize lawns adjacent to roadside rights-of-way, marshes, wild meadows, or pastures.

Valuable trees with trunk diameters under 4” should be protected with hardware cloth wrapped to the height of anticipated snow depth. Never mulch gardens, young trees, or berry bushes with tame hay. Clean chopped corn cobs, wood chips, conifer bark, and stones are suitable mulches for use in areas of high vole populations.

Several formulations of rodenticides are commercially available for indoor and outdoor use. Rodenticides should be reserved for use in years of high population densities. The most efficient distribution of rodenticide is to locate bait stations at the bases of plants to be protected or to space them at 10-20 foot intervals along well-defined rodent trails. Both plastic and metal bait stations are available. These devices provide protection against accidental poisoning of children and non-target animals. In addition, they protect the bait from weather. Bait stations should be checked frequently (three or more times each week), refilled as bait is eaten, and cleaned of any fouled bait, rodent feces, or urine.

Trapping for voles is usually not an efficient control tactic. However, where their activities are restricted to small, well-defined areas such as pole barns, greenhouses, etc., traps can be useful.

Deer mice and house mice (imports from Europe and Asia) can often be controlled with a program of habitat management and trapping. Habitat management for both species must focus on removal of access to food. All human and pet food products stored where mice could be present should be in metal or glass containers with tight-fitting lids. The exception is leafy vegetables, which are not attractive to these species of mice.

Both deer mice and house mice are strong climbers and can easily scale most kitchen cabinetry. Refrigerators and freezers provide safe food storage; pantries do not.

Be careful how and where you feed pets and wildlife. Do not leave pet food out in dishes or feeders for periods longer than 20-30 minutes. With a little training, your pets will learn to complete their feeding within this time. Bird feeders

within 50 feet of your house should have seed catch aprons or you should thoroughly remove all dropped seeds daily.

Thick hay or straw mulches, straw bales placed against foundations as windbreaks, and firewood stacked on the patio, deck, porch, or against the garage wall all provide cover for voles and mice. Be certain also to keep all retaining walls in good repair. Spaces between rocks or timbers could be used by mice as temporary hiding spaces or as entrances to extensive burrow systems.

Finally, deer mice remaining after your habitat alterations can be removed with a good trapping program. Standard single catch or multiple catch mouse traps (snap type) are sufficient. Have sufficient traps available to saturate the area—one trap every 15-20 lineal feet around the perimeter of the area you're protecting. Only trap at night. Set traps at dusk, check them every 45 minutes until you retire. Keep them well-baited with fresh bait.

Bait traps with a mixture of peanut butter and bird seed or rolled oats. Use just a small amount of bait (not more than a dab the size of a lead pencil eraser). Place the traps along walls, rows of boxes, at inside corners, by garage doors, etc. Trap first along the exterior of your house and associated buildings. Keep trapping until at least three consecutive nights pass with no catch (or sprung traps). Next, move the trapping program indoors and repeat the process. Always place traps perpendicular to walls, etc. with triggers pointed toward the wall. Push the traps to within 1/8" of the wall.

Bats

These flying mammals are valued members of our wildlife community. They are not rodents and are not closely related to rodents in spite of common folk lore. In addition, they do not consume large volumes of mosquitoes nor do they serve as control of crop insect pests even though they do consume substantial volumes of moths. Their mode of flying, object avoidance, and their circulatory physiology have all been studied with regard to aviation and space flight technology.

All of the bat species inhabiting Minnesota are insectivorous. Two species, the little brown and the big brown, commonly invade our homes and other buildings. Damage can occur to buildings from their urine and droppings. In buildings which have had large bat colonies for long periods, structural wood and wall coverings may show deterioration. The more usual situation is a small number of bats living in a home where the owners are not aware of their presence except through slight scratching and/or squeaking noises. In this situation bats are nuisance problems and normally not health threats.

Long-term control of bats requires successfully excluding them from their roosts. This can only be accomplished by closing all openings which do or can serve as entry/exit points. Bats can pass through circular holes the diameter of a nickel. Any cracks or slit openings $^3/_8$" or wider will permit bat entry. Permanent openings such as vents must be screened with $^1/_4$" or finer metal screening. If this "batproofing" can be accomplished, home owners will have no significant problems with bats.

In temperate regions of North America batproofing should be completed during the months of October through March. Any exclusion done during spring and summer can result in trapping baby bats. This will kill them and lead to odor and insect problems as the carcasses decompose. Exclosure after mid-August can be done with some confidence that the young are flying along with the adults. There are several designs for trapdoor or exclusion "valves." What's needed is a simple device that will allow bats to exit but not return. Flapper

valves made of heavy rubber sheeting (truck innertube, etc.) or flexible plastic work well when installed over circular openings. Plastic or metal chutes work well to exclude bats from large cracks or other elongated openings.

Batproofing should proceed from identification of all openings, to systematic closing of the least likely openings, to installation of exclusion devices over the remaining openings. Under normal circumstances and weather conditions one to four days will be required to exclude the colony. After this period permanent structural repairs can be completed. It should not be necessary to destroy bats in order to successfully eliminate problems.

Do not handle live bats with bare hands. Good quality leather or other heavy-duty work gloves are adequate to protect against bites. When working in areas where there are bat droppings, always wear respiratory protection against the inhalation of spores from the fungus *Histoplasma capsulatum*, the cause of histoplasmosis.

KEY TO LAWN AND GARDEN DAMAGE FROM WILD ANIMALS

Mounds of soil

1. 1 to 2 gallons in volume—pocket gopher
2. 1 pint to 2 quarts in volume—Eastern mole

Pressure ridges

1. Ridges with openings—short tailed shrew
2. Ridges with no openings—Eastern mole

Small trails in lawn, grassy areas, or flower beds

1. Very irregular pattern and open holes size of 50-cent piece—short tailed shrew
2. Trail not too irregular, no open holes, occasional clusters of dry grasses in a loose ball—meadow vole

Small holes in ground

1. Earth raised to cone shape, hole about diameter of lead pencil in center of cone—night crawlers
2. Earth raised 1-3” in a cone shape, hole in center of cone about diameter of nickel; soil chronically wet, marsh, edge of lake, etc.—crayfish
3. Earth not noticeably raised, a few well-spaced holes about the diameter of a 50-cent piece—short tailed shrew or house mouse
4. Earth not raised, many holes at irregular intervals, all shallow or dead-end, resembling golf divots—striped skunk (fall), grey squirrel (spring)

Medium holes in ground

1. Diameter of hole about the size of a racquetball, very clean entrance, no loose soil or mound—thirteen lined ground squirrel
2. Diameter of hole about the size of tennis ball, very clean entrance, no loose soil or mound, often under woodpile or next to building foundation—brown rat (Norway rat)

Large holes in ground

1. Dead-end burrow or trench-like cavity among shrubs or in garden area—cottontail rabbit

2. Large mound of soil, burrow entrance more round than oblong and 8-10” in diameter, on hill, under woodpile, under edge of building—woodchuck
3. Large mound of soil, burrow entrance more oblong than round, entrance 6-12” in diameter, under edge of building, etc., skunky odor—striped skunk

Tree trunks/limbs debarked

1. Tree/shrub seedling to 3” diameter tree trunk, girdled or nearly girdled, ground level up to 1-3’—meadow vole
2. Tree/shrub seedling to 3” in diameter debarked but usually not girdled, large gouge in bark and woody tissue, ground level to 1-3’—cottontail rabbit
3. Limbs of maples tripped or debarked in chunks, trunk may or may not be damaged—squirrels
4. Tips of branches with flower buds nipped off, oak and/or elm—gray squirrel

RESOURCES

University of Minnesota Extension Service Publications

Master Gardeners receive many of these publications as a part of their training or Core Course. New publications are continually added to the Distribution Center. The most up-to-date listing is available online at http://www.extension.umn.edu. Click on Publications, or search the site for publications of interest. Many of these fact sheets can be read online and are also available from county extension offices. Longer publications or those containing many photographs or illustrations may not be available online. Master Gardeners should order publications through their home county extension office. Public orders may be placed by calling 1-800-876-8636 (outstate) or 612-624-4900 (local).

FS 1139 Moles and Shrews
FS 1141 Bats
FS 1143 Non-poisonous Snakes
EP 6721 Backyard Wildlife

Videos of Minnesota Gardening TV Programs

These are 30-minute videos developed as a series of programs aired in the Twin Cities for the general public. They are available from the University of Minnesota Extension Service Distribution Center: call
612-624-4900 (local) or 1-800-876-8636 (outstate).

VH 6628 Living With Wildlife

Yard and Garden Briefs

Deer: Coping with Deer in Home Landscapes
Pigeons (Rock Doves)
Raccoons
Voles
Woodpeckers On and Around Homes in Minnesota

chapter 13

woody plants

chapter 13

woody Plants

WOODY PLANTS

by Nancy Rose, Regional Extension Educator - Horticulture

INTRODUCTION

A woody plant can be defined as a perennial plant that has a woody structure that persists throughout all seasons of the year. Trees, shrubs, and some vines are classified as woody plants. Woody plants, especially trees and shrubs, are the main components of most planned landscapes. Because of their structural importance and longevity in the landscape it's essential to select these plants carefully, basing decisions primarily on site and environmental factors. The many species and cultivars of woody plants available provide a myriad of ornamental features to select from as well.

LEARNING OBJECTIVES

1. Understand the classification of woody plants and their nomenclature.
2. Understand the landscape function and value of various types of woody plants.
3. Understand the process of plant selection based on site and environmental factors.
4. Understand the basic process of identifying a woody plant.
5. Become familiar with a number of woody plants that are appropriate for use in Minnesota landscapes.
6. Know where to find valid information on woody plants.

TYPES OF WOODY PLANTS

Woody plants can be classified as trees, shrubs, or vines.

- **Tree**: grows with one or a few main trunks, usually over 15 feet tall.
- **Shrub**: grows with numerous branching stems, usually under 15 feet tall.
- **Vine**: grows with numerous long, thin, flexible stems that require support to grow upright.

There are certainly some exceptions to these broad definitions. For example, some large multi-stemmed shrubs such as nannyberry viburnum (*Viburnum lentago*) may grow taller than 15 feet in some sites. There are also single-trunked trees that grow less than 15 feet tall, such as Sargent crabapple (*Malus sargentii*) which matures at about 10 feet tall. Pruning or grafting can also blur the line between trees and shrubs. For example, gray dogwood (*Cornus racemosa*) typically grows as a 6 to 10 feet tall multi-stemmed shrub, but with early pruning and removal of sucker growth it can be trained as a single-trunked small tree. Small trees can also be formed by grafting shrubs at a 3 to 6 feet height onto compatible standards (understock trunks). An example of this is tree-form dwarf Korean lilac, in which the small, rounded shrub, dwarf Korean lilac (*Syringa meyeri* 'Palibin'), is grafted onto a Japanese tree lilac (*Syringa reticulata*) standard.

NOMENCLATURE

Successful selection and use of woody plants first requires an understanding of plant nomenclature. It is essential to know the structure of plant names so that you can find the plant you are looking for in reference material, on websites, or at nurseries or garden centers. In order to search for or communicate about any given plant you should know both its botanical name and its common name (if it has one).

Common names make it relatively easy to communicate about a plant with people who may not be familiar with botanical names. Common names may be broad (oak, maple, juniper) or more specific (Northern pin oak, red maple, dwarf Japgarden juniper). However, the pitfalls of only using common names quickly become apparent. For example, the name "red maple" may mean the species *Acer rubrum* to some, while others use the name "red maple" to indicate red-leafed cultivars of Norway maple (*Acer platanoides*). And one of our most common native juniper species, *Juniperus virginiana*, goes by the common name "Eastern red cedar", doubly confusing because the common name makes no mention of "juniper", and the plant is not in the true cedar genus, *Cedrus*. As a final example of the potential for confusion with common names, consider this list of plants which are all associated with the common name ironwood:

- Ironwood *Ostrya virginiana*
- Ironwood *Carpinus caroliniana*
- Ironwood *Parrotia persica*
- Ironwood *Backhousia sciadophora*
- Ironwood *Cliftonia monophylla*
- Ironwood *Eugenia confusa*
- Ironwood *Mesua ferrea*

Botanical names, on the other hand, are very specific to each plant. Botanical names (also referred to as Latin names or scientific names) follow a binomial system developed by Swedish botanist Carl Linnaeus (also known as Carl von Linné or Carolus Linnaeus) in the 1700s. Latin and Greek provide the language bases for most botanical names.

In the binomial system plants are identified by their two-part **species** name. The two parts of the species name are the **genus** and the **specific epithet**. The genus name is capitalized while the specific epithet is in lower case. The entire species names is italicized. The plural of genus is genera; species is both singular and plural.

Example:
The species name for common honeylocust is *Gleditsia triacanthos*.

species

genus	specific epithet
↓	↓
Gleditsia	*triacanthos*

Some plants may be further identified to the level of botanical **variety** (usually abbreviated as var. or v. when writing out the plant name). A variety is a naturally occurring variation of a species which will generally breed true from seed. For example, thornless individuals of the typically thorny common honeylocust occur naturally in the wild. Seeds collected and grown out from these thornless individuals produce a high percentage (over 70 percent) of thornless seedlings. A thornless common honeylocust is identified in this way:
Gleditsia triacanthos var. *inermis*
(In Latin the word *inermis* means unarmed, which in this case indicates "without thorns".)

For ornamental woody plants an even more common designation is the **cultivar** (a contraction of "cultivated variety") name. A cultivar is a plant that has been selected for a specific trait that varies from the species (e.g. different leaf size or form, different flower color) and has been designated with a cultivar name. Woody plant cultivars are almost always vegetatively propagated in order to maintain the desired trait. For example, 'Autumn Spire' red maple (*Acer rubrum* 'Autumn Spire') is propagated by rooting stem cuttings. Therefore each resulting plant is genetically identical to the original plant. Cultivar names are capitalized, not italicized, and set off in single quotation marks.

In recent years the process of patenting plants and using **trademark names** has added confusion to plant nomenclature. When a plant is patented, the patent holder controls the propagation and distribution rights for that plant for 20 years. In the patent application, the plant is identified by species and cultivar names; the patent protects that specific plant. After 20 years anyone can propagate and sell the plant using that cultivar name.

Some plant breeders and growers have sought to extend the period in which they have market control over their introductions by using trademark names. A trademark (indicated as ™, or, if a registered trademark, as ®) never expires as long as the holder renews it as required. A trademark protects only the use of that name and is not tied to any particular plant. This has led to introducers assigning odd, codelike cultivar names to plants, then using a pleasant trademark name in association with that plant. For example, the shrub rose cultivar 'MEIpitac' is marketed with the trademark name Carefree Wonder™. This rose cultivar was also patented, using the cultivar name 'MEIpitac'. After 20 years, anyone may propagate and sell this rose under its cultivar name 'MEIpitac', but of course most of the rose-buying public would not recognize that name and would continue to buy only the plants sold by the holder of the trademark name Carefree Wonder™.

It is also possible for growers to take an existing, non-patent-protected cultivar and sell the plant in association with a trademark name that they own. An actual example of this is the attractive spring-flowering 'Grefsheim' spirea (*Spiraea* x *cinerea* 'Grefsheim'), which was selected and named more than 100 years ago. A major U.S. wholesale nursery offers this plant for sale with the trademark name First Snow™, perhaps assuming that consumers will find that a more desirable name than its actual cultivar name.

Recently updated nursery standards require plant labels that use trademark names to also show the true cultivar name, though this is often in much smaller print.

All in the Family:

Gardeners and plant professionals are primarily interested in identifying plants at the species level (genus + specific epithet). However, there are some interesting aspects to learning about plant families. Family is the next broadest plant classification above genus. Families may encompass anywhere from one to hundreds of genera. Knowing family relations can help with plant identification; for example, all of the genera in the Betulaceae (birch family) bear male flowers in pendant, cylindrical catkins that are present through the winter. Genera within the Betulaceae that are commonly grown in Minnesota include *Betula* (birch), *Alnus* (alder), *Carpinus* (hornbeam, et al.), *Corylus* (hazelnut), and *Ostrya* (hophornbeam, et al.).

A few plant family fun facts:

- Family names are capitalized but not italicized.
- Most family names end with –aceae.
- The Ginkgoaceae has only one genus which contains only one species (*Ginkgo*; *Ginkgo biloba*).
- The Orchidaceae is one of the largest families with about 800 genera and over 17,000 species.

TREES, SHRUBS AND VINES: **Function and value in the landscape**

Different types of woody plants serve different functions within the planned landscape. Careful study of the site will help you determine which plant types are needed in each area within the site. There are many choices of plant species and cultivars within all of these plant groups.

Most planned landscapes use a combination of **deciduous** and **evergreen** woody plants. Deciduous plants lose their leaves in autumn and grow new leaves in spring. Evergreen plants retain their green (living) leaves throughout the year, though each leaf will eventually be shed (evergreen leaf retention typically ranges from 2 to 4 years but may be longer in some species). Evergreen woody plants are designated as **broad-leafed** evergreens or **narrow-leafed** evergreens. Broad-leafed evergreens have leaves that resemble typical deciduous plants. Examples of broad-leafed evergreens include boxwood and many species of rhododendron and holly. Narrow-leafed evergreens have needle- or scale-like leaves. Examples of narrow-leafed evergreens include pine, spruce, fir, arborvitae, and juniper.

Deciduous woody plants

Deciduous trees, shrubs, and vines provide much landscape interest from spring through autumn with foliage, flowers, fruit, and autumn color. In Minnesota, deciduous plants are leafless for 5 to 6 months of the year. During this time they can still provide interest through features such as bark, fruit, and branching structure, but they do not serve some of their summer functions such as shading and screening.

Deciduous trees:

Dividing deciduous trees by approximate mature heights, here are some of the functions and values of large, medium, and small trees in the landscape:

Large trees (mature height 50 feet or more):

- Provide a sense of scale. While trees can certainly be the tallest element in a landscape, be aware that very large trees growing close to small houses can throw off scale and feel overwhelming.
- Provide visual canopy and sense of enclosure in outdoor living areas.
- Provide shade. Large deciduous trees placed east or southeast and west or southwest of houses can reduce summer cooling costs.
- Ornamental features. Large deciduous trees are generally not notable for flower interest or showy fruit, but many provide excellent autumn foliage color and striking winter silhouettes.
- Wildlife food and habitat. Large trees provide nesting and sheltering sites for birds and some mammals. Acorns and other seeds and fruits provide wildlife food.

Medium trees (mature height 25 to 50 feet):

- Provide sense of scale. Many medium sized trees make excellent substitutes for large trees on small sites or near small houses where they are more in scale.
- Provide visual canopy and sense of enclosure in outdoor living areas.
- Provide transition from large trees to lower elements in the landscape.
- Provide shade. Even a 30 foot tall tree can provide significant shade to a one or two story house.
- Ornamental features. Many trees in this size range provide flower, foliage, and fruit interest.
- Wildlife food and habitat. Medium-sized trees provide nesting and sheltering sites for birds and some mammals as well as fruit and seeds for food.

Small trees (mature height to 25 feet):

- Provide sense of scale. Small trees are in scale with most houses and can be used in close proximity.
- Provide sense of enclosure in smaller outdoor areas such as patios or entry ways.
- Provide transition between smaller and larger landscape elements.
- Ornamental features. Many small trees provide multiple seasons of interest from foliage, flowers, fruit, autumn foliage color, bark, and branching habit.
- Wildlife food and habitat. Many small trees provide nesting and sheltering sites and food for birds.

Deciduous shrubs:

Deciduous shrubs offer an amazing range of sizes (less than 1 foot to over 15 feet tall), growth habits, foliage textures and colors, flowers, fruits, and other ornamental features. Shrubs are a major component of many planned landscapes. They can be planted singly, in small groups, or in mass plantings. Important landscape functions of shrubs include:

- Connect houses and other structures with their surroundings.
- Connect landscape elements. Shrubs of various sizes provide pleasing transitions between tall elements such as shade trees or buildings and lower elements such as groundcovers, turf, and paving.
- Fill vertical and horizontal spaces, including hedges and screening.
- Ornamental features. Deciduous shrubs provide multiple seasons of interest from foliage, flowers, fruit, autumn foliage color, bark, and branching habit.
- Wildlife food and habitat. Many shrubs provide nesting and sheltering sites and food for birds.

Evergreen woody plants:

In long-winter regions like ours, evergreens are an especially valuable component in the landscape. In warmer areas (Zone 6 and warmer) many broad-leafed evergreen trees and shrubs are used in landscaping, but in Minnesota's Zone 3 - 4 climate the narrow-leafed evergreens (pine, spruce, fir, hemlock, arborvitae, juniper, yew, etc.) represent the majority of landscape evergreens. Evergreen trees and shrubs serve the following functions in the landscape.

Evergreen trees:

- Provide mass and substance in landscape.
- Provide winter color.
- Provide visual screening
- Block wind and some noise.
- Wildlife habitat. Evergreens provide important shelter for birds and other wildlife.

Evergreen shrubs:

- Connect landscape elements.
- Fill vertical and horizontal spaces, including hedges and screening.
- Provide winter color.
- Block wind and some noise.
- Ornamental features. Dwarf conifers in particular provide a unique range of plant sizes, forms, foliage textures and colors.

Vines:

Vines comprise a unique and often underused plant group. They are a good choice for sites with limited horizontal space. In addition to a number of woody perennial vines, there are also many attractive and useful vines that are herbaceous perennials or annuals. The vines commonly grown in Zones 3 and 4 are deciduous. Vines do need support in order to grow upright, so you may need to supply a specialized structure such as a trellis or arbor when planting some vines.

There are several methods by which vines may climb. When selecting a vine for planting, it's important to know its climbing method so it can be placed in an appropriate site and be given a suitable structure to climb on if needed. Common methods of climbing for vines are:

- **Twining**. Stem twining is probably the most common adaptation for climbing . As the stem tips grow they actually move in a circular pattern, seeking out a support such as a branch or wire. The vine will then twine around the support, allowing the plant to grow upward. Vigorously twining vines like honeysuckle or bittersweet can wrap around large supports such as posts, but smaller twiners need more slender supports like string or wire. Twining vines require a support structure or they will grow prostrate on the ground. Overly vigorous twining vines can girdle or shade out small plants.
- **Adhering**. Some vines are adapted to climbing straight up flat surfaces with the aid of either sticky holdfasts or aerial rootlets. For example, Virginia creeper and Boston ivy bear clusters of sticky disks that act like suction cups, cementing themselves to vertical surfaces so the vine can climb farther up. Other vines such as trumpet creeper use large clusters of hairy aerial rootlets to plaster itself to the support. These vines do not require a separate support but should be planted close to the surface on which they will adhere. They are great for covering masonry walls, but they can be a problem on painted wood since the holdfasts or rootlets are tough to scrape off should the surface need repainting.
- **Twining petioles**. Clematis have a rather unique adaptation for climbing: twining petioles. The petioles are the stalks that hold the leaves, and they will twine around supports to help the vine continue to grow upward. The petioles are fairly short and can only twine around fairly thin supports, so give clematis a fine textured support structure such as wire fencing or nylon netting.
- **Tendrils**. Tendrils are actually modified leaves and may look like branched threads or small coiled springs, seen on vines such as grapes. These tendrils wind tightly onto nearby supports and, like the twining petioles of clematis, attach best to fairly thin supports. Some vines combine tendrils with twining stems or adhering holdfasts.

Vines serve these functions in the landscape:

- Screening (on vertical structures).
- Ground cover, if allowed to spread.
- Soften or mask structural features such as fences or buildings.
- Ornamental features: flowers, foliage, fruit, fall color.
- Food for humans, birds, and wildlife.

Conifer or Evergreen?

The botanical terms "evergreen" and "conifer" are NOT synonymous, but unfortunately they are often used that way in common parlance. As previously mentioned, an evergreen is a plant that retains green leaves throughout all seasons of the year for several years. A conifer is a plant in the order Coniferales that bears seeds in specialized structures called cones. The confusion perhaps stems from the fact that most of the commonly grown conifers in Minnesota are indeed evergreen: think pines (*Pinus*), spruce (*Picea*), fir (*Abies*), and arborvitae (*Thuja*). Even junipers (*Juniperus*) bear cones, though the fleshy, tightly closed scales make these cones look more like berries. These plants can all be described as "evergreen conifers". But there are also some conifers that are not evergreen. A prime example is American larch, also known as tamarack (*Larix laricina*), a Minnesota native. Larch is one of the small group of trees known as "deciduous conifers"; they bear cones, but they also lose their leaves annually. Other deciduous conifers include bald cypress (*Taxodium distichum*) and dawn redwood (*Metasequoia glyptostroboides*); unfortunately neither of these unique trees is fully hardy in Zone 4.

SELECTING THE RIGHT PLANT FOR THE RIGHT PLACE

Walk into a large nursery or garden center and you may feel overwhelmed by the number of woody plants that are available. Adding woody plants to your landscape has many advantages, but it also requires significant investments in money, time, and effort. In order to develop healthy, long-lasting plantings it's important to do some research before selecting trees, shrubs, and vines. Careful selection, proper planting, and follow-up maintenance will go a long ways toward ensuring that your plant purchases add value and enjoyment to your home.

When selecting woody plants, here are the major factors you should consider:

- **Purpose**
- **Plant size/Site space**
- **Hardiness**
- **Sun/wind exposure**
- **Soil type/Soil moisture**
- **Soil pH**
- **Disease/Insect/Maintenance issues**

Purpose

Why do you want to add a tree, shrub, or vine to your landscape? Determining the purpose of the addition is the first step in making a thoughtful plant selection. Some purposes include:

- **Shade**. Shade from trees can make outdoor living areas more inviting in hot weather and, when strategically placed, can reduce energy needed to cool homes. Large shade trees will provide large areas of shade, but medium or small trees may provide enough shade for a spot such as a patio or deck. Also consider whether too much shade could be a detriment; for example, vegetable gardens, fruit trees, and sun-loving annual and perennial flowers will not thrive in shade.
- **Screening / Hedge**. Do you want to screen a view year 'round? If so, dense evergreens may be your choice. Do you just want a little more backyard privacy in the summer? Then deciduous trees or shrubs may be enough. Limited space along a property line? Perhaps a sturdy trellis planted with vines is the answer.

- **Accent plant**. Accent plants serve to move the viewer's eye through the landscape and to highlight features such as an entryway to the home or a pathway. Planted singly or in small groups.
- **Specimen plant**. Specimen plants are often planted singly and are selected for having an outstanding ornamental feature in at least one season. For example, a star magnolia (*Magnolia stellata*) in the front yard would look spectacular in spring bloom. Some plants have specimen features in several seasons; for example 'Autumn Brilliance' serviceberry (*Amelanchier* x *grandiflora* 'Autumn Brilliance') has showy spring bloom and outstanding autumn color.
- **Group or mass planting**. Trees and shrubs of all sizes may be planted in groups. For example, 5 or more birches could be planted to form a grove; 3 American cranberry bush viburnums could be planted at the corner of a house; or a hundred Japanese spireas could be mass planted near a commercial parking lot.
- **Ornamental features**. Simply having attractive features can be a legitimate reason to select a plant. However, if you do not also consider environmental factors and cultural needs you may find that the plant requires lots of maintenance or may turn out to be short-lived. This is acceptable if you understand the risks. For example, if you love hybrid tea roses you can certainly plant them, as long as you are aware that for peak performance these roses will require high maintenance in the form of pesticide sprays, fertilizing, pruning, and winter protection.

Plant size/Site space

The most common mistake made in landscaping is planting trees and shrubs too close to other plants and to structures. This often results in plants intruding on pedestrian walkways, interfering with power lines, blocking window views, and/or inhibiting the normal growth of nearby plants. Take these steps to help prevent the problem:

- **Assess the site space**. Take a tape measure and measure out how much space you have for plants. Keep plants far enough away from buildings so that there will be several feet of open space between mature plants and the building. Don't forget to look up; plants that grow too close to power lines may end up being radically pruned or removed.
- **Know the plant's mature height and width before planting.** That cute little shrub in a 2-gallon pot will grow much bigger within a few years. Research the potential size of the species or cultivar you want to plant by checking reliable references. You may find slightly different size ranges listed in different references, but it should at least give you a good idea of mature size.
- **Know the plant's growth rate.** A shrub with a mature height of 10 feet might reach that height in 5 years if it has a rapid growth rate, or it might take 20 years if it is very slow growing (a dwarf conifer, for example). Slow-growing plants may be spaced more closely if desired, since it will take them longer to reach mature size.
- **Know the plant's growth habit**. This is important especially for shrub species that sucker extensively. Suckers are new plant sections that arise from the roots or rhizomes of the parent plant. Some species such as staghorn and smooth sumacs (*Rhus typhina*, *R. glabra*) form large colonies through sucker growth. This may be a desirable or undesirable landscape trait, depending on the particular site.

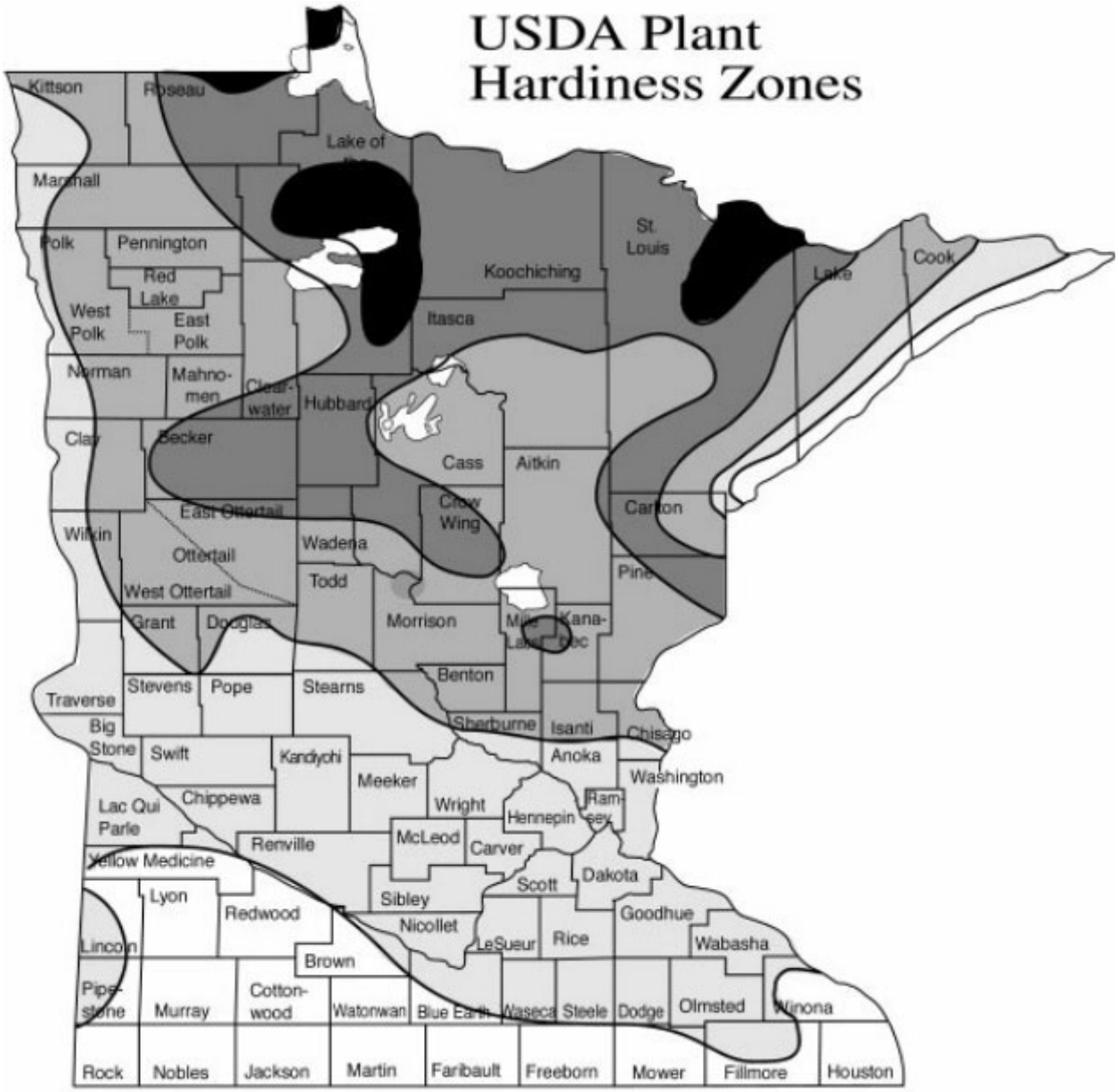
Hardiness

Cold hardiness is an essential concern when selecting woody plants in Minnesota. Winter survival of woody plants is a complex issue. It is affected by a plant's genetic makeup and by specific environmental and climatic

conditions which may vary from year to year. Woody plant species with a wide geographical distribution may show an equally wide range of cold hardiness. In these cases it's important to select individual plants from a provenance (original seed source) with a climate similar to that of the planting location. For example, red maple (*Acer rubrum*) grows natively in the United States from Maine to Florida. A red maple originating in Maine would be better adapted to growing in Minnesota than one from Florida because of greater similarities in latitude and climate between Minnesota and Maine.

In order to have some kind of rating system for woody plants several organizations have developed cold hardiness zone maps over the years. The most widely used and accepted map is the USDA Plant Hardiness Zone Map. The current USDA map was introduced in 1990 and uses temperature data from 1974 to 1986. The USDA map divides North America (Canada, the United States, Mexico) into eleven zones, with Zone 1 being the coldest. The zones are based on the average annual minimum temperature and are divided by 10 degree F increments. The zones are further divided into sections "a" and "b" by 5 degree F increments, with "a" being the colder section.

Minnesota falls within USDA Zones 3 and 4, with several small sections of Zone 2b in the far northern part of the state. Here are the average annual minimum temperatures for these zones:



Average Annual Minimum Temperature

Temperature (C)	Zone	Temperature (F)
-40.0 to -42.7	2b	-40 to -45
-37.3 to -40.0	3a	-35 to -40
-34.5 to -37.2	3b	-30 to -35
-31.7 to -34.4	4a	-25 to -30
-28.9 to -31.6	4b	-20 to -25

While this zone map is useful for giving an idea about a tree or shrub species' hardiness range, there are many factors that should be considered beyond a zone rating. Some important aspects of cold hardiness include:

- **Cold hardiness** is not determined only by the lowest annual winter temperature. Woody plants have different levels of cold hardiness through the year (see next point). This is why it's really not possible to say that a certain plant is hardy to exactly -27 degrees, for example.
- **Acclimation and deacclimation.** Every year, woody plants go through a process of acclimation (progressively developing greater cold tolerance) and deacclimation (progressively losing cold tolerance). Acclimation occurs starting in late summer and into autumn as daylength shrinks and temperatures become colder. Woody plants usually reach their greatest degree of cold hardiness in mid-winter. Then, as days lengthen and temperatures warm towards spring, woody plants start to deacclimate. Winter injury often occurs not from mid-winter low temperatures but from sudden temperature changes during the acclimation and deacclimation periods.
- **Plant health**. A number of factors can alter a plant's ability to tolerate cold temperatures. Plants that are stressed by factors such as insect or disease damage, drought, or nutrient deficiency are often more susceptible to cold injury. Factors that delay normal acclimation in autumn (e.g. excessive fertilizing or heavy pruning in late summer or early fall; presence of bright lights at night which can mimic long daylength) make plants more susceptible to winter injury.
- **Microclimates**. Environmental factors such as sun, shade, wind protection, city heat sink effects, water bodies, and topography can affect temperatures on a very localized level. You may find that a friend who lives a few miles away can successfully grow a shrub species that has repeatedly suffered winter dieback at your house, simply because she has a more favorable microclimate. Adventurous gardeners enjoy experimenting with marginally hardy plants by carefully siting the plants in protected microclimates.
- **Snow cover/ Mulch**. The insulation provided by snow cover or applied mulch such as straw can aid winter survival for some marginally hardy woody plants. Even hardy plants may suffer more damage in winters that lack snow cover because of greater depth of soil freezing and loss of soil moisture which can damage fine feeder roots.

A common frustration for gardeners is finding several **different zone ratings** for one plant listed in different catalogs or reference books. From the list above, you can see why it is difficult to assign a precise zone rating for any plant. There is no formal testing process for woody plant hardiness; for new cultivars, hardiness ratings usually are provided by the introducer. The introducer may or may not have tested the plant in different hardiness zones. Commercial references (catalogs, websites) often seem to list wider zone ranges than other references, perhaps to include more potential customers. If you find conflicting zone ratings for a plant you're interested in growing it's worth checking with gardening friends, public gardens, or other local resources to see how the plant has performed in your area.

Sun exposure

Woody plant species have specific preferences for sun exposure and may not thrive under other light conditions. When selecting plants for a specific site in your landscape consider what that site's sun/shade conditions will be in all seasons of the year; remember the dramatic change in light levels once large deciduous trees leaf out.

Typical descriptions of sun exposure levels include:

- **Full sun.** At least 8 hours of direct sunlight each day during the growing season. The majority of woody plants grow best in full sun or at least part-day sun.
- **Part-day sun.** Distinct periods of sun and shade during the day. A pattern of morning sun and afternoon shade is ideal for some plants including clematis and certain gold-foliaged plants that may suffer sunburned leaves in full sun.
- **Filtered shade**. The amount of shade cast by large trees varies depending on the density of their leaf canopy. Tree species with fairly open canopies such as honeylocust cast dappled or filtered shade which allows moderately shade tolerant species to be grown near them.
- **Full shade**. Dense canopied trees such as sugar maples and Norway maples create dense shade which can make it difficult to grow other woody plants near them. Dense shade from buildings, especially on the north sides of buildings, also makes it difficult for most plants to grow.

Winter sun can cause damage to leaves and bark of some evergreen and deciduous woody plants. A number of broadleaf and needled evergreens are susceptible to **winter burn** on their foliage. Winter burn occurs when sunlight heats the leaves enough to cause stomata (leaf pores) to open, resulting in loss of water from the leaves. Strong wind can exacerbate the water loss. In warmer seasons the plant would respond by drawing water into the roots then transporting the water to the leaf to replace lost water. When the ground is frozen, though, water cannot be replaced. This can lead to desiccation (drying) of leaf cells and possibly browning and death of the entire leaf. The dead foliage often becomes very noticeable in late winter to early spring. Buds and stems are less susceptible to winter burn than leaf tissue, so new growth may cover old winter burned foliage by midsummer. In severe cases of winter burn pruning or complete plant removal may be required. To help reduce the chance of winter burn, water all evergreens thoroughly in autumn before the soil freezes and apply several inches of mulch around the plants. Shading or wrapping evergreens may also help prevent winter burn. When planting winter burn-susceptible evergreens such as yews and rhododendrons, site them on north or east sides of buildings or other locations where they will be shaded in winter.

Winter sun can also cause **sun scald** on the trunks of thin-barked deciduous trees. Sun scald occurs when winter sun, including reflection off snow, heat tissue on the south to southwest side of tree trunks. This tissue can be warmed enough to become active, but when the sun is no longer heating the trunk the ambient below-freezing air temperatures can cause sudden chilling and damage to the tissue. This can result in sections of dead tissue on the trunk. Kraft paper trunk wrapping was previously recommended but studies have not shown it to be effective. Current recommendations to reduce the chance of sun scald on thin-barked trees are shading the trunk with sections of loose-fitting white PVC tubing or with a board loosely tied to the south side of the trunk. Protection should be removed in the spring.

Soil type / Soil moisture

Many woody plants will grow well in a fairly broad range of soil types. Other plants are fairly particular about soil type and especially about soil moisture levels. Soil type and soil moisture/drainage can vary from spot to spot even on a fairly small property. Before selecting any tree, shrub, or vine it's important to know the site conditions and soil preferences of that plant.

Sandy soils tend to drain quickly, which is often a good trait, but they can also hold too little water and lose nutrients quickly. Clay soils hold moisture and nutrients well but may also drain too slowly and be difficult to work if too dry.

Adding organic matter to any type of soil is usually beneficial, but it is not really possible to completely change the soil type by doing so. It's better to select plants that are adaptable to your site's soil conditions rather than try to drastically change the soil.

Soil pH

Soil pH is measured on a scale of 0 to 14. A pH of 7 is neutral; above 7 is alkaline, below 7 is acidic. The best pH range for most plants is from 5.5 to 7.0, since most nutrients are most available at this pH level. Many woody plants will tolerate somewhat alkaline soils, above pH 7.0. Some woody plants definitely require acid soils (usually in a pH range of 4.5 to 5.5, possibly up to 6.0 for some). Some particularly desirable ornamentals are in this acid-loving categories, including azaleas and rhododendrons (*Rhododendron* spp.), blueberries (*Vaccinium* spp.), winterberry (*Ilex verticillata*), and summersweet (*Clethra alnifolia*).

The only way to determine soil pH on a site is to have soil samples tested. For the most accurate testing for soil pH as well as soil nutrients and texture soil, samples should be analyzed by a soil lab like the University of Minnesota's. It is possible to raise or lower soil pH in at least a limited area but it may require ongoing treatments to maintain a particular soil pH. This may be worthwhile for limited planting sites, but not for an entire property. For example, if you have a soil pH of 6.8 and you'd like to grow some azaleas, you can use sulfur to lower the soil pH to 5.5 in a limited planting area for the azaleas. Building a raised bed or berm with soil amended specifically for acid-loving plants may be the best option on higher pH soils.

Disease/Insect/Maintenance Issues

No woody plant is completely unaffected by diseases or insects. But when selecting plants, choosing those that are known to be relatively problem free can go a long ways toward reducing pesticide use, reducing maintenance time, and providing a healthy, long-lived landscape. This doesn't mean you can't select a few plants that you know will require some extra care in the form of disease or insect control, or greater maintenance needs such as extensive pruning or winter protection, as long as you are aware of the issues before planting.

A general strategy for selecting low pest problem, low maintenance woody plants follows:

- **Select pest resistant cultivars**. Let's say you want to plant a flowering crabapple in your yard. There are dozens of crabapple cultivars available from nurseries and garden centers. These cultivars vary widely in their susceptibility to common disease problems such as apple scab. Cultivars such as 'Hopa' and 'Radiant' are extremely susceptible to apple scab, often resulting in moderate to severe defoliation of the tree by late summer. On the other hand, cultivars such as 'Prairifire' and 'Donald Wyman' have good resistance to apple scab, resulting in lower maintenance needs and greater landscape value.
- **Select alternative species or hybrid within a genus**. Some tree and shrub species have few or no cultivars available, or all cultivars that are available may be equally susceptible to a pest problem. In this case, you may want to look for a different species but within the same genus. For example, you might want to plant a red oak (*Quercus rubra*) but you are concerned about the issue of oak wilt, a serious disease problem. There are no oak wilt resistant cultivars of red oak (in fact, there are few cultivars of red oak at all). But other species of oak (including white oak [*Q. alba*] and bur oak [*Q. macrocarpa*]) are less susceptible to oak wilt and would certainly serve landscape functions similar to red oak.

- **Select a completely different plant.** Perhaps you were thinking about planting a green ash (*Fraxinus pennsylvanica*), a large tree that's been widely used for commercial and residential landscaping in Minnesota. While it has many good traits, there have been increasing disease and insect problems with this species, including the threat of emerald ash borer, a devastating insect problem that has not yet been found in Minnesota. All ash species are susceptible to emerald ash borer, so simply selecting an alternative species within a genus is not a good option in this case. Your best course of action is to consider all trees that have the qualities you were looking for (specific size, soil tolerances, etc.) and narrow down your selection from those. In many cases, it's best to begin the plant selection process by looking at a number of different species within a broad category (e.g. large shade tree, small flowering shrub), rather than having one specific plant in mind first.

INVASIVE WOODY PLANTS

We've looked at a number of reasons NOT to select a particular woody plant, such as high susceptibility to pest problems, high maintenance needs, and having cultural requirements that do not match with existing planting site conditions. A plant's potential to be invasive is another cause for concern.

Invasiveness can be defined in a number of ways. At the broadest level, an invasive woody plant can be defined as any plant growing where it is not desired. More narrowly defined, an invasive woody plant is one that can increase its population in an area to the point that it crowds out the existing plants in that area. This is of special concern when non-native plants invade and displace native plant communities.

There are both non-native and native (indigenous to North America) plants that have the potential to be invasive. Invasiveness can also vary from region to region. For example, English ivy (*Hedera helix*), native to Eurasia, is extremely invasive in the mild climate of the Pacific Nothwest states, where it climbs high into trees and can overwhelm small plants on the ground. In Minnesota, however, English ivy is marginally hardy, at most surviving only as a ground cover in warmer parts of Zone 4.

Minnesota does have a number of invasive woody plant species distributed throughout the state. Here are some of the non-native invasive woody plants commonly encountered in the state:

- Common buckthorn (*Rhamnus cathartica*)
- Glossy buckthorn (*Rhamnus frangula*) including cultivar 'Columnaris'
- Shrub honeysuckles (*Lonicera tatarica*, *L. maackii*, *L.* x *bella*)
- Russian olive (*Elaeagnus angustifolia*)
- Siberian elm (*Ulmus pumila*)
- Siberian pea shrub (*Caragana arborescens*)
- White mulberry (*Morus alba*)

The following non-native woody plants may be invasive in some areas. They are still widely used in landscaping.

- Japanese barberry (*Berberis thunbergii*)
- Burning bush (*Euonymus alatus*)
- Norway maple (*Acer platanoides*)
- Amur maple (*Acer ginnala*)

Several North American native plants are also invasive in at least parts of the state. The following two species are fairly common:

- Black locust (*Robinia pseudoacacia*)
- Prickly ash (*Zanthoxylum americanum*)

Other native plants that may be aggressive or invasive on some sites include:

- Boxelder (*Acer negundo*)
- Poison ivy (*Rhus toxicodendron*)
- Sumac (*Rhus typhina, R. glabra*)
- Wild grape (*Vitis riparia*)
- Virginia creeper (*Parthenocissus quinquefolia*)
- Silver Maple (*Acer saccharinum*)
- Green ash (*Fraxinus pennsylvanica*)

Government agencies, the nursery industry, and the gardening public will continue to have to wrestle with the problem of invasive plants in the future. While gardeners enjoy the diverse ornamental qualities that plants from different parts of the world bring us, we certainly need to be aware of the potential for environmental damage from those plants that do turn out to be invasive. The example of common buckthorn, a Eurasian species once widely planted here as a hedge plant but now a damaging invader, makes us aware of the seriousness of the issue.

IDENTIFYING WOODY PLANTS

Identifying woody plants in the field or from samples (e.g. leaves, branches) requires observation skills and attention to details. As with identifying birds, frequent practice and good reference materials will help you improve your plant identification skills.

Dichotomous keys are one type of reference that may help with plant identification. These keys offer a series of choices that allows you to narrow down the possibilities for the plant you are keying out. Keys require at least some familiarity with taxonomic terms since the choices offered describe some part of the plant. This may start as broadly as a choice between alternate or opposite leaf arrangement and may narrow to details about something like the degree of serration on leaf margins. Many reference books have glossaries that define the taxonomic terms used in keys.

References (books, websites) that provide detailed photographs or drawings of plants are also useful for plant identification and can often be used in conjunction with written keys. You may find it useful to take photographs of correctly identified plants and refer to them when attempting to key out an unknown plant.

Features such as flower and fruiting structures can often lead to the “Aha!” moment when trying to identify a plant, so look carefully for things like cones, catkins, and seed pods. Sometimes even the presence of certain disease or insect problems can help with plant identification; for example, the presence of witches’-brooms (abnormal clusters of fine, twiggy growth on branches) could help in identifying a hackberry tree in winter, since witches’-brooms are a fairly common problem with this species.

Whether you are identifying a plant on site or from a client’s descriptions, here are some questions to consider in order to help you pin down the plant’s identity:

What is the growth habit? (e.g. tree, shrub, single or multiple trunks, upright, spreading)
What size (height and width), approximately?
Deciduous or evergreen? (usually obvious, but in summer some broadleaf evergreens could be mistaken for deciduous, and deciduous conifers may look evergreen)
Leaf arrangement?

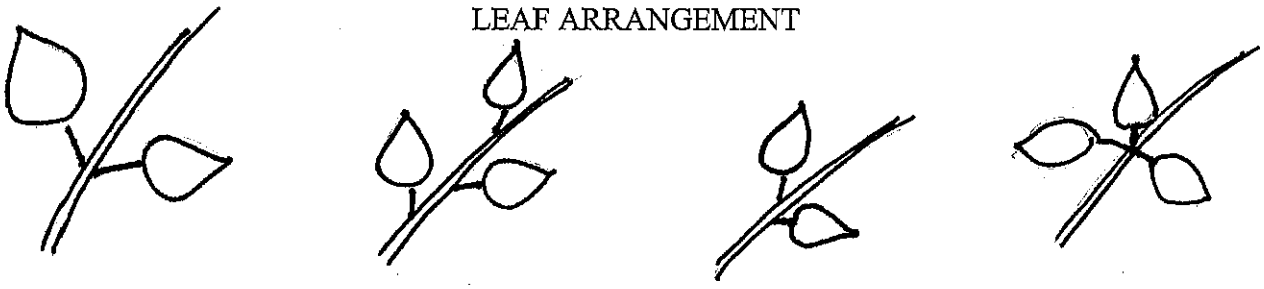
- Opposite
- Alternate
- Whorled
- Sub-opposite

Are leaves simple or compound?
Leaf shape (including leaf tips and bases) and size?
Leaf margins?
Leaf surfaces?
Leaf venation?
Leaf color, summer and autumn?
Bark color and texture? (may vary between younger and older stems)
Flower structure? (borne singly or in clusters? form of clusters?)
Flower color and size?
Fruit? Borne singly or in clusters? Arrangement of clusters?

- Dry seedpod or capsule
- Fleshy (berry, pome, drupe, etc.)
- Nut
- Cone

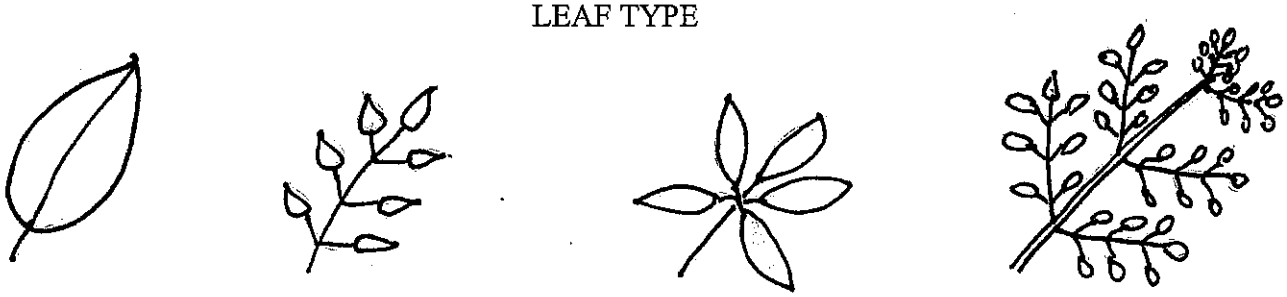
Shape , size, color of winter buds?
Branching pattern?
Are there thorns?

LEAF ARRANGEMENT



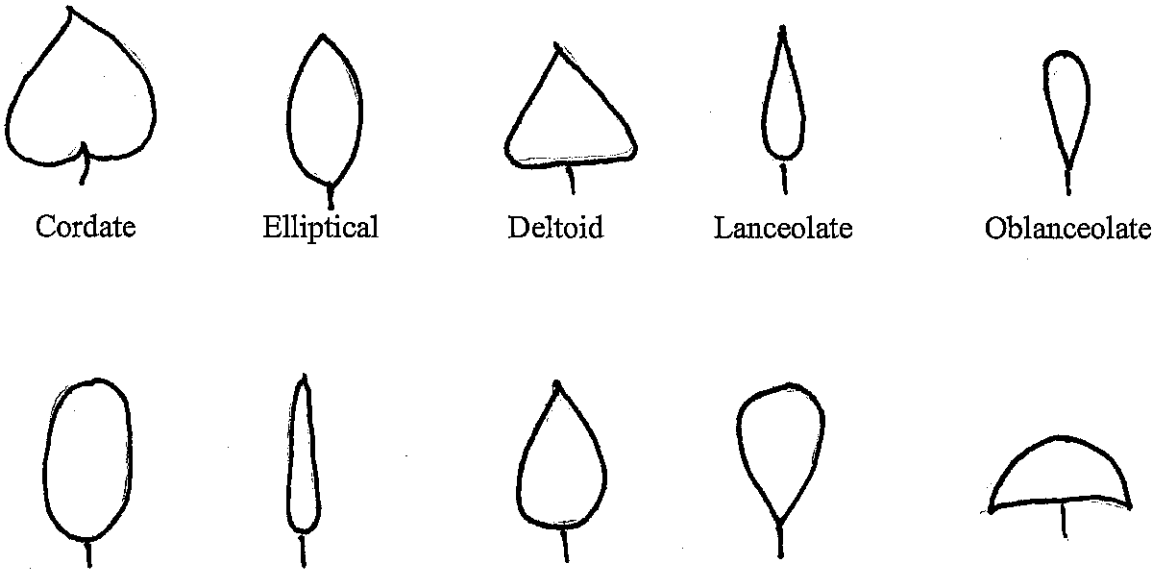
Opposite | Alternate | Subopposite | Whorled

LEAF TYPE



Simple | Pinnately compound | Palmately compound | Bipinnately compound

LEAF SHAPES



Cordate | Elliptical | Deltoid | Lanceolate | Oblanceolate

Oblong | Linear | Ovate | Obovate | Flabellate

LEAF MARGINS

Entire | Serrate | Doubly-serrate | Dentate | Crenate | Lobed

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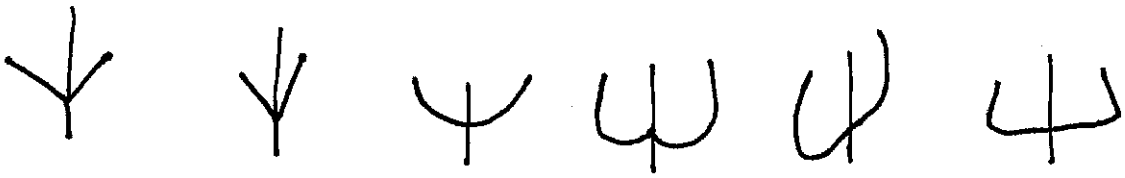
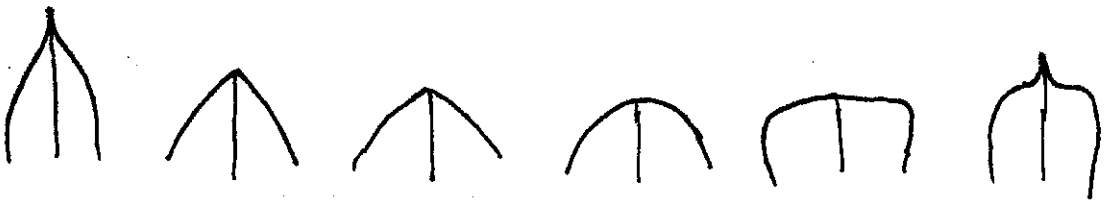
LEAF BASES



Acute | Cuneate | Rounded | Cordate | Oblique | Truncate

LEAF APICES



Acuminate | Acute | Obtuse | Rounded | Truncate | Cuspidate

LEAF SURFACES

Glabrous--- the surface is smooth, not hairy.
Pubescent--- short, soft hairs cover the surface.
Villous--- long, straight hairs cover the surface.
Tomentose--- covered with wool-like hair.
Scabrous--- covered with short, prickly hairs.
Glaucous--covered with a bluish-white waxy substance.
Rugose--surface is wrinkly.

RECOMMENDED WOODY PERENNIAL VINES FOR MINNESOTA

Hardy kiwi (*Actinidia arguta*); twining; requires sturdy support; fruit is smooth-skinned, grape-sized; male and female plants required for fruit production; full sun; may suffer winter dieback and death of flower buds in Zone 4; select hardy cultivars such as 'Ananasnaja'

Arctic kiwi (*Actinidia kolomitka*) - twining; requires sturdy support; full sun; foliage shows white variegation (with pink tones in cool weather); cultivar 'Arctic Beauty'; Zone 4, possibly 3b.

Fiveleaf akebia (*Akebia quinata*) - twining; delicate compound leaves; small purple flowers; sun or partial shade; stems often die back in winter in Zone 4 but is usually crown hardy.

Dutchman's pipe (*Aristolochia macrophylla*) -twining; shade tolerant; large, heart-shaped leaves provide quick cover for summer screening; bears unusual (but not showy) pipe-shaped small flowers in summer. Zone 4.

Trumpet creeper or trumpet vine (*Campsis radicans*) - aerial rootlets; clusters of orange, trumpet-shaped flowers in summer, attractive to hummingbirds; full sun or partial shade; generally not as vigorous in Zone 4 as it is in warmer climates.

American bittersweet (*Celastrus scandens*) - twining; vigorous, needs sturdy support; male and female plants needed for fruit production; clusters of bright red-orange fruits are attractive for fresh or dried decorations; full sun or partial shade. Zone 3.

Clematis (*Clematis*) - many species and hybrids; twining petioles; many slender stems; need moist, cool, well-drained soil. Zone 3 or 4.
Large-flowered hybrids: Many cultivars available with flower colors in white, pink, magenta, shades of purple to blue-purple, and bicolors.
C. alpina and cultivars – early flowering; white, pink, or blue pendant flowers
C. macropetala and cultivars – early flowering; blue or pink pendant flowers
C. tangutica – late summer flowering; bright yellow flowers.
Sweet autumn clematis (*C. terniflora*) – many small, fragrant white flowers in early autumn. Zone 4.
C. texensis and cultivars – bell or tulip-shaped flowers; true reds, pinks.

Climbing hydrangea (*Hydrangea anomola* subsp. *petiolaris*) - aerial rootlets; limited hardiness in Zone 4 but can be used as an attractive ground cover; shade tolerant; the species bears white lacecap type flowers but blooms are rarely produced in Zone 4.

Dropmore Scarlet honeysuckle (*Lonicera* x *brownii* 'Dropmore Scarlet') - twining; many slender stems; clusters of narrow, trumpet-shaped red-orange flowers that attract hummingbirds; heavy bloom in early summer with lighter rebloom until frost; full sun; Zone 3.

Mandarin honeysuckle (*Lonicera* 'Mandarin') - twining; many slender stems; bright orange flowers from late spring into summer; full sun; Zone 3.

Trumpet honeysuckle (*Lonicera sempervirens*) – twining; many slender stems; clusters of narrow, trumpet-shaped red-orange flowers that attract hummingbirds; blooms early summer with some rebloom; full sun or partial shade; yellow-flowered cultivar 'John Clayton'; Zone 4

Moonseed (*Menispermum canadense*) - twining; native vine notable for shade tolerance; large, rounded leaves provide quick screening; deep purple-black, grapelike fruit (not edible) on female plants. Zone 3.

Virginia creeper (*Parthenocissus quinquefolia*) - adhering holdfasts; can be aggressive; high-climbing if allowed to grow on trees; early fall color, excellent bright red; deep blue-black fruits readily eaten by birds; full sun or partial shade. Related species: *P. q.* var. *engelmanii* - has smaller leaves, is slightly slower growing; *P. inserta* - very similar to *P. quinquefolia* but lacks adhesive discs, climbs by tendrils and twining. Zone 3.

Boston ivy (*Parthenocissus tricuspidata*) - adhering holdfasts; good on stone, brick, or unpainted wood structures; nice yellow-red-purple fall color; full sun or partial shade; Zone 4.

Grape (*Vitis* hybrids, including 'Bluebell', 'Concord', 'Edelweiss', 'Swenson Red') - twining; needs regular pruning for good fruit production; wild grape (*Vitis riparia*) can also be used but may be overly aggressive for some sites; full sun for best fruiting; Zone 3-4.

Kentucky wisteria (*Wisteria macrostachys*) - twining; needs sturdy support; clusters of fragrant light purple flowers in early summer with some later rebloom; species seedlings vary in hardiness and are generally not hardy in Zone 4, but the cultivars 'Blue Moon' (best) and 'Aunt Dee' are Zone 4 hardy.

RESOURCES

University of Minnesota Extension publications:

150 Years of Hardy Plants
A Practitioner's Guide to Stem Girdling Roots of Trees
Azaleas and Rhododendrons for Minnesota
Beginner's Guide to Minnesota Trees, A
Blueberries for Home Landscapes
Choosing Landscape Evergreens
Fitting Trees and Shrubs into the Landscape
Insect Pests of Roses
Japanese Beetle Management in Minnesota
Leaf and Needle Diseases of Trees
Leaf Beetles in Urban Landscapes
Living Snow Fences
Minimizing De-Icing Salt Injury to Trees
Minnesota Gardening: How to Buy a Tree
Minnesota Hardy
Minnesota Trees
Native Trees for Landscape Use
Oak Wilt in Minnesota
Planting and Transplanting Trees and Shrubs
Planting Trees and Shrubs for Long-Term Health
Planting Trees in Minnesota
Protecting Trees and Shrubs Against Winter Damage
Protecting Trees From Construction Damage, a Homeowner's Guide
Pruning Trees and Shrubs
Recommended Trees for: Northern Tallgrass Prairie
Recommended Trees for: Northwest and Central Minnesota
Recommended Trees for: Southeast Minnesota
Recommended Trees for: Southwest Minnesota
Roses for the North: Performance of Shrub and Old Garden Roses at the Minnesota Landscape Arboretum
Sawflies of Trees and Shrubs
Scale Insects of Trees and Shrubs
Selecting Hardy Roses for Northern Climates
Tough Trees and Shrubs for Tough Sites
Tree Fertilization: Guide for Fertilizing New and Established Trees in the Landscape
Tree Owner's Manual
Trees, Shrubs and Vines for Minnesota Landscapes
Verticillium Wilt of Trees and Shrubs

Books:

Brickell, Christopher and Judith Zuk eds. 2004. *The American Horticultural Society*
A to Z Encyclopedia of Garden Plants, 2nd edition

Dirr, Michael A. 1998. *Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture, Propagation and Uses*

Dirr, Michael A. 1998. *Hardy Trees and Shrubs*

Griffiths, Mark. 1994. *The Royal Horticultural Society Index of Garden Plants*

Huxley, Anthony ed. 1992. *The Royal Horticultural Society Dictionary of Gardening*

Rehder, Alfred. 1987. *Manual of Cultivated Trees and Shrubs*, 2nd edition

Sternberg, Guy with Jim Wilson. 2004. *Native Trees for North American Landscapes*

Steiner, Lynn M. 2004. *Landscaping with Native Plants of Minnesota*

Rose, Nancy, Don Selinger, John Whitman. 2001. *Growing Shrubs and Small Trees in Cold Climates*

Harris, Richard W. 1991. *Arboriculture: Care of Trees, Shrubs, and Vines in the Landscape*

Fiala, Fr. John L. 1994. *Flowering Crabapples: The Genus* Malus

Stearn, William T. 1996. *Stearn's Dictionary of Plant Names for Gardeners*

Coombes, Alan. 1994. *Dictionary of Plant Names*

Web sites:

Landscape Plants of the Upper Midwest – U Wisconsin:
http://www.midwestlandscapeplants.org/

USDA Plants Database:
http://plants.usda.gov/index.html

The Right Tree Handbook:
http://www.mnpower.com/treebook/

Forest and Shade Tree Health:
http://www.cnr.umn.edu/FR/extension/forestandshadetreehealth.html

Midwest Plant Selection – Morton Arboretum:
http://www.mortonarb.org/plantinfo/plantclinic/planttrees/plantclinic_planttrees.htm

U Connecticut Plants Database:
http://www.hort.uconn.edu:591/search.html

Sustainable Urban Landscape Information Series:
http://www.sustland.umn.edu/

MN Tree Care Advisors plant information:
http://www.mntca.org/Reference_manual/Tree_info/Minnesota_Tree_Index.htm

Yard and Garden Briefs:
http://www.extension.umn.edu/projects/yardandgarden/

Yard and Garden Line Newsletter: http://www.extension.umn.edu/projects/yardandgarden/ygline-news.html

U of Mn Soil Testing Laboratory:

http://soiltest.coafes.umn.edu/

Plant nomenclature:
http://herbarium.usu.edu/treatments/accepted_names_and_synonyms.htm

http://www.ishs.org/icra/

http://fp.bio.utk.edu/mycology/Nomenclature/nom-index.htm

http://www.winternet.com/%7Echuckg/dictionary.html specific epithets

http://garden-gate.prairienet.org/botrts.htm root words

International Code of Botanical Nomenclature:
http://www.bgbm.fu-berlin.de/iapt/nomenclature/code/SaintLouis/0000St.Luistitle.htm

Plant identification and ID keys:
http://www.hort.uconn.edu/plants/keys/trees/treekey01.html

http://www.extension.iastate.edu/pages/tree/

http://forestry.msu.edu/uptreeid/default.htm

http://dnr.wi.gov/org/land/forestry/treeid/keys.htm

http://www.dnr.state.wi.us/org/caer/ce/eek/veg/treekey/ (tree key for kids)

http://www.cnr.vt.edu/dendro/dendrology/idit.htm

http://www.extension.umn.edu/distribution/naturalresources/DD6593.html
(A Beginner's Guide to MN Trees)

Invasive plants:
http://www.dnr.state.mn.us/invasives/terrestrialplants/index.html

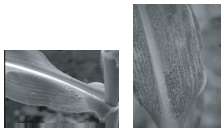
http://www.dnr.state.wi.us/invasives/plants.htm

http://tncweeds.ucdavis.edu/index.html

http://www.invasive.org/

Monitor for:

Common Smut



Common Rust

Caution! – Poor tip fill can be due to poor pollination brought on by silk clipping, planting too close, poor fertility, and weather

Lodging

Tomatoes (*Lycopersicon esculentum*)

- Most popular vegetable in the garden
- Each plant can yield up to 15 lbs. of fruit
- Types and sizes are endless and can be either determinate or indeterminate in growth pattern
- Great for containerized gardening
- Self pollinated (very efficient)
- Spontaneous mutations have produced a variety of colors

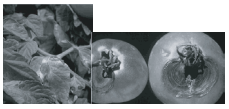
Growing and Harvesting

- Establish planting using transplants
- Avoid producing spindly plants (What causes this?)
- Harden off the transplants for about 2 weeks (How?)
- Plants should be 6-7 weeks old when placed in the garden (after danger of frost)
- Plant seedlings deep so they are well covered by the soil (roots will be produced along the buried stem)
- With peat pot transplants – tear one side of the pot to encourage root growth

Growing and Harvesting

- Space staked or trellised plants 24" apart in rows 3 ft. apart (reduces fruit rot)
- Prune staked plants to 1 or 2 main stems
- Remove other suckers
- Cages also work well
- Ventilation between plants is important (Why?)
- Harvest when vine-ripe and before cracking
- Leave pedicel on fruit (Why?)

Monitor for:

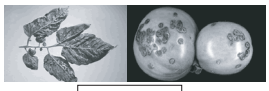


Early Blight

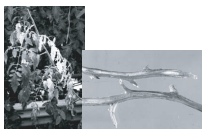
Verticillium

Late Blight

Monitor for:

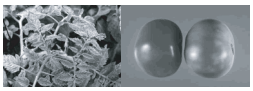


Bacterial Spot



Fusarium Wilt

Bacterial Speck



Tobacco Masaic Virus

appendices

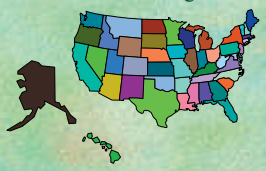
program information

appendix I

University of Minnesota Extension Service

Master Gardener Program/Hort 1003

1862 Morrill Act
Land Grant Colleges



1914 Smith Lever Act:
Cooperative Extension

UNIVERSITY OF MINNESOTA

Teaching

Research

Extension

Extension's Mission:

- Making a difference by **connecting community needs and University resources** to address critical issues in Minnesota.

MG Core Course Objectives

- To present university based cultural information about horticulture.
- To understand the procedures necessary for diagnosis of horticultural pests, and recommend resources for their prevention and control.
- To prepare volunteers to become effective horticultural teachers in their communities.
- To meet other Master Gardeners and Extension staff, locally and at the U.
- To become familiar with horticultural resource materials.
- To identify your interests, strengths and areas where you can volunteer.

University of Minnesota Master Gardener Program

Policy and
Core Value
Statement

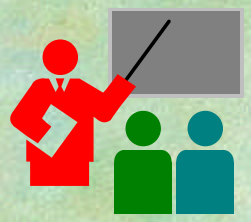
University of Minnesota Extension Service
Master Gardener Core Value

- University of Minnesota Master Gardeners teach research-based horticultural information. This information may be new or different from your personal experience or opinion. **Teaching research-based information is Extension's purpose and mission.** This is an important core value of Extension and Master Gardeners are expected to uphold this value.

Minnesota Master Gardener Program

* **INTERN**
  1st year
  48 hr education +
  50 hr volunteer =
  CERTIFIED MG

* **ACTIVE MG**
  2nd year (& more)
  5-12 hr class +
  25 hr volunteer



MG Program: What Counts ?

- ✓ ID yourself as an Extension Master Gardener,wear your nametag.
- ✓ Educational Activity; non-profit.
- ✓ Approved by local Extension Educator or program coordinator.
- ✓ Would the Extension Educator do this ?
- ✓ Am I teaching others, is there a transfer of knowledge ?

Washington County Fairgrounds Display Garden

Olmsted County Buckthorn Busters

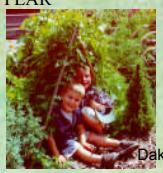
Master Gardener Program

MASTER GARDENER

- Help County Staff
- Assist with State Programs
- Stay Up-to-date
- SEND IN YOUR HOURS EACH YEAR

STATE and COUNTY

- Provide Update Materials
- Quarterly Newsletters
- Service Awards
- Educational Conferences
- Opportunities to Serve



Dakota County JMG

Minnesota MG Internet Policy

- Minnesota Master Gardeners must make recommendations based on University research. Information and recommendations from the Internet must be taken only from Extension sites, preferably from Minnesota and the North Central region. Texas and Ohio have outstanding sites, which may or may not apply to Minnesota conditions. The Internet now gives Master Gardeners access to more information than ever, however, **only University Extension sites, especially those with similar climates should be used for recommendations.**

Important Internet Addresses:

- **U of MN Extension Homepage: www.extension.umn.edu**
- **U of MN Master Gardener Homepage: www.mg.umn.edu**

MG Online Class

- Class Address: **http://www.umn.edu**
- Click on: myU
- Click on: myToolkit
- username: **garden**

password: **SignOn123**

capitals letters S and O are required

- Click on Hort 1003

Master Gardener Listserve: mastgar

- Send your email address to: **meyer023@umn.edu**
- Include **your name, county and year of training**. Listserve directions will be sent to you, along with email from MG in Minnesota.

Thank YOU for Volunteering !

- **The "master" in Master Gardener doesn't mean you know everything about gardening, it means you volunteer for the University of Minnesota Extension Service.**
- **We hope you enjoy you the Master Gardener Program.**

UNIVERSITY OF MINNESOTA
Extension
SERVICE

University of Minnesota Extension Service Mission Statement:

Connecting community needs and University resources.

Vision Statement:
The vision statement articulates our dreams for the Extension Service of 2010

We envision Minnesota communities which:
seek to improve the quality of life, the economy and the environment.
develop the capacity to address and solve their problems.
respect and embrace an increasingly pluralistic society.
successfully seek and utilize University resources.
help to shape research and outreach in the land grant university.

We envision a University of Minnesota Extension Service which:
meets the needs of urban, suburban and rural Minnesota communities.
creates and responds to opportunities for learning and builds the capacity of communities to address important local issues.
sustains the flexibility to address selected priorities and to respond to emerging issues, while maintaining focus on its basic mission.
embraces the contributions of persons from diverse cultures and backgrounds to build a successful pluralistic society.
has the courage to end some programs and educational efforts as others are created.
exhibits good stewardship of all its resources.
demonstrates program impact.
recruits and retains employees who are dependable and accessible, who value helping people and who work in an open and friendly manner.

We envision the University of Minnesota as:
an institution recognized worldwide for its fulfillment of the land grant promise.
an institution which values and rewards excellence in outreach on a par with research and classroom teaching.

EXTENSION LAW AND THE EXTENSION COMMITTEE

The University of Minnesota Extension service had its official origin with the state legislature action of 1909 and the Smith Lever Act of 1914. The latter act created the extension service and appropriated funds for its support on a national basis. Today every land grant college in the United States has an extension service. The University of Minnesota is the land grant college in Minnesota. Over the years, Extension has received its support from federal, state, and county funds. In 1953, the present Minnesota Extension Law was enacted by the state legislature. There have been several amendments to this law since, but the purpose of the extension service has remained the same over the years, and that is to provide Minnesotan's informal continuing education programs. Extension service programs are those that state residents indicate they need.

The director of the University of Minnesota Extension Service is represented in the field by the district extension directors, county extension educators, program assistants, and extension volunteers.

The County Extension Committee is an organization established under state law that represents the Board of County Commissioners in each county of the state in extension personnel, programming, and budget matters. The County Extension Committee is made up of nine members. Included on the committee are the Chair of the Board of County Commissioners, one other Commissioner elected by the board, the County Auditor, who by law is secretary of this committee, and six members appointed at large by the Board of County Commissioners. The Extension committee selects its own chair and vice-chair who serve for one year. The at-large members appointed to the Extension Committee by the Board of County Commissioners serve three-year terms. Two members are appointed each year.

The Master Gardener Program was created by Extension to meet an enormous increase in requests from home gardeners for horticultural information. This increase derives primarily from the urban and transient nature of modern American life. Fifty years ago, an Extension agent dealt with the questions of a few hundred farm families. In many regions, however, land that once constituted a single farm now encompasses several subdivisions increasing the number of families an extension office must serve by the hundreds. In addition, many of these new families are recent arrivals, and are unfamiliar with the grasses, shrubs, trees, insects and diseases, which comprise the micro environment of their new urban or suburban home. They often call their local Extension office for home horticulture advice.

Consequently, the Master Gardener program was created in 1972 in the state of Washington. Today, in most states Master Gardeners have become a vital part of Extension's ability to provide consumers with up-to-date, reliable knowledge so they can enjoy and protect the value of horticulture around their homes. Master Gardening has also become a fun, useful volunteer activity which gives participants a sense of community spirit, accomplishment, and intellectual simulation.

In Minnesota, the Master Gardener program in 1977. Since that time, over 4500 people have taken the Master Gardener training. Most counties have an active group of Master Gardeners who fulfill the mission of the Extension Service.

Master Gardener Mission and Policy Statement Mission

The mission of the University of Minnesota Extension Service Master Gardener Program is to support Extension by providing volunteers trained in horticulture to educate the public with research based information on the best practices in consumer horticulture and environmental stewardship.
The Master Gardener Program will provide an environment for its volunteers that is friendly and supportive so their training, experience, and enthusiasm will produce maximum benefits to their communities.

Policy
The title "University of Minnesota Extension Service Master Gardener" is to be used only and exclusively in Extension programs in which trained interns and certified Master Gardeners provide horticultural education. They are expected to identify themselves as such only when doing nonprofit public service work in these Extension sponsored programs. Master Gardeners are trained paraprofessionals assisting Extension staff and are responsible to the local Extension Educator or designated coordinator. Master Gardeners are advised to neither advertise their places of business, nor use their title in business advertisements for their employer. This is an Extension public service program providing unbiased, research information. Appearing as a commercial activity, having association with commercial products, or giving implied Extension endorsement of any product or place of business is improper.

The Master Gardener training program provides scientifically based information approved by University of Minnesota experts so that Master Gardeners and the people they assist can make informed choices. When Master Gardeners make recommendations, including the use of commercial products (e.g. fertilizers, insecticides, herbicides and fungicides), they are expected to disseminate scientifically defensible information approved by the University of Minnesota. Master Gardeners work with gardeners who have many different philosophies. Even though Master Gardeners respect individual beliefs, they do not provide information, especially pest and disease control that does not have a scientific basis. For pest and disease control Master Gardeners use only University of Minnesota recommendations and the current pesticide label. Questions concerning commercial production and commercial pest control are to be referred to a local county Extension Educator or state Extension specialist.

Core Value Statement. University of Minnesota Master Gardeners teach research-based horticultural information. This information may be new or different from a volunteer's personal experience or opinion. Teaching research-based information is Extension's purpose and mission. This is an important core value of Extension and Master Gardeners are expected to uphold this value.
Participants must complete a 48-hour training program followed by a 50-hour internship within the first year before becoming certified active Master Gardeners. Certification is valid only for one year. Re-certification requires at least 25 annual hours of volunteer service approved by Extension and a minimum of 5 hours of educational training. Individual counties may require additional education to retain active status.

Qualifying education hours are determined by the qualifications of the presenter, not the topic of the program. Education hours should be programs taught or sponsored by Extension specialists, Extension staff, or University specialists or professors, or approved by Extension Educators or Master Gardener Program Coordinators. Education hours are learning opportunities where Master Gardeners are LEARNING. Volunteer or service hours are hours where Master Gardeners are EDUCATING others.

Driving time to volunteer work can be counted towards volunteer hours. Up to 5 hours (of the annual 25) volunteer hours can be administrative work. Administrative work beyond 5 hours should be approved by Extension Educators or Master Gardener Program Coordinators.

Internet Policy. Minnesota Master Gardeners must make recommendations based on University research. Information and recommendations from the Internet must be taken only from Extension sites, preferably from Minnesota and the North Central region. Texas and Ohio Extension, for example, have outstanding websites, which may or may not apply to Minnesota conditions. The Internet now gives Master Gardeners access to more information than ever, however, only University Extension sites, especially those with similar climates should be used for recommendations.

Database Categories. Five status categories are maintained in the State MG database for record keeping purposes. These are: Intern or Master Gardener in Training = A*; Active MG = A; Temporarily Inactive = TI; E = Emeritus; and Permanently Inactive = PI.

"A*" Master Gardeners are Interns in training and in their first year of the program. Active or "A" are Master Gardeners who complete a minimum of 25 volunteer and 5 education hours annually and turn in these hours to the State office.

Temporarily Inactive, "TI" is a status approved in 2001 by the State Advisory Board. A TI MG is someone in good standing having completed the Core Course, and at least one year of volunteer service. TI allows a Master Gardeners to still remain in the program but have a temporary leave from volunteer hours. While not encouraged, TI allows for a major change in lifestyle, such as a baby, an illness, or other circumstances that make it unrealistic for a volunteer to fulfill their volunteer hours. To be classified as TI, the local county Extension Educator or MG coordinator should approve the change and notify the state MG office. After one year of TI status, volunteers must complete educational hours. The TI status is only issued for

one year, the second year participants are excused from volunteer hours but must complete the required state (5) or local county hours of education. The maximum length of time for TI status is 2 years: 1 year with no volunteer or education hours, the second year with education, but no volunteer hours. By the third year volunteer hours must be completed or the participant will be moved to PI status. The year(s) of inactive status will not count towards state awards, such as 10, 15, 20 and 25-years. Temporarily Inactive or TI MGs can still subscribe to mastgar and have access to educational information.

Emeritus or "E" is a semi-active status for Master Gardener volunteers who have made a significant contribution to the program but now must limit active participation usually due to health reasons. Emeritus MG continue to serve as a resource to other MG volunteers, and participate in MG activities. Emeritus is NOT an award, but a status change. Emeritus MG volunteers continue to report hours, if possible. To be considered for Emeritus status, a volunteer must be an active MG with a minimum of 10 years or 1000 hours. Emeritus status may be changed to "PI" upon request of the volunteer or county. Requests must be initiated by the county Extension Educator or a Master Gardener colleague and must be approved by the State Advisory Board.

Permanently Inactive or "PI" MG are no longer active and completing volunteer hours. They remain in the database for record keeping purposes. After three years in the PI status, MG must re-take the Core Course to become active again.

Those not continuing in the program will not be re-certified and should be aware that if they represent themselves as Master Gardeners, they are violating their original commitment to Extension. Use of Extension titles or logos by persons who are not interns or active Extension Master Gardeners are subject to prosecution.

Transfer Policy. Master Gardeners moving to Minnesota should have a letter mailed from their home county or state Extension office to the new Minnesota county where they will be volunteering. This letter should state that they are an active Master Gardener in good standing with the program. It is recommended that all transferees take the Minnesota MG Core Course. Transferees from adjacent states: Wisconsin, Iowa, North Dakota, and South Dakota, are not required to take the Minnesota Core Course. Transferees from all other states are required to take the Core Course. All transferring Master Gardeners must purchase the current textbook and class materials in order to be able to give up-to-date University of Minnesota recommendations. If Minnesota residents take Master Gardener training in an adjacent state, such as ND or WI, they will be considered Minnesota Master Gardeners if they purchase the current MN textbook and materials and are approved by their home county Extension office.

The training and experience gained in the Master Gardener program are valuable and may rightfully be listed and featured as qualifications when seeking employment. Once employed, and while serving as a paid employee, or if self-employed, Master Gardeners should not advertise credentials or give the appearance of being a Master Gardener at the place of business unless the place of business is specifically designated as Extension Master Gardener educational event or diagnostic clinic.

Experienced Master Gardeners will probably receive invitations to speak before groups, such as garden clubs, and many also teach classes in community education programs. A Master Gardener may choose 1) to act as a private individual and accept an honorarium, but should not display Master Gardener credentials or count the activity as volunteer time. Or the MG may choose 2) to request a check for expenses and an honorarium be written to the proper county fund. Some counties set a standard fee, which is paid to the county office. Such policy is determined by the local county Extension Educator, Master Gardener Program Coordinator, or local MG group . These teaching hours can be counted toward volunteer time. Extension policy does not approve of Master Gardeners receiving reimbursement checks directly from clients. Accountability in auditing is a concern at both the county and state levels. Master Gardeners are not to receive personal compensation for volunteer work, nor are they to turn in volunteer hours for which they receive compensation.

Many Master Gardeners volunteer in other horticultural organizations. Such work cannot be credited as Master Gardener hours unless all of the following criteria are met: 1) the individual is clearly identified as an Extension Master Gardener; 2) the activity is educational and non-profit; and 3) the activity is pre-approved by the local county Extension Educator. Master Gardeners are primarily trained to fulfill the needs of the local county Extension offices. Thus volunteering for other organizations should be secondary to Extension needs.

At the October 2005 Advisory Board meeting a minimum age requirement of 18 years was established for participants in the Minnesota Master Gardener program.

Active Master Gardeners are covered by Extension comprehensive liability insurance policy while acting within the scope of their authorized duties. Personal autos and aircraft are excluded.

The work of Master Gardeners is much appreciated by Extension as well as local gardeners and communities. Master Gardener efforts serve to multiply the capabilities of Extension Educators to achieve the Extension mission of "Making a difference by connecting community needs and University resources to address critical issues in Minnesota."

Mary H. Meyer
Extension Horticulturist
State Master Gardener Coordinator

12/2005

Volunteer Opportunities for Master Gardeners

There are many ways in which Master Gardeners may serve their volunteer time. Following is a list of some of the ways Master Gardeners have fulfilled their service requirement.

1. Answer office phones, mail, or walk-ins with horticultural questions. Set regular hours and publicize them. One successful twist has been using voice mail for Master Gardeners.
2. Plant Clinics — Garden centers, schools, libraries, fairs, and shopping malls are likely locations. Master Gardeners diagnose plant problems. No formal presentation is necessary, but it helps to have some horticultural activity demonstrated or some props to draw attention to the Master Gardeners.
3. News media — News releases are needed for publicizing Master Gardener events. Most small town papers welcome feature articles or even regular columns. Radio question and answer programs are popular. Cable TV may be interested in well-done video programs. Master Gardeners can write articles for the Master Gardener and/or extension newsletter.
4. Horticultural teaching — Master Gardeners can teach extension and community ed, gardening classes, speak at garden clubs, civic groups, and church groups. Check in your county office for slide sets and videos to use in teaching.
5. Community beautification projects — Planning and maintenance of flowerbeds or ornamental plantings in public parks, at community entrances, extension office, other public sites Be cautious with this one. maintenance rapidly wanes. Try to incorporate some educational aspect, such as demonstrating use of different mulches, raised beds, or irrigation systems.
6. Demonstration gardens — See #5 above. Plan for an open house event to highlight the work.
7. Community garden programs — Organize, coordinate and monitor community gardening programs. You may target certain populations — low-income, minority, children, etc.
8. Youth programs — Master Gardeners can be excellent 4-H leaders, project trainers, and judges (or judge's assistants) at county fair. Cloverbud or Discovery 4-H programs often include a plant science section. Many schools, preschools/daycare centers, welcome program ideas.
9. Horticulture therapy — Gardening programs can be developed for senior citizens or for the physically, mentally, or emotionally impaired.
10. Home visits — Some problems require on-site analysis. Master Gardeners can make these one-on-one calls. Coordinate these with your county Extension Educator.
11. Coordinate program's scheduling of Master Gardeners — Organize and schedule Master Gardeners for clinic-schedule (and follow-up); on volunteers staffing the phone lines; plan periodic updates for Master Gardeners.
12. Artistic skills — Photographers can build a slide library for horticultural presentations. Samples of insect and disease problems can be pressed, mounted, and labeled for use at clinics and at training events.
13. Compile volunteer hours.
14. Publication development — Many garden topics are not covered by extension fact sheets. Master Gardeners can research the topic and write it up as a one-page fact sheet for local distribution. Coordi nate with your local Extension Educator and appropriate specialist.

MASTER GARDENER VOLUNTEER TIME AND CONTACT RECORD

NAME_____ COUNTY _____YEAR _____
ADDRESS_____ CITY_____, MN ZIP_____

DATE	ACTIVITY & LOCATION	TOTAL # OF CONTACTS	HOURS WORKED	EDUCATIONAL HOURS	* EXPENSES & MILEAGE
	Total page 1				

Send one copy to your COUNTY EXT. OFFICE and one
Copy to: Master Gardener State Office, MN Landscape Arboretum,
3675 Arboretum Drive, Chaska, MN 55318

*USE FOR YOUR TAX RECORDS
Hours can be reported online; see:
www.mg.umn.edu/

MASTER GARDENER VOLUNTEER TIME AND CONTACT RECORD

NAME_____ COUNTY _____YEAR _____
ADDRESS_____ CITY_____, MN ZIP_____

DATE	ACTIVITY & LOCATION	TOTAL # OF CONTACTS	HOURS WORKED	EDUCATIONAL HOURS	* EXPENSES & MILEAGE
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Finding and Generating Reliable Gardening Information

by Lois Stack and Richard Browsowski, University of Maine

As a Master Gardener volunteer, you are expected to relay research-based information to the public. You can imagine the problems that could occur if poor or incorrect information were passed on to others. Gardeners who base their activities on misinformation can lose money by producing a poor crop, damage their family's health by producing inferior fruits and vegetables, and contribute to environmental pollution by improper use of products.

This manual was written and edited by university and extension workers who research horticultural information in the field, lab, and literature. Great care has been taken to present a complete and accurate compendium of gardening information. But new questions always arise, and you will sometimes find that you need to go beyond your Master Gardener training and this manual to find answers.

This chapter will help you assess the reliability of information which you encounter in the future, and do applied research on your own to answer local questions. It will also give some ideas of how to incorporate applied research into your Master Gardener volunteer project.

Assessing the Reliability of Gardening Information

Just because information is printed or broadcast does not make it valid or reliable. You will sometimes need to search for answers to questions that arise in your role as a Master Gardener. You may search for new information in books, gardening magazines and research journals. You may also learn of new gardening products and practices reported by newspaper, radio and television. This information will range from the logical to the outlandish. Much of it will be of interest to you because it is horticultural in nature. How can you tell if information is legitimate and applicable to your situation?

Use the following checklist of questions to determine whether you can rely on a new source of information. When you ask yourself these questions about a new book or article, every answer does not have to be "yes" in order for the information to be useful to you. But if you find yourself answering "no" many times, you may want to look for another information source.

Who is presenting the information?

Are the author's gardening credentials indicated?

Does the author have proper training/experience in the topics presented?

Can you contact the author or publisher to ask further questions?

Does the author stand to gain financial benefit by persuading you to use a product?

Does the author represent a reputable institution or concern, either private or public?

If a writer other than the person who researched the topic interprets information, is it presented accurately and completely?

Is supporting information presented?

Is the information based on research?

Is the information footnoted with references to supporting statements?

Is the information based on solid data rather than hearsay or anecdotes (stories or infrequent occurrences)?

Are additional data or graphics presented to help support the information?

If graphics or photos accompany the information, are they easy to view and understand?

What kind of study was used to arrive at the conclusions presented?

Were trials or repeated studies performed?

Is other supporting evidence presented, based on other people's research?

Does the information "fit" with previous studies?

If the information does not "fit" with previous studies, is enough information presented for you to determine whether it is a break-through in knowledge, or just a fluke?

What is the publication date?

If the information is old, does it fit today's con-text?

If the information is old, is it consistent with newer information you have read on the same topic?

Is the information logical and reasonable based on your experience?

[Remember, the fact that information is old does not mean it is not good. Much of our gardening information is based on research or observations done many years ago. However, some older research has been replaced by newer findings.]

If the information is new, does it seem to contradict all previous literature on the same topic? If so, it might either be a fluke, or a brilliant new discovery; it's hard to tell from just one report.

What is the origin of the information?

Is the information from a reliable institution, college or university? [When a university or college publishes research, a team of reputable, experienced researchers generally reviews the information.]

Does the climate in which the research was done have an effect on the findings, and is that climate similar enough to that of Maine to be used here?

If the information is from a very different climate, are enough details given to help you adapt it?

Doing Applied Research to Answer Local Questions

Sometimes, you will be able to find an exact answer to a gardening question by referring to this manual or to other sources of information. Many times you will find information that is easily adapted, based on your experience and what you have learned through your studies. But in some cases, you will find information that needs to be tested in order to determine whether it is useful.

Here are some examples of information which you may read or hear about, but which you should test before relying on:

> A seed catalog offers a tomato that matures in 75 days. Can you guarantee a crop in 75 days? (Would 75 days in southern California produce the same crop as 75 days in Maine?)
>
> A book claims that a new perennial flower is hardy to USDA hardiness zone five. Since central Oregon, northern New Mexico, southern Vermont and coastal Maine all lie within zone five, can you plant this perennial with confidence?
>
> An advertisement on television touts a plant that repels mosquitoes from your patio. Can the plant repel as many mosquitoes as you and your family attract? Will a single plant's effect be significant several feet away?

You will also find that the more you garden, the more questions you will have. Good gardeners spend time in their gardens, and observe events that generate new questions. An observation is just that — until it is tested under conditions which help link causes with effects.

Here are some examples of events, which you may observe, and want to study more closely before drawing a conclusion:

> You plant marigolds around the edge of your vegetable garden for the first time, and notice that rabbits are less numerous than in past years. Do the marigolds keep the rabbits out?
>
> You try a new kind of spinach, and see fewer aphid problems than you saw last year. Is the new spinach less susceptible to aphid damage than the old one, or are there just fewer aphids this year due to the weather?
>
> You plant a crabapple in your yard, and notice that your eating-apple tree produces more fruit. Did the crabapple help in pollination, or is the apple tree just more mature and productive, or is the weather more conducive to a good apple yield than in the previous year?

You can learn the answers to gardening questions in many ways. Reliable references may provide the information you need. Talking to experts and to other experienced gardeners may provide insight. And in some cases, you can con-duct your own research to find answers.

Simple, effective research can be done in any garden. Here are the basic steps:

1. Formulate a question that can be answered.

Some questions cannot be answered. For example, the question, "Is one tomato better than another?" cannot be answered until you define better — bigger, juicier, lower acid, more red, etc. On the other hand, the question, "Does one tomato mature earlier than another?" can be answered by growing both tomatoes under the same conditions and recording the number of days to fruit ripening. If the answer to this question is going to be generalized to many locations, then the testing should be done in many locations (tomatoes perform differently under various environments).

2. Set up an experiment to clearly address the question.

Think carefully about your question, and read about what research already exists about it. This will help you set up a test plot that really addresses the question. It will also help you relate your results to other people's findings. When you set up your experiment, try to determine if any outside factors might bias the outcome, and either eliminate those factors or take them into consideration when you collect data. Any factors that can be eliminated will not have an impact on your results.

3. **Observe and collect data.**
Methods of collecting data vary depending on your research question. You might measure plant height, weigh fruits, count insects, or observe whether a plant survived the winter. In some cases, data is not collected from an entire plot, but rather from a representative sample of the plot. You might count the aphids on every third plant within each treatment, or count the number of mature fruits per plant on one sampling date. In a small research plot, data is usually collected from each plant. Be consistent in the way you collect information. Always have just one per-son collect the information to avoid human variability. Always measure carefully.

4. **Analyze the data.**
Numbers must be analyzed in order to be useful. One very useful statistical method for comparing treatments is the mean, or average. For example, if three plants of tomato type one produce 9, 10 and 11 pounds of fruit, and three plants of tomato type two produce 7, 10 and 13 pounds of fruit, can you say there is a significant difference in their yield? These numbers alone are difficult to interpret, but you can compare the mean yields. Add 9 + 10 + 11 and divide by three for a mean (average) yield of ten pounds of fruit from tomato number one. Tomato number two produces a mean yield of (7 + 10 + 13) divided by three, or ten pounds of fruit. Based on this one piece of information, you can say that the average yields of the two types of tomatoes are equal. Now you can say that the two means are identical. More complicated data requires more powerful statistical procedures than you may be able to perform at home; either seek help from your Cooperative Extension office before you begin your study, or simplify your study.

5. **Draw conclusions from the data.**
You have heard that "numbers can lie." One example of inaccurate conclusions drawn from numbers is seen in the tomato yield example above. Looking only at mean yields, the two types of tomatoes appear to be identical in yield (both yield ten pounds of fruit per plant). However, the fact that the individual plants of tomato number two varied more in their yield (ranging from 7 to 13 pounds of fruit per plant) than the plants of tomato number one (ranging from 9 to 11 pounds of fruit per plant) suggests the need for a more extensive study to look at uniformity. A second example of inaccurate conclusions drawn from numbers is seen when people try to generalize their results far beyond the conditions in which they con-ducted their research. Making a broad generalization based on just a few plants grown under one set of conditions is not really legitimate. It would be misleading to state that "a particular tomato matures in 75 days" without describing the length and warmth of the seasons in which it was tested. Likewise, it is not legitimate to state that a plant is "hardy to zone five" if only one plant is tested in one location, for one winter.

Here are a few more things to consider when setting up a test plot:

1. **Use a control** *(check plot)***.**
For example, if you are testing the effectiveness of a treatment for black spot on roses, then you must know how much dam-age would be done in the same circumstances without any treatment. You would probably also want to be able to compare your new treatment to a standard recommendation. In this case, you would set up an experiment in which you would leave some control plants untreated, treat some plants with the standard treatment, and treat some plants with your experimental treatment.

2. **Replicate** *(repeat)* **your treatments.**
In any situation, conditions vary somewhat. For example, because the soil is not identical in all areas of your garden, crops may be exposed to different fertility levels, drainage and pH in different spots. Repeating your treatments helps you estimate this variability. It makes your experiment more valid by reducing the effect of those differences. Usually, three to four replications are enough.

3. **Randomize your treatments.**
If you were comparing three tomato types for yield, you might grow three plants of each one in a plot, and set out three replications of this plot. Rather than arranging the plants in the same sequence in each replication, you should randomize their arrangement, to make a more objective study and to eliminate any bias when you take samples or measurements. For example, a plant on the south edge of the plot would be exposed to more sun, and might produce a higher yield. If you consistently planted one type of tomato on the south edge of each replication, this would bias your results.

4. **Eliminate as many variables as possible beyond the one you are testing.**
For example, the tomato plots described above should be placed in the same garden, exposed to the same rainfall and irrigation and other weather-related factors. Then you will be able to compare the results, knowing that any differences you measure are a result of your treatment.

5. Ask for help when you need it.
Complex research questions can require a great deal of time, money, technical know-ledge and statistical expertise. But you can do simple one-variable research in your home garden to answer some questions. If you are in doubt about how to ask a good research question, where to find relevant literature, how to set up the plot, or how to collect and analyze data, ask an expert!

Using Applied Research in Your Master Gardener Volunteer Project

You can teach people about gardening by telling them facts, but seeing is believing! If you become involved in a teaching and demonstration garden, you can show people the things you are talking about. Experimental plots can help.

Here are three ideas for demonstration plots which can show people horticultural processes in action, and provide a place for you to collect the numbers to back up what you see:

Compare various mulches' effect on tomato yield.
Grow plots of tomatoes with a black plastic mulch, a clear plastic mulch, and a six-inch mulch of straw. Use tomatoes in bare soil as a check plot. Use five tomatoes per treatment, with three randomized treatments per block. You will need 60 plants of the same tomato cultivar (four treatments x five plants/ treatment x three treatments per block). Harvest fruits weekly and weigh total fruit per plant. Average the yields per treatment at the end of the season.

Compare the number of cut zinnia flowers produced per plant and per row-foot in the garden, as influenced by plant spacing within the rows.
Direct seed zinnias (all one cultivar) at various spacings (3", 6", 12"). Plant a five-foot row of zinnias for each treatment, and replicate three times. (Space the rows three feet apart to avoid the interference of shading from neighboring rows.) You can easily determine the number of seeds needed for this study. Cut mature flowers daily, and total them per treatment. At the end of the season, you can divide your totals by the number of plants per treatment to see which plant spacing yielded the most cut flowers per plant. You can also divide your totals by the number of feet of row, to see which spacing was most productive in terms of space in the garden.

Compare five different cultivars of sweet basil to see which one produces the most dried basil.
Grow a ten-foot row of each basil cultivar per treatment, and plant three randomized replicates. Use identical cultural techniques. At the end of the season, harvest three plants randomly from each treatment and dry them before weighing them, so that you won't be comparing the plants' water content. This sampling technique allows you to observe many plants, follow larger-scale cultural practices, obtain data, and still enjoy the unsampled plants as herbs.

Minnesota Master Gardener Listserve

To be added to the Minnesota Master Gardener listserve:
mastgar@lists.umn.edu

Send your name, county, year of training and email address to:
meyer023@umn.edu

This listserve is only for active and intern Master Gardeners in Minnesota. Extension staff who choose to be on the list are also included. Master Gardeners can answer and post question by sending a message to the list address. Extension staff often answer questions as well as post administrative news pertaining to Master Gardeners.

Minnesota Master Gardener Internet Policy

Minnesota Master Gardeners must make recommendations based on University research. Information and recommendations from the Internet must be taken only from Extension sites, preferably from Minnesota and the North Central region. Many other states such as Texas and Ohio have outstanding sites, which may or may not apply to Minnesota conditions. The Internet now gives Master Gardeners access to more information than ever, however, only University Extension sites, especially those with similar climates should be used for recommendations. Always check the University of Minnesota first, then look for other Extension information.

University of Minnesota Extension Service Homepage:
http://www.extension.umn.edu

Extension Master Gardener Home Page:
http://www.mg.umn.edu

MASTER GARDENER DIVERSITY SUBCOMMITTEE

GOALS & ACTIONS

Adopted on June 22, 2005 by the State MG Advisory Board for MN MG Program. Activities updated 11-13-06 by committee members.

GOAL #1 **To increase the cultural competency of Master Gardener s**	**GOAL #2** **To provide equal access to Master Gardener services and info for all cultures in MN**	**GOAL #3** **To culturally diversify the Master Gardener membership**
ACTION #1: Educate the current MG members on lifestyles, traditions and horticulture as they relate to other cultures. • Include the topic of diversity as part of the 2007 MG Core Course • Encourage local MG programs to contribute to these 3 goals • Invite speakers to teach MGs about diverse cultures at local monthly meetings and as special training • Provide articles in the state MG newsletter and/or on the website • Update and promote use of the new MG diversity website, and other resources: http://www.mg.umn.edu/Diversity%20Section/index%20diversity.htm http://www.extension.umn.edu/topics.html?topic=1&subtopic=300	ACTION #1: Typically, the second generation of immigrants - the children - speak English and act as translators for their parents. Utilize the Junior Master Gardener Program and other activities to spread the word about Extension services, MG services and information to adults in various cultures. By reaching the children, it is also feasible that we are propagating the next generation of Master Gardeners.	ACTION #1: Explore the feasibility of recruiting culturally diverse MG candidates. If there seems to be interest, determine ways to promote the program to various communities. If needed, translate the "How to Be a Master Gardener" brochure into various languages.
ACTION #2: Assume our audiences are diverse. Therefore, as resources are updated or created, they should include information pertinent to various cultures. While the MG is not expected to present in various languages, handouts should be provided in other languages as needed. Information and guidelines should be provided to MG members about Extension materials available in various languages (on both national and local levels), and translation resources for new materials.	ACTION #2: Visit with leaders of the various ethnic groups in the state to discuss ways to partner with them to make the resources and services of the MG program more available to their communities. Seek ways to engage community members and assist them. Ask how to involve members of their communities in the MG program.	ACTION #2: As needed, consider creating 2-3 scholarships to cover the Core Course expenses for MG interns from diverse backgrounds. The goal of this action is to have MGs that give back to their communities and mentor new MG interns. These scholarship winners should be paired with strong mentors who are well acquainted with the MG organization, the opportunities and horticulture.
ACTION #3: Include ethnic plants in gardens at regional research and outreach centers (Rosemount, Morris, St. Paul, etc.) to serve as a location for MG and public education. At these locations, include literature in various languages.	ACTION #3: Be more visible. When feasible, schedule MG information booths and speakers at culturally diverse events such as Cinco de Mayo, Juneteenth, and Festival of Nations. Include handouts in various languages.	ACTION #3: Consider alternatives or additions to traditional MG recruitment, training, and participation. Identify other ways to partner with diverse communities to meet their needs and learn from them.

UNIVERSITY OF MINNESOTA

Welcome to the Minnesota Master Gardener Core Course from the State Diversity Committee!

The following is information about the Master Gardener State Diversity Committee, a volunteer opportunity where you, as a Minnesota Master Gardener, can make a difference to people of various cultures who have chosen to make Minnesota their new home.

About the State Diversity Committee

Many Master Gardeners volunteer for projects focused on ethnic communities within our state. The State Diversity Committee is an off-shoot of the State Advisory Board, and is comprised of Master Gardeners from various counties. It is focused on helping Minnesota Master Gardeners better understand and serve communities of various cultures within their counties through gardening, agriculture and the love of horticulture.

Representatives from various counties are active on the committee - Hennepin, Ramsey, Washington, and Houston – and the list is growing all the time! Committee members work together to develop resources for Master Gardeners, and to share information and ideas about local projects with various cultural groups. The Committee also serves as a diversity-focused extension of the State Advisory Board. Meetings are held every two months at various locations within the metro area at an ethnic restaurant. Master Gardeners outside the metro area can participate in person, or via email. Our 2006 state conference, hosted by Scott/Carver Master Gardeners, was entitled *Celebrating Diversity in Gardening*, and was a great success!

Examples of some of the continuing education events and diversity-based projects Master Gardeners have worked on are listed in the box on the right. We invite you to join this important – and fun – committee!

The following information is detailed on the State Master Gardener website. It is focused on providing resources for Master Gardeners throughout the state to use when serving communities of various cultural backgrounds.

Goals of the State Master Gardener Subcommittee on Diversity

Hot topics!

Continuing Education Opportunity: Learn about Hmong Traditions and Culture
HAMAA Community Center
October 21, 2006

Master Gardeners Making a Difference: Project presentations at the 2006 Minnesota Master Gardener State Conference.

1. Ramsey-Washington Metro Watershed District Projects - Linda Neilson & Rochelle Robideau, Ramsey District
2. Second Grade Diversity and International Garden - Norrie MacIlraith & Pat Mack, Olmsted County
3. The Global Garden - Hilde Manuel, Anoka County
4. Hennepin County Home School Garden - Dale Longfellow, Hennepin County
5. The Summer Garden Project - Judy Wothke, & Sue Ann Mullen, Winona County

New resource:
Growing Home, Stories of Ethnic Gardening by Susan Davis Price

- Learn about the three fundamental goals of the Minnesota Master Gardener Program that focus on expanding our reaching and teaching to people who are new to our state.

Diversity Resources

- Websites and books to help Master Gardeners increase cultural understanding and a subset of translated materials or resources to find them;
- A list of speakers who have agreed to be on this list and who are approved for speaking to your group about specializing in topics pertaining to different cultures.

Activities and Event Ideas for Minnesota Master Gardeners

- Various activities for local Master Gardener meetings and training events that will expand Master Gardeners' understanding the use of plants in various cultures;

    - A Local Culinary Adventure: Asian Vegetables from the St. Paul Farmers' Market
    - A St. Paul Farmers' Market Asian Vegetable Recipe
    - Asian Vegetables Brainteaser
    - Learning Circle Lessons: Minnesota Nice or Not: Yesterday, Today and Tomorrow

Articles & Links for Master Gardeners

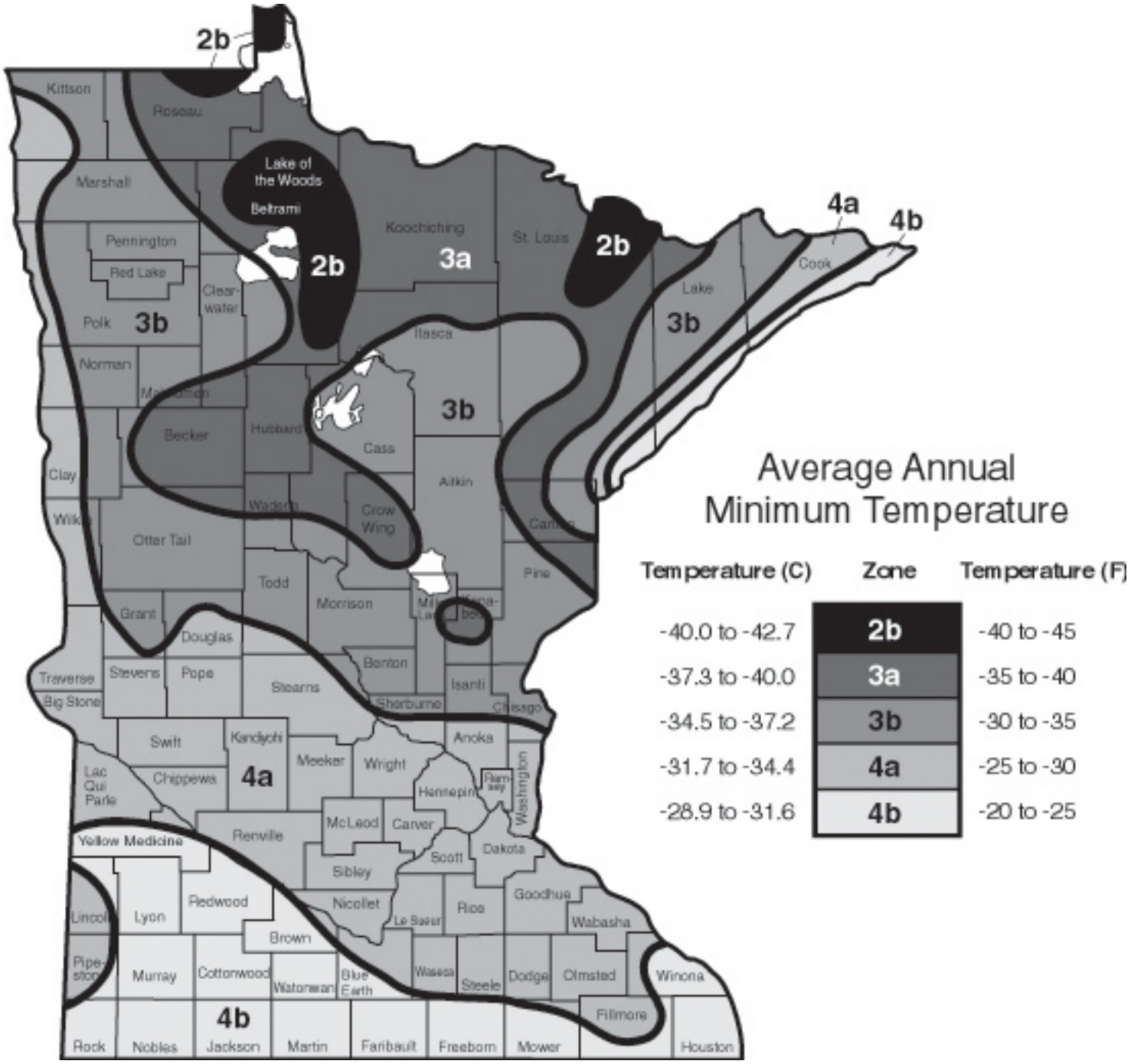
- Articles written by fellow Master Gardeners about their teaching experiences with diversity and suitable for re-printing in county newsletters or as hand-outs

appendix

2

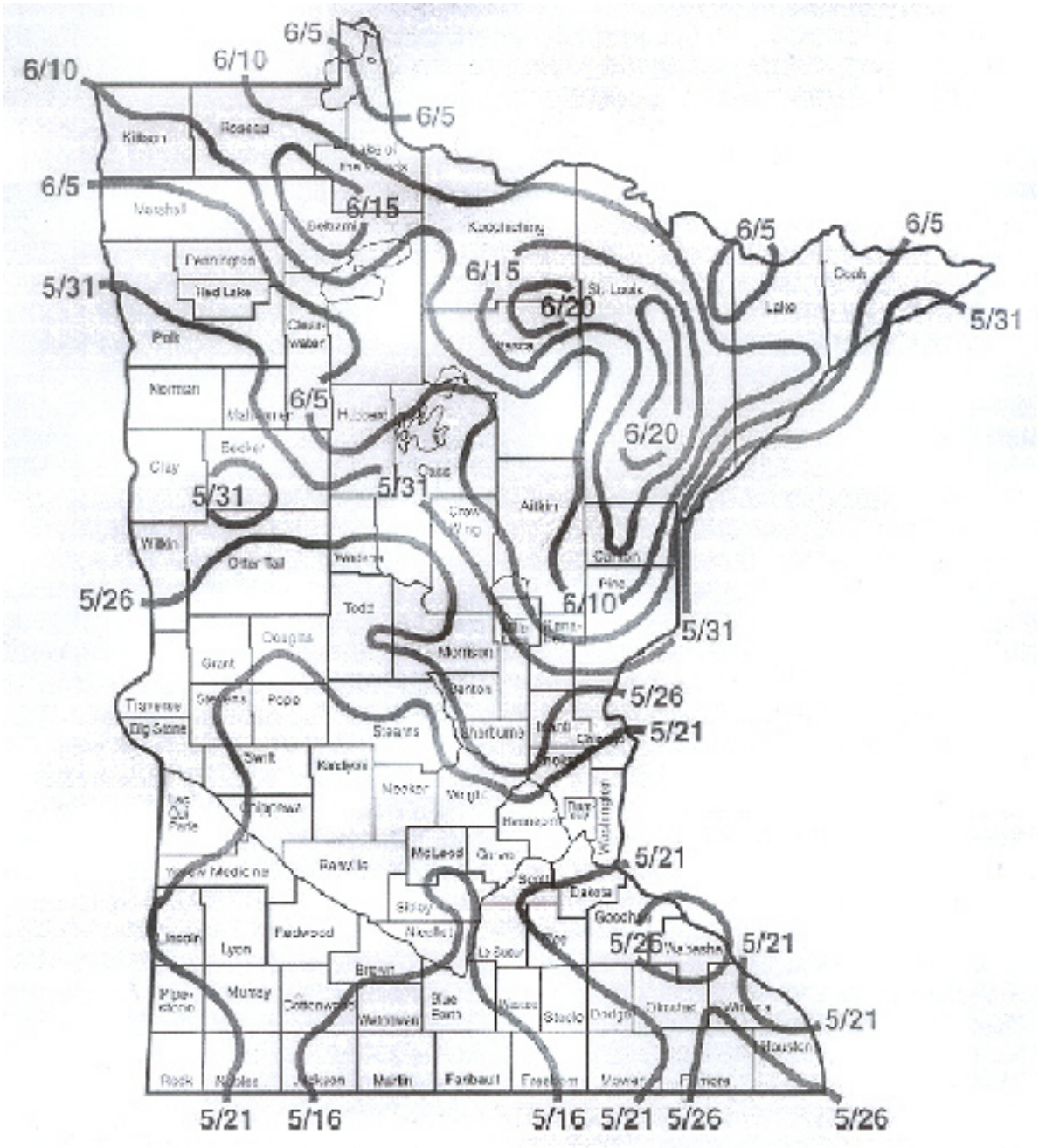
climate maps

USDA PLANT HARDINESS ZONES

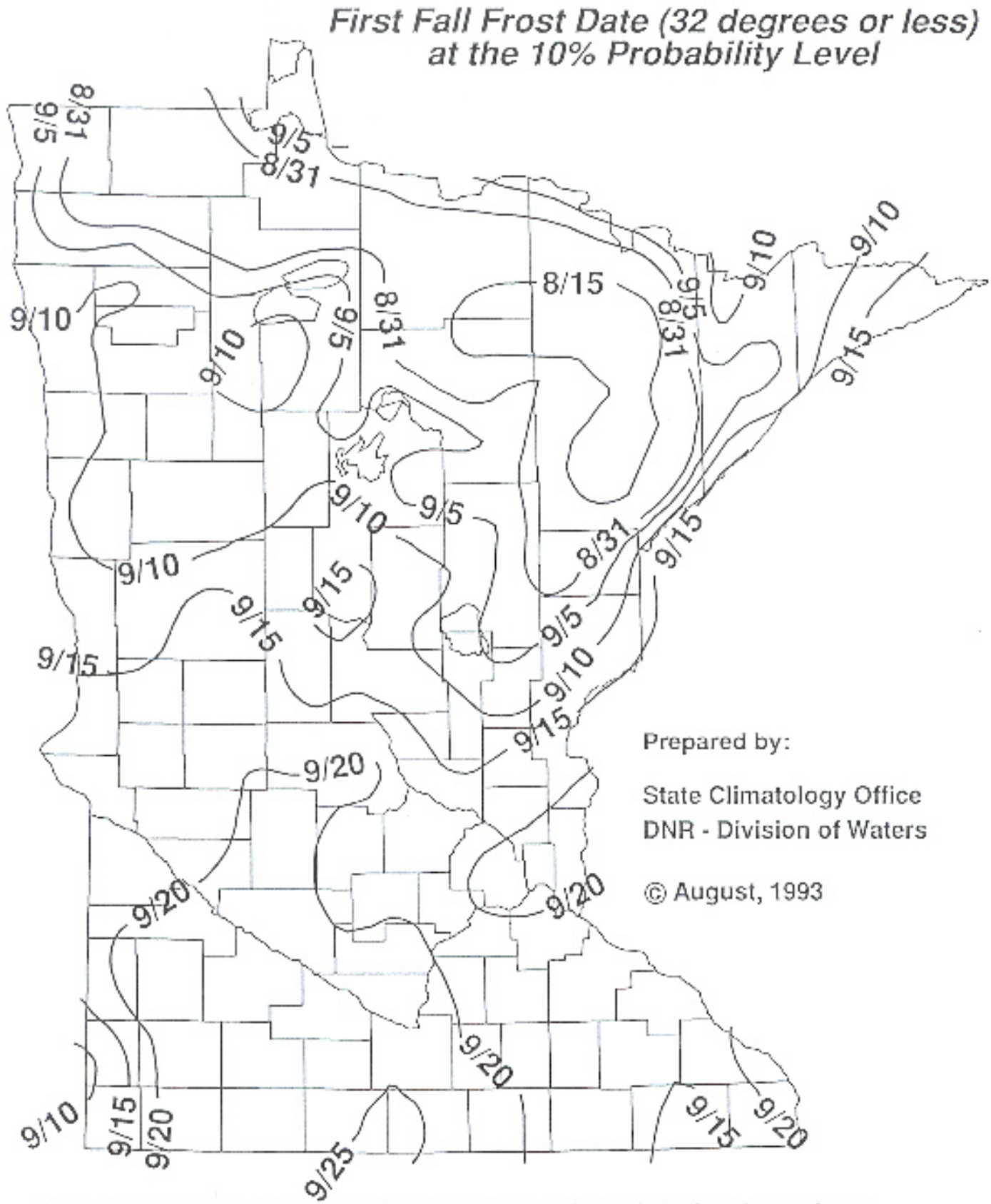


Minnesota Hardiness Zone Map - USDA, 1990

AVERAGE SPRING FROST DATE



Last Spring Frost Date (32° or less) at the 10% Probability Level



90 percent of years have a first fall frost on or later than the above dates.

appendix

3

soils

UNIVERSITY OF MINNESOTA
Soil Testing Laboratory

PROFESSIONAL TURF AND LAWN AND GARDEN
SOIL SAMPLE INFORMATION SHEET

Send **ONE (1)** soil sample **with** this information sheet

Includes landscape trees and shrubs

MAIL SOIL TEST REPORT TO

Name John Q Public

Address 100 Sandy Lane

City/St/Zip Minneapolis, MN 55451

Phone 612-123-4577

Soil Location: County Blue Earth

Check for $ 15.00 enclosed

OPTIONAL REFERENCE

Please give this sample a name, maximum of 4 letters or numbers. Indicate this name on the soil container and record it here.

F	G		

This name will be on your report to identify the sample area.

Fertilizer Recommendations Requested for: *(CHECK ONLY ONE)*

New Lawn / Turf
- ☐ (101) Before seeding or sodding

Existing Grass
- ☐ (102) Home lawn
- ☐ (103) School / Industrial Grounds
- ☐ (104) Athletic field
- ☐ (105) Park / Cemetery
- ☐ (106) Golf tee
- ☐ (107) Golf fairway
- ☐ (108) Golf green

Gardens
- ☐ (110) Vegetable garden
- ☒ (111) Flower garden

Fruit
- ☐ (112) Tree fruits
- ☐ (113) Small fruits
- ☐ (114) Blueberries

Trees and Shrubs
- ☐ (115) Broadleaf
- ☐ (116) Evergreen
- ☐ (117) Azalea & Rhododendron

For Grass Only

Is grass watered regularly?
- ☐ (1) Yes
- ☐ (2) No

Are clippings removed?
- ☐ (1) Yes
- ☐ (2) No

Check Tests Requested

☒ Regular test, $15.00, includes phosphorus, potassium, pH – lime requirement, total organic matter, and estimated texture.

☐ Excessive salts (soluble salts) $5

☐ Lead test (requires separate sample) $15

The following tests are only made available to professionals since the interpretation of test results are provided only for limited situations.

- ☐ Sulfur $4
- ☐ Nitrate $5
- ☐ Boron $6
- ☐ Calcium / Magnesium $6
- ☐ Total organic matter $4
- ☐ Iron, Zinc, Copper, and Manganese $10

The tests provided by the University of Minnesota Soil Testing Laboratory are for the purpose of evaluating the soil fertility and soil pH level (routine test), and/or problems due to excessive salts or fertilizer materials (soluble salt test). Based on these test results and the type of plants to be grown, you will be sent the appropriate fertilizer recommendation that will provide adequate levels of phosphorus and potassium necessary for good plant growth without adverse effects on the environment.

Soil for home lawn, garden, trees and shrubs are not tested for nitrogen because this nutrient is very mobile in soils. Therefore, the nitrogen recommendation is based on plant type requirements and the relative organic matter level in the soil as determined by the laboratory. Trace element tests are not recommended for lawns and gardens because research has shown that adequate amounts are found in most soils of the state. Trace element tests may be useful in some professional operations for special problems.

Problems with plants may be caused by factors other than soil fertility, e.g., disease, insects, insufficient light, soil moisture or compaction, or climatic conditions. An evaluation of soil fertility and pH is an important first step in diagnosing problems. If soil fertility is not found to be a problem, then the other factors affecting plant growth should be evaluated to determine possible causes. Your County Extension Educator can help you if you need further information to diagnose your problem.

On the website, go back to "Follow instructions for collecting soil samples" for full sampling information and mailing instructions.

Soils and Fertilizers

Master Gardener Core Course

University of Minnesota Extension Service

Topic Covered

- An introduction to soils
- Soil physical properties
- Improving soil drainage
- Composting and managing yard wastes
- Soil chemical properties
- Nutrient movement
- Soil testing
- Soil amendments and fertilizer management
- Nutrient deficiency symptoms

An Introduction to Soils

Soil is the unconsolidated mineral and organic material on the surface of the earth that serves as a natural medium for the growth of plants

How is Soil Formed?

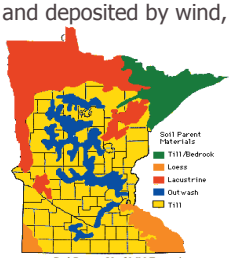
There are five soil forming factors

1. Parent Material
2. Climate
3. Biota
4. Topography
5. Time

Varied combinations of these five factors cause soil to develop and behave differently

Parent Material

Most parent materials in Minnesota were transported and deposited by wind, water, or ice

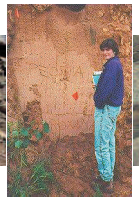


Parent Material

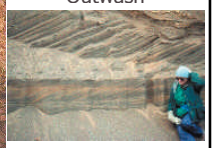
Parent materials impart distinct physical and chemical characteristics to a soil

Till

Loess

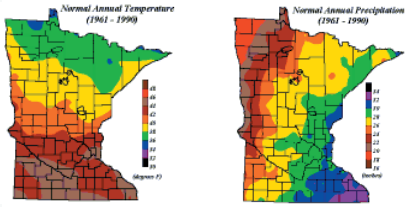


Outwash



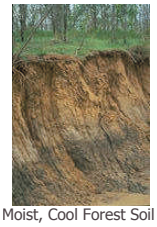
Climate

Warmer temperatures and higher precipitation increase the rate of soil formation

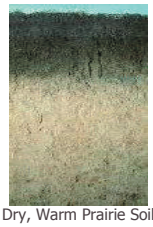


Climate

Soil formation in Minnesota is often slowed by cold temperatures and/or lack of rainfall



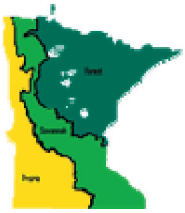
Moist, Cool Forest Soil



Dry, Warm Prairie Soil

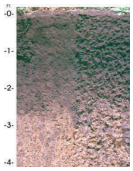
Biota – plants

Minnesota has three distinct types of native vegetation – prairie, forest, and a mixed transition zone

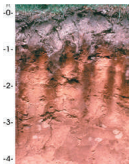


Biota – plants

- Deep roots of prairie plants add organic matter to subsurface layers
- Falling leaves contribute to the organic surface layers of a forest soil



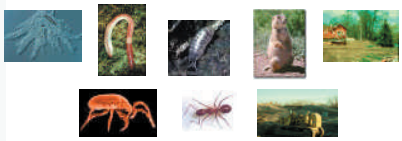
Prairie Soil



Forest Soil

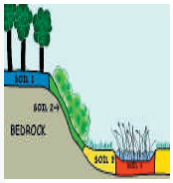
Biota - microorganisms/animals

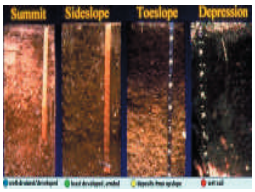
- Soil microbes, microscopic multicellular organisms, worms, insects, and vertebrates
- Decompose organic material, recycle nutrients, and redistribute the soil



Topography

Landscape position influences soil formation through runoff, erosion, deposition, and drainage





Topography

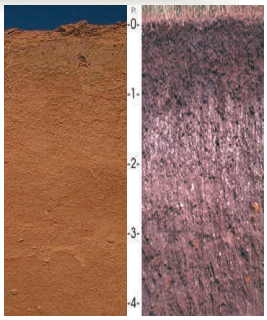
Slope aspect affects soil microclimate and type of vegetation

Time

Much of Minnesota's parent material was deposited by glaciers 10-13,000 yrs ago

Time

The "age" of a soil is not based on the number of years it has been forming, but rather on the extent to which it has developed (as a result of the other soil forming factors)



Young Soil **Mature Soil**

Urban Soil Formation

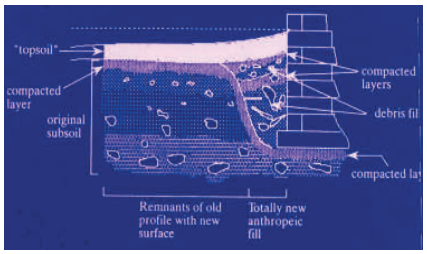
Urban soils are disturbed and altered during construction and other human activities

Compacted Urban Soils

Results from initial construction or subsequent maintenance practices and traffic patterns

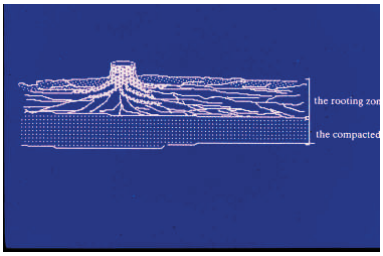
- Compaction is a serious problem
- Increases bulk density and water runoff
- Decreases water infiltration and root growth

Profile of an Urban Soil



Source: Craul, P.J. 1992. Urban Soil in Landscape Design. John Wiley and Sons, Inc. pg 117.

Root Zone Compaction



Source: Craul, P.J. 1992. Urban Soil in Landscape Design. John Wiley and Sons, Inc.

Characteristics of Urban Soil

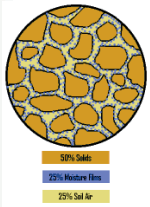
- Modified soil structure/rooting depth
- Restricted aeration/drainage
- Soil pH usually elevated
- Higher soil temperatures
- Reduced organic matter
- Soil crusting
- Interrupted nutrient cycling/biological activity

Soil Physical Properties

Master Gardener Core Course

Soil Composition

Soil is composed of solids, water, and air



- Solids (50%)
  - Sand, silt, clay (90-99%)
  - Organic matter (1-10%)
- Water (25%)
  - H_2O
  - 100-1000 ppm soluble salts
- Air (25%)
  - High CO_2 (10-20 times as high as the atmosphere)

What is Soil Texture?

Soil texture refers to the size of soil particles and their relative proportions in a specific soil

Soil Particle	Diameter (mm)	Relative Size
Sand	0.05 – 2.0	Barrel
Silt	0.002 – 0.05	Plate
Clay	<0.002	Dime

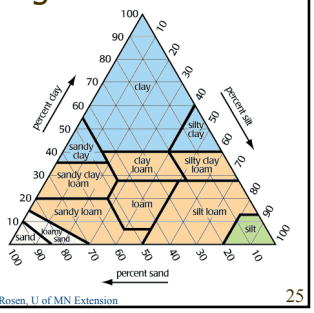
Categories of Soil Texture

Soils are grouped into three general categories based on texture. Specific classification requires lab analysis.

General Name	Relative Texture	Classification
Sandy Soil	Coarse	Sand
		Loamy Sand
Loam Soil	Moderately Coarse	Sandy Loam
	Medium	Loam
		Silt Loam
		Silt
	Moderately Fine	Sandy Clay Loam
		Silty Clay Loam
		Clay Loam
Clay Soil	Fine	Sandy Clay
		Silty Clay
		Clay

Textural Triangle

Clay has a dominant effect in determining textural class and soil physical properties



Examples of Soil Textures

Textural Class	Proportion of Particles (%)		
	Sand	Silt	Clay
Sand	90	5	5
Loamy Sand	80	10	10
Sandy Loam	70	15	15
Loam	40	40	20
Silt Loam	25	60	15
Clay Loam	20	50	30
Clay	10	20	70

The "Feel" Method

Textural class can be determined by feeling the soil with your fingers

Begin by placing a small sample of moist soil in the palm of your hand.

Squeeze and flatten the soil between your fingers and thumb. Extrude a ribbon of soil ¼" thick.

Manipulate the soil until the longest possible ribbon is formed.

Fine-textured Soils

- Form long, shiny, pliable ribbons
- Moist ribbons feel smooth and sticky
- Dry clods are very hard

Medium-textured Soils

- Do not form long ribbons
- Feel fairly smooth and floury or soapy
- Loams & sandy loams are slightly gritty
- Silts are not gritty
- Dry lumps are readily broken

Coarse-textured Soils

- Do not form ribbons
- Casts fall apart easily
- Feel very gritty
- Not slick or smooth

Characteristics of Fine Soil

Clay loams and clays

- "Heavy" soils
- High nutrient and water holding capacities
  - 2.0 to 3.5 inches water/foot soil
- Poor drainage
- Most difficult to manage

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Characteristics of Medium Soil

Loams and silt loams

- "Ideal" balance of soil properties
- Moderate nutrient and water holding capacities
  - 1.7 to 2.8 inches water/foot soil
- Good drainage

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Characteristics of Coarse Soil

Sands, loamy sands, sandy loams

- "Light" soils
- Low water holding capacity
  - 0.6 to 1.3 inches water/foot soil
- Excessive drainage
- Low in nutrients
  - Especially N and K

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Organic Soils (Peats or Mucks)

- >20-30% organic matter
- Low in P and K
- Supplies N
- Drainage problems
- Slow to warm in Spring

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What is Soil Structure?

- Arrangement of soil particles (sand, silt, clay) into groups (aggregates)
- Binding agents
  - Microbial gums, fine roots, organic matter, fungal hyphae, iron oxides, and clay bind soil particles together

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What is Soil Structure? (cont'd)

- Unlike soil texture, soil structure can be improved by management
- Soil structure also can be degraded by poor management

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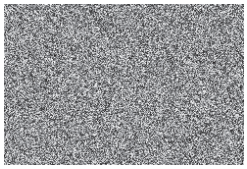
Structure - Granular

Granular structure consists of soil particles held in loose, rounded aggregates

- Most often found
  - At the soil surface
  - In grassland soils
  - In soils high in organic matter



What is Soil Organic Matter?

Organic matter affects most soil properties

- Forms of organic matter
  - Plant/animal residues
    - Various stages of decomposition
  - Humus
    - Decomposition by-product
    - Resistant to further degradation

Importance of SOM

- Improves soil physical properties
  - Drainage
  - Aeration
  - Easier to work
- Increases water holding capacity
  - Especially in sandy soils

Importance of SOM (cont'd)

- Improves soil fertility
  - Source of nutrients
  - Increases ability of soil to hold and release nutrients
- Drives soil biology
  - Feeds microbes and earthworms
- Reduces soil crusting

Improving Soil Drainage

Master Gardener Core Course

Restrictive Layers

Adding topsoil may create a restrictive layer if not properly incorporated

Poor Drainage Indicators

- Impeded water movement
- Areas of standing water
- Soggy/wet lawns
- Moss in lawn
- Gray colored or mottled subsoils
- Poor plant growth
  - Due to lack of air in root zone
- Increased runoff

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Solution: Lawn and Garden

- Mix in compost yearly (gardens)
- Subsoil, renovate
- Do not work soil when it is wet
- Raised beds
- Tile drains

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Solution: Small Areas/Containers

- Mixtures/amendments
  - Soil
  - Peat
  - Compost
  - Vermiculite
  - Perlite

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Soil Mixes for Containers

- Mechanical support for roots
- Adequate moisture holding capacity
- Adequate drainage
- Nutrient supply
  - Usually a secondary priority in container mixes

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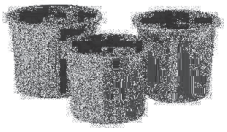
Loam-Based Mixes

- Soil
  - Low clay content
  - Loam
  - Sandy loam
- Sand
- Peat
- Compost



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Loamless (soil-less) Mixes

- Common components
  - Peat
  - Vermiculite
  - Ground bark
  - Styrofoam beads
  - Rockwool
  - Fine sand
- Example mixtures
  - 1 peat, 1 vermiculite, 1 perlite
  - 2 peat, 1 fine sand, 1 perlite

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Managing and Composting Organic Yard Waste

Master Gardener Core Course

Cause for Concern?

Managing organic yard wastes is increasingly important with bans on burning and limited landfill space

Methods of Management

- Backyard composting
- Municipal composting
- Mixing directly with soil
- Mulching

Definitions

- Composting
  - Controlled decomposition of organic materials by microorganisms

- Compost
  - Partially decomposed organic matter

Why Compost?

- Compost
  - Easier to handle and mix with the soil
  - Supplies nutrients and organic matter
  - Improves soil structure
  - Increases soils ability to hold water
  - Supports living soil organisms
  - Reduces weed seeds and pathogens
  - Buffers soil from chemical imbalances

Suitable Compost Material

- Leaves

- Grass clippings
  - May compact
  - Add with bulky items

- Manure from herbivores
  - Horse or cow manure, rabbit droppings
  - Do not use if animal is sick

Suitable Material (cont'd)

- Fruit
  - Oranges, grapefruit, lemons
  - Cut into ¼ to ½ inch pieces before composting
- Vegetables
  - May compact due to wetness
  - Add with dry, bulky, brown/high carbon items

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Suitable Material (cont'd)

- Coffee grounds and tea bags
  - Including filter
- Straw, wood chips, landscape trimmings
  - Cut to less than 2 inches
  - Good sources of bulky items
- Sawdust
  - From untreated wood
  - High in carbon

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Suitable Material (cont'd)

- Newspaper
  - Shred before composting
- Paper and paperboard
  - Cereal boxes, paper plates, napkins
  - Break into small pieces or make a wet slurry and mix it into compost
- Egg shells
  - Add calcium

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Unsuitable Compost Material

- Animal by-products
  - Meat, chicken, lard/grease, bones, whole eggs, cheese and milk (attracts animals)
- Pet waste and human waste
  - Might contain diseases that could be transmitted to humans

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Unsuitable Material (cont'd)

- Inorganic trash
  - Plastic, foil, and metals
  - Will not break down in the composting process
- Pesticides, gasoline, diesel or oil
  - Potentially toxic to human health and the environment

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Unsuitable Material (cont'd)

- Diseased plants, weeds with seeds
  - Killed by proper composting temperature
- Walnut leaves
  - Toxic to many plants
  - Small amounts if well composted
- Grass clippings recently treated with herbicide
  - Must be thoroughly composted

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Composting Requirements

- Microbial decomposition requires
  - Aeration
  - Moisture
  - Small particle size
  - Nutrients
    - Particularly nitrogen

Aeration

- Microbes need air for decomposition
- Aerate by turning the pile or adding bulky items
- Aeration will reduce odor problems

Moisture

- Pile should contain 45 to 55% water
- Feel like a damp sponge when squeezed
- Add water if necessary
- Don't let the compost get soggy
  - Reduces air

Small Particle Size

Reducing particle size of raw materials

- Increases the rate of decomposition
- Decreases the size of the compost pile
- Don't go too small
  - Fine particles compact and restrict aeration

Nutrients

- Think of composting as a process where you are "growing microorganisms"
- Microbes need nutrients just like plants
  - Use carbon (C) for energy
  - Need nitrogen (N) for proteins
- Compostable material has more C than N
  - Ratio of C/N important
  - Controls rate of decomposition

Nitrogen

- C/N ratio of 20-30 is required for rapid composting
- May need to add N for high C/N material
  - Straw, sawdust, and leaves
- General recommendations
  - 1/2 cup 27-3-3 **or** 1-2" of animal manure
  - For each 8-9" layer, in a pile area of 25 sq ft

Caution: do not add fertilizer containing a herbicide

C/N Ratios

Material	C/N Ratio
Coffee Grounds	20:1
Corn Stalks	60:1
Cow Manure	20:1
Fruit Wastes	35:1
Grass Clippings	20:1
Horse Manure/Litter	60:1
Leaves	60:1
Newspaper	50-200:1
Vegetable Trimmings	12-20:1

Material	C/N Ratio
Oak Leaves (green)	26:1
Peat Moss	58:1
Pine Needles	60-110:1
Rotted Manure	20:1
Sawdust / Wood	600:1
Straw	80-100:1
Table Scraps	15:1
Sawdust (weathered for 2 months)	325:1

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Temperature

A minimum pile temperature of 130 to 150°F for at least 3 days is necessary to destroy weed seeds and plant pathogens (15 days is more effective)

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Compost Bin Structures

- Can be made from readily available materials
  - e.g. plastic bags/bins or barrels/drums
- Pre-made bins are widely available

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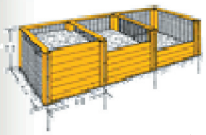
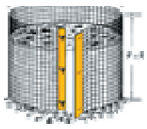
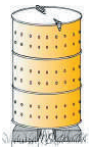
Constructing a Compost Bin

You can construct your own compost bin

- Chicken wire or woven wire fencing
- Rot resistant lumber
- Metal posts
- Typical size: 5′ x 5′ x 5′

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Compost Bin Location

- Protect your bin
  - Drying winds
  - Direct sunlight
- Bin placement
  - Avoid offending neighbors
    - Odors
    - Visual

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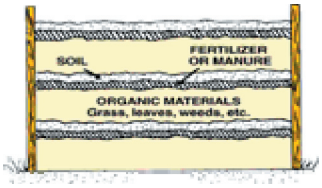
Preparing the Compost Pile

- Build in layers
- Organic materials, soil, and nutrients



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Use of Soil in a Compost Pile

- Inoculating with microorganisms
  - Soil can provide the microbes for decomposition
  - Usually they do not need to be added
- Compost "starter" is not considered necessary
  - Nutrients may be helpful, but are cheaper in fertilizer

Lime and Composting

- Lime not needed in most backyard situations
  - Most finished composts are naturally alkaline
  - Used primarily for pine needles, fruit wastes, and anaerobic decomposition (garbage bag method)
  - Neutralizes acids during initial decomposition
- Application rates
  - 1 cup limestone per 25 sq ft for every 8-9" layer
  - 1 cup per 30 gallons (garbage bag method)
- Avoid over-applying lime – leads to loss of N

Maintaining the Compost Pile

- Control water and air
- Mix periodically
  - Speed decomposition
  - Control odors
- Pile should heat up
  - From microbial activity
  - 130 – 150°F in middle
  - Mix outer part of pile to the inside and let it heat again

Finished (Mature) Compost

- Well managed compost pile
  - Ready in about 4-9 months
  - Little activity during winter
- Poorly managed pile
  - Will take 1-3 years
- Finished compost
  - One-half original volume
  - Has an earthy smell

Uses of Compost

- Benefits
  - Contains nutrients
  - Improves soil structure and drainage
  - Increases soil water holding capacity
  - Stimulates soil biological activity

Uses of Compost

- As a soil amendment
  - Add 1-2" to soil surface, incorporate 6-8" deep
  - Reduce fertilizer rates by one-half
- As a mulch
  - Maintain 2-4" layer for weed suppression
- In potting mixes
  - Up to 30% of the volume

Mulches for Gardens

Mulch is any substance used to cover the soil

- Benefits of mulching
  - Reduced water evaporation
  - Weed suppression
  - Modified soil temperature
    - Less fluctuation in winter
    - Cooler in summer
  - Increased biological activity in the soil
  - Reduced soil erosion

Types of Mulch

- Straw
- Compost
- Wood chips
- Lawn clippings
- Peat, manure
- Plastics
  - Clear – increases soil temperature as high as 90°F, weeds can be a problem
  - Black – increases soil temperature 3-6°F, suppresses weeds

Soil Chemical Properties

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Essential Plant Nutrients

Nutrients derived from water or air

- H - Hydrogen
- C - Carbon
- O - Oxygen

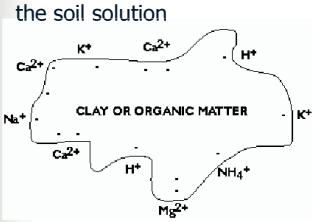
Essential Plant Nutrients

Nutrients derived from the soil and/or fertilizer

- Macronutrients
  - Primary
    - N - Nitrogen
    - P – Phosphorus
    - K – Potassium
  - Secondary
    - S – Sulfur
    - Mg – Magnesium
    - Ca – Calcium
- Micronutrients
  - Fe – Iron
  - Mn – Manganese
  - Cu – Copper
  - Zn – Zinc
  - B – Boron
  - Mo – Molybdenum
  - Cl - Chlorine

Soil Cation Exchange Capacity

CEC is the amount of positively charged ions a soil can hold – reduces leaching and buffers the soil solution



Soil Solution

K^+ Mg^{2+} Ca^{2+} H^+

Texture and CEC

Fine-textured soils have larger cation exchange capacities than coarse-textured soils

	Typical CEC
Clay Loam	32
Loam	24
Silt Loam	18
Sandy Loam	12
Loamy Sand	6

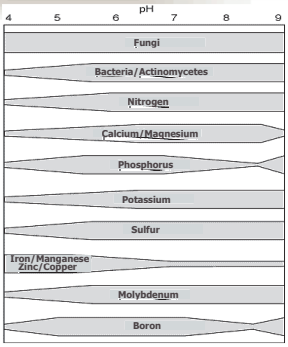
Soil pH

A measure of hydrogen ion concentration (H^+)

- Acid
  - High concentration of H^+
  - pH less than 7
- Neutral
  - pH = 7
- Alkaline
  - Low concentration of H^+
  - pH greater than 7

Soil pH

- Microbial activity
- Nutrient availability
  - optimum pH about 1 unit lower for organic soils/media



Mineral soils

Optimum pH

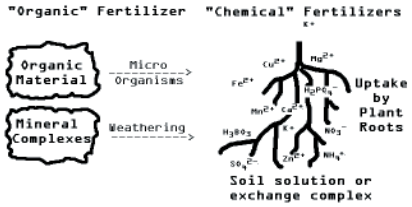
The optimum pH for most vegetables, fruits, and landscape plants is 5.5 – 7.0

Some have more acid requirements

Plant	Optimum pH
Pin Oak	5.0 – 6.5
Potato	4.8 – 5.4
Blueberry, Cranberry, Rhododendron, Azalea, Blue Hydrangea	4.2 – 5.2

Sources of Plant Nutrients

Plant nutrients come from both organic and chemical sources



Nutrient Movement

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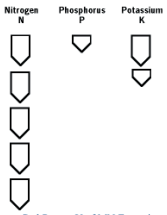
Relative Nutrient Mobility

- Nitrogen moves much faster than phosphorus and potassium in the soil
- Phosphorus has very limited mobility in the soil



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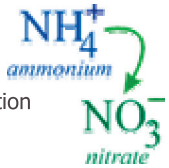
Nitrogen Pollution

- Nitrogen leaching
  - Nitrate form of N
  - Impairs drinking water quality
  - Contributes to eutrophication of rivers and lakes



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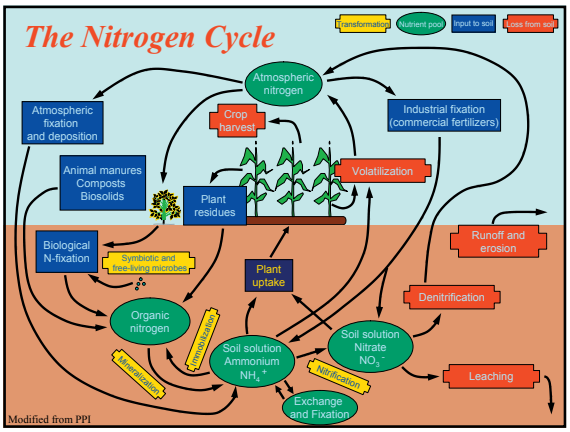

Sources of Nitrogen

- Animal wastes
- Septic tanks
- Fertilizer runoff

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Phosphorus Pollution

- Reduces water quality
  - Oxygen depletion
  - Fish/aquatic life die
- Algal blooms in lakes
  - Cloudy water
  - Unpleasant odor
  - Unappealing for recreational activity

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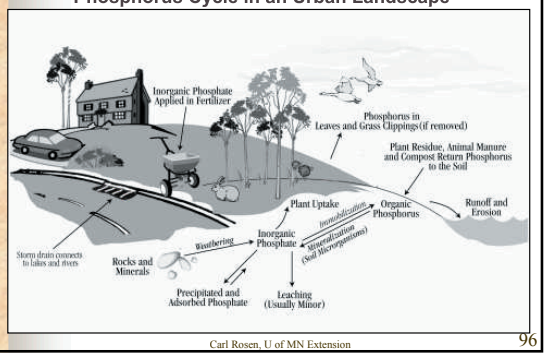
Phosphorus Cycle in an Urban Landscape



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Sources of Phosphorus

- Eroded soil
- Leaves and grass clippings left in the street
- Animal waste - including pet waste
- Improperly maintained septic systems
- Fertilizer

Soil testing is important to determine P needs

Phosphorus Fertilizer Restrictions

- New law that restricts P fertilizer application to turf
- Went into effect January 1, 2004 for metro area
  - P applied only if soil test indicates a need
- January 1, 2005 – law is effective for the entire state

Soil Testing, Soil Amendments, and Fertilizer Management

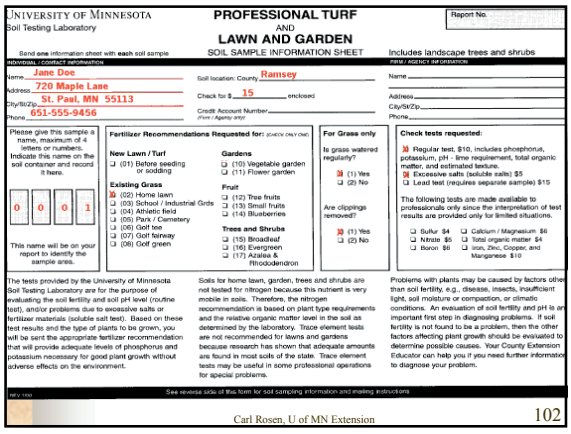
Master Gardener Core Course

Lawn/Garden Soil Sampling

- Where?
  - One sample from a uniform area
- How?
  - Use trowel, spade, sampling tube
  - Sample to 6" depth for gardens, new lawns
  - Sample to 3" depth for established lawns
  - Sample to 12" depth for trees, shrubs, and perennial fruits

Soil Sampling (contd)

- Sample from five or more well scattered spots in the area
- Place soil in bucket
- Mix thoroughly
- Place one pint in a container and send to laboratory



UNIVERSITY OF MINNESOTA
Soil Testing Laboratory

PROFESSIONAL TURF AND LAWN AND GARDEN
SOIL SAMPLE INFORMATION SHEET

Report No.

Send one information sheet with each soil sample

Includes landscape trees and shrubs

INDIVIDUAL / CONTACT INFORMATION

Name: Jane Doe
Address: 720 Maple Lane
City/St/Zip: St. Paul, MN 55113
Phone: 651-555-9456

Soil location: County: Ramsey
Check for $ 15 enclosed
Credit Account Number (Firm / Agency only)

FIRM / AGENCY INFORMATION

Name
Address
City/St/Zip
Phone

Please give this sample a name, maximum of 4 letters or numbers. Indicate this name on the soil container and record it here.

0 0 0 1

This name will be on your report to identify the sample area.

Fertilizer Recommendations Requested for: (CHECK ONLY ONE)

New Lawn / Turf
- ☐ (01) Before seeding or sodding

Existing Grass
- ☒ (02) Home lawn
- ☐ (03) School / Industrial Grds
- ☐ (04) Athletic field
- ☐ (05) Park / Cemetery
- ☐ (06) Golf tee
- ☐ (07) Golf fairway
- ☐ (08) Golf green

Gardens
- ☐ (10) Vegetable garden
- ☐ (11) Flower garden

Fruit
- ☐ (12) Tree fruits
- ☐ (13) Small fruits
- ☐ (14) Blueberries

Trees and Shrubs
- ☐ (15) Broadleaf
- ☐ (16) Evergreen
- ☐ (17) Azalea & Rhododendron

For Grass only

Is grass watered regularly?
- ☒ (1) Yes
- ☐ (2) No

Are clippings removed?
- ☒ (1) Yes
- ☐ (2) No

Check tests requested:
- ☒ Regular test, $10, includes phosphorus, potassium, pH - lime requirement, total organic matter, and estimated texture.
- ☒ Excessive salts (soluble salts) $5
- ☐ Lead test (requires separate sample) $15

The following tests are made available to professionals only since the interpretation of test results are provided only for limited situations.
- ☐ Sulfur $4
- ☐ Nitrate $5
- ☐ Boron $6
- ☐ Calcium / Magnesium $6
- ☐ Total organic matter $4
- ☐ Iron, Zinc, Copper, and Manganese $10

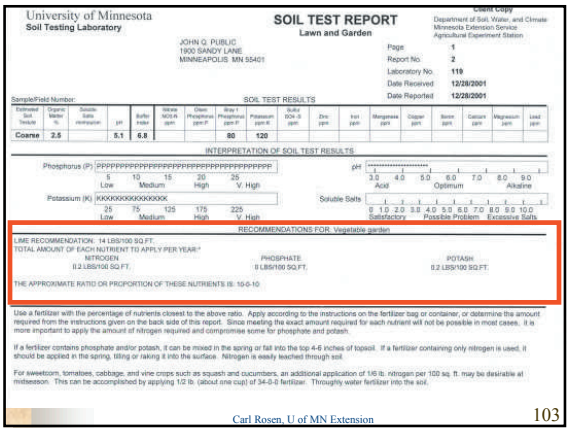
The tests provided by the University of Minnesota Soil Testing Laboratory are for the purpose of evaluating the soil fertility and soil pH level (routine test), and/or problems due to excessive salts or fertilizer materials (soluble salt test). Based on these test results and the type of plants to be grown, you will be sent the appropriate fertilizer recommendation that will provide adequate levels of phosphorus and potassium necessary for good plant growth without adverse effects on the environment.

Soils for home lawn, garden, trees and shrubs are not tested for nitrogen because this nutrient is very mobile in soils. Therefore, the nitrogen recommendation is based on plant type requirements and the relative organic matter level in the soil as determined by the laboratory. Trace element tests are not recommended for lawns and gardens because research has shown that adequate amounts are found in most soils of the state. Trace element tests may be useful in some professional operations for special problems.

Problems with plants may be caused by factors other than soil fertility, e.g., disease, insects, insufficient light, soil moisture or compaction, or climatic conditions. An evaluation of soil fertility and pH is an important first step in diagnosing problems. If soil fertility is not found to be a problem, then the other factors affecting plant growth should be evaluated to determine possible causes. Your County Extension Educator can help you if you need further information to diagnose your problem.

REV 1/00

See reverse side of this form for soil sampling information and mailing instructions



University of Minnesota
Soil Testing Laboratory

SOIL TEST REPORT
Lawn and Garden

Client Copy

Department of Soil, Water, and Climate
Minnesota Extension Service
Agricultural Experiment Station

JOHN Q. PUBLIC
1900 SANDY LANE
MINNEAPOLIS MN 55401

Page 1
Report No. 2
Laboratory No. 119
Date Received 12/28/2001
Date Reported 12/28/2001

SampleField Number:

SOIL TEST RESULTS

Estimated Soil Texture	Organic Matter %	Soluble Salts mmhos/cm	pH	Buffer Index	Nitrate NO3-N ppm	Olsen Phosphorus ppm P	Bray 1 Phosphorus ppm P	Potassium ppm K	Sulfur SO4-S ppm	Zinc ppm	Iron ppm	Manganese ppm	Copper ppm	Boron ppm	Calcium ppm	Magnesium ppm	Lead ppm
Coarse	2.5		5.1	6.8			80	120									

INTERPRETATION OF SOIL TEST RESULTS

Phosphorus (P): PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
5 Low, 10 Medium, 15, 20 High, 25 V. High

Potassium (K): KKKKKKKKKKKKKKK
25 Low, 75 Medium, 125, 175 High, 225 V. High

pH: 3.0 4.0 5.0 6.0 7.0 8.0 9.0
Acid, Optimum, Alkaline

Soluble Salts: 0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
Satisfactory, Possible Problem, Excessive Salts

RECOMMENDATIONS FOR: Vegetable garden

LIME RECOMMENDATION: 14 LBS/100 SQ.FT.
TOTAL AMOUNT OF EACH NUTRIENT TO APPLY PER YEAR:*

NITROGEN	PHOSPHATE	POTASH
0.2 LBS/100 SQ.FT.	0 LBS/100 SQ.FT.	0.2 LBS/100 SQ.FT.

THE APPROXIMATE RATIO OR PROPORTION OF THESE NUTRIENTS IS: 10-0-10

Use a fertilizer with the percentage of nutrients closest to the above ratio. Apply according to the instructions on the fertilizer bag or container, or determine the amount required from the instructions given on the back side of this report. Since meeting the exact amount required for each nutrient will not be possible in most cases, it is more important to apply the amount of nitrogen required and compromise some for phosphate and potash.

If a fertilizer contains phosphate and/or potash, it can be mixed in the spring or fall into the top 4-6 inches of topsoil. If a fertilizer containing only nitrogen is used, it should be applied in the spring, tilling or raking it into the surface. Nitrogen is easily leached through soil.

For sweetcorn, tomatoes, cabbage, and vine crops such as squash and cucumbers, an additional application of 1/6 lb. nitrogen per 100 sq. ft. may be desirable at midseason. This can be accomplished by applying 1/2 lb. (about one cup) of 34-0-0 fertilizer. Throughly water fertilizer into the soil.

Garden: Lime Recommendation

For vegetables apply lime if pH is less than 6.0

1 lb of ground limestone equals about 1.5 cups

Buffer Index	Lime to Apply (lb/100 sq ft)
Below 6.5	22
6.5	20
6.6	18
Above 6.6	14

Buffer Index and Buffers

- Buffer index: a lab measurement used to determine lime needs
- Buffer: anything that resists an opposing force
  - High buffering capacity – soil resists change in pH
  - Low buffering capacity – soil pH can change rapidly
  - High buffer index = low lime requirement
  - Low buffer index = high lime requirement

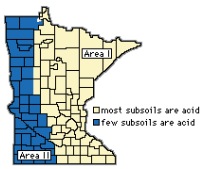
Soils are Buffers

Soils high in clay and organic matter have a high buffering capacity and a low buffer index

Sandy Soil	Clay Loam Soil
pH = 5.1	pH = 5.1
buffer index = 6.8	buffer index = 6.2
lime requirement = 14 lb/100 sq ft	lime requirement = 22 lb/100 sq ft

Raising Soil pH

- Have soil tested before adding lime
- Few soils in western Minnesota need lime
- Incorporate liming amendments to a depth of 6 inches before planting



Raising pH: Liming Materials

- Limestone
  - Ag lime (agricultural limestone)
- Calcium carbonate
  - Calcitic lime (calcite)
- Calcium + magnesium carbonate
  - Dolomitic lime (dolomite)
- Both types of limestone are effective liming materials
  - Dolomite is preferred when soil Mg is low

Raising pH: Wood Ash

Soil pH can be raised by adding wood ashes

- Rates
  - 3/4 to 2 lb of wood ashes = 1 lb ag-lime
  - 2 lbs/100 sq ft / year (monitor pH)
  - One-time application of 10 to 14 lbs/100 sq ft can be made (based on soil test)
- Considerations
  - Excessive rates can cause salt and/or micronutrient problems
  - If soil pH is above 7.0, wood ashes are not recommended

Lowering pH: Elemental Sulfur

Never add elemental sulfur until your soil has been tested to determine initial pH

- Slow to react (2-4 months)
  - Controlled by soil microbes
- Rate to lower soil pH ½ unit
  - Loams: 12 lb/1000 sq ft
  - Sands: 4 lb/1000 sq ft
- Incorporate to a depth of 6-12 inches before planting

Lowering pH: Iron Sulfate

Never add iron sulfate until your soil has been tested to determine initial pH

- Faster reacting (2-3 weeks)
- Rate to lower pH by ½ unit
  - Loams: 60 lb/1000 sq ft
  - Sands: 25 lb/1000 sq ft
- Incorporate 6-12 inches before planting

Lowering pH: Other Materials

- Aluminum Sulfate
  - Not recommended except for blue hydrangea
- Acid Peat
  - Broadcast and incorporate six months to one year before planting
  - 50:50 (soil:acid peat) in planting hole
- Ammonium containing fertilizers
  - Supply nitrogen
  - Do not exceed recommended N rate

Modifying Soil pH

- Most liming materials contain Ca, but Ca does **not** raise pH
  - e.g. in limestone it is the carbonate
- Elemental S lowers pH, but sulfate (SO_4) does **not** lower pH
  - e.g. in Fe- or Al-sulfate it is the Fe or Al
- Materials like gypsum (Ca-sulfate) are neutral salts

Understanding Fertilizer Labels

%N	$\%P_2O_5$	$\%K_2O$
15	**25**	**10**
Nitrogen	Phosphate	Potash

Understanding Fertilizer Labels

- Forms of Nitrogen
  - Ammoniacal – 6.2%
  - Urea – 5.9%
  - Nitrate – 2.0 %
  - Water insoluble – 0.9%

    15.0% total N
- Available Phosphoric Acid (P_2O_5) = 25%
- Soluble Potash (K_2O) = 10%

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Understanding Fertilizer Labels

- Complete fertilizers
  - Contain the three primary plant nutrients – N, P, K
    - e.g. 10-10-10
- Single nutrient fertilizers
  - Contain one of the three primary plant nutrients
    - e.g. 46-0-0)
- Fertilizer grade
  - Refers to N : P_2O_5 : K_2O ratio
    - e.g. 15-25-10 is a 3-5-2)

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Organic vs. Inorganic Fertilizers

- Organic
  - Nutrients slowly released
  - Low burn potential
  - Improve soil structure
  - May contain weed seeds
  - Usually higher cost
  - Acceptability for certified organic crop production depends upon the certifying agency
- Inorganic (manufactured soluble fertilizers)
  - Nutrients quickly available
  - High burn potential

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Inorganic Fertilizers

Inorganic Fertilizer	% N	% P_2O_5	% K_2O
Ammonium sulfate	21	0	0
Ammonium nitrate	34	0	0
Urea	45	0	0
Calcium nitrate	15	0	0
Monoammonium phosphate	11	48	0
Diammonium phosphate	18	46	0
Rock phosphate	0	5	0
Superphosphate	0	20	0
Conc. superphosphate	0	46	0
Green sand	0	1	6
Muriate of potash	0	0	60
Potassium sulfate	0	0	50
Potassium – magnesium sulfate	0	0	22
Blends (N, P, K)	10	10	10
	12	12	12
	27	3	3
	6	12	12
	18	6	12

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Organic Fertilizers

Organic Fertilizer	% N	% P_2O_5	% K_2O
Manure (fresh)			
bat	6.0	9.0	3.0
cattle	0.55	0.55	0.45
hog	0.50	0.35	0.45
horse	0.65	0.25	0.50
poultry	1.00	0.85	0.45
rabbit	2.4	1.4	0.6
sheep	0.9	0.5	0.8
Alfalfa hay	2.5	0.5	2.1
Bone meal (steamed)	1.0	15.0	0.0
Fish scraps	9.0	7.0	0.0
Lawn clippings	1.2	0.3	2.0
Leaves (sugar maple)	0.7	0.1	0.8
Milorganite *	5.0	3.0	2.0
Straw (wheat)	0.6	0.2	1.0
Grain straw	0.6	0.2	2.1
Sawdust	0.2	0.1	0.2
Wood ashes	0.0	2.0	6.0

* Not acceptable for organic fruit and vegetable production

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Slow Release Fertilizers

Slow release fertilizers are primarily used for potted plants and turf

- Advantages
  - Low burn potential
  - Nitrogen available over longer period of time
- Disadvantages
  - High cost
  - May not provide enough N for fast growing crops
- Examples – Osmocote, Sierrablend, UreaForm

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Nitrogen Recommendations

For vegetable gardens

Organic Matter (%)	**N to Apply** (lb N/100 sq ft)
Low (<3.1)	0.20
Medium to High (3.1 – 19)	0.15
Organic Soil (>19)	0.10

Sweet corn, tomatoes, cole crops, and vine crops may need additional nitrogen at midseason (1/6 lb N/100 sq ft)

Phosphorus Recommendations

For vegetable gardens

Phosphorus Soil Test (ppm)		**Phosphate to Apply** (lb P_2O_5/100 sq ft)
*Bray P**	*Olsen P***	
0-5	0-3	0.4
6-10	4-7	0.3
11-15	8-11	0.2
16-25	12-18	0.1
>25	>18	0.0

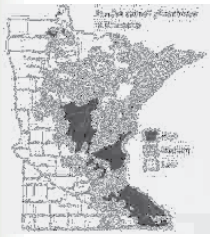
*Use the Bray P1 test when soil pH is 7.4 or less.
**Use the Olsen P test when soil pH is >7.4.

Potassium Recommendations

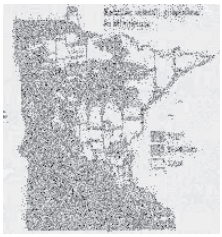
For vegetable gardens

Potassium Soil Test (ppm)	**Potash to Apply** (lb K_2O/100 sq ft)
0-50	0.4
51-100	0.3
101-150	0.2
151-200	0.1
Over 200	0.0

Relative Subsoil P and K

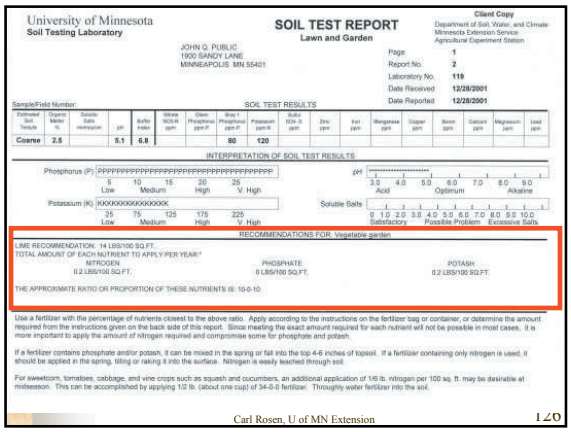


Phosphorus



Potassium

Calculating the Rate of Fertilizer to Apply Based on a Soil Test Report



University of Minnesota
Soil Testing Laboratory

SOIL TEST REPORT
Lawn and Garden

Client Copy
Department of Soil, Water, and Climate
Minnesota Extension Service
Agricultural Experiment Station

JOHN Q. PUBLIC
1800 SANDY LANE
MINNEAPOLIS MN 55401

Page 1
Report No. 2
Laboratory No. 119
Date Received 12/28/2001
Date Reported 12/28/2001

Sample/Field Number:

SOIL TEST RESULTS

Estimated Soil Texture	Organic Matter	Soluble Salts mmhos/cm	pH	Buffer index	Nitrate NO3-N ppm	Olsen Phosphorus ppm P	Bray 1 Phosphorus ppm P	Potassium ppm K	Sulfur SO4-S ppm	Zinc ppm	Iron ppm	Manganese ppm	Copper ppm	Boron ppm	Calcium ppm	Magnesium ppm	Lead ppm
Coarse	2.5		5.1	6.8			80	120									

INTERPRETATION OF SOIL TEST RESULTS

Phosphorus (P) PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
5 10 15 20 25
Low Medium High V. High

Potassium (K) KKKKKKKKKKKKKKK
25 75 125 175 225
Low Medium High V. High

pH
3.0 4.0 5.0 6.0 7.0 8.0 9.0
Acid Optimum Alkaline

Soluble Salts
0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
Satisfactory Possible Problem Excessive Salts

RECOMMENDATIONS FOR: Vegetable garden

LIME RECOMMENDATION: 14 LBS/100 SQ.FT.
TOTAL AMOUNT OF EACH NUTRIENT TO APPLY PER YEAR:*

NITROGEN	PHOSPHATE	POTASH
0.2 LBS/100 SQ.FT.	0 LBS/100 SQ.FT.	0.2 LBS/100 SQ.FT.

THE APPROXIMATE RATIO OR PROPORTION OF THESE NUTRIENTS IS: 10-0-10

Use a fertilizer with the percentage of nutrients closest to the above ratio. Apply according to the instructions on the fertilizer bag or container, or determine the amount required from the instructions given on the back side of this report. Since meeting the exact amount required for each nutrient will not be possible in most cases, it is more important to apply the amount of nitrogen required and compromise some for phosphate and potash.

If a fertilizer contains phosphate and/or potash, it can be mixed in the spring or fall into the top 4-6 inches of topsoil. If a fertilizer containing only nitrogen is used, it should be applied in the spring, tilling or raking it into the surface. Nitrogen is easily leached through soil.

For sweetcorn, tomatoes, cabbage, and vine crops such as squash and cucumbers, an additional application of 1/6 lb. nitrogen per 100 sq. ft. may be desirable at midseason. This can be accomplished by applying 1/2 lb. (about one cup) of 34-0-0 fertilizer. Throughly water fertilizer into the soil.

Example

From the soil test report:

- Phosphorus = 80 (very high)
- Potassium = 120 (medium high)

Recommendations

- Pounds of nutrient to apply per 100 sq ft

N	P_2O_5	K_2O
0.2	0	0.2

Calculating Fertilizer Rates

- Measure garden area to be fertilized in square feet
- Select a fertilizer grade with the closest ratio of plant nutrients to accommodate the recommendation
- Determine pounds of fertilizer required based on nitrogen recommendation

Calculating Fertilizer Rates

Steps

- Calculate garden area
  - 20′ x 15′ = **300 sq ft**
- Select fertilizer
  - Determine ratio of nutrients needed
    - 0.2 N : 0 P_2O_5 : 0.2 K_2O = **1:0:1**
  - Select a fertilizer blend close to this ratio
    - Must compromise between available options if exact ratio is not available

Calculating Fertilizer Rates

Steps (cont'd)

- Available fertilizer options
  - 27-0-3 (9:1:1)
  - 12-12-12 (1:1:1)
  - 25-0-12 (~2:0:1)
  - 5-10-5 (1:2:1)
- None are exact, but **25-0-12** is the closest
  - ~2:0:1 vs. desired ratio of 1:0:1
  - 1:1:1 would apply a large excess of P

Calculating Fertilizer Rates

Steps (cont'd)

- Selecting a fertilizer blend
  - Avoid applying excess P
  - Make sure N is supplied at recommended rate
  - Better to apply a little less K than too much P or too little N
- Calculate the required amount of fertilizer
  - Based on recommended N rate
  - Use table (or do by hand)

Old Soil Test Report

Table to Determine Total Amount of Fertilizer to Apply Based on Actual Nitrogen Recommended:

Fertilizer		Nitrogen Recommended		
		0.1 lbs. N/100 sq. ft	0.2 lbs. N/100 sq. ft	1.0 lb. N/1000 sq. ft
Grade		Total lbs. fertilizer to apply / 100 sq. ft		Total lbs. fertilizer to apply/1000 sq. ft
45-0-0 (urea)		0.22	0.44	2.2
37-3-3		0.27	0.54	2.7
36-6-6		0.28	0.56	2.8
33-0-0		0.30	0.60	3.0
32-4-4	32-3-10	0.31	0.62	3.1
30-4-4	30-0-10	0.33	0.66	3.3
28-3-3	28-4-6	0.36	0.72	3.6
27-7-7	27-3-3	0.37	0.74	3.7
25-5-5	25-3-12	0.40	0.80	4.0
24-8-16	24-0-15	0.42	0.84	4.2
22-4-4	22-6-3	0.45	0.90	4.5
21-0-0	21-3-12	0.48	0.96	4.8
20-20-20	20-4-8	0.50	1.00	5.0
19-19-19	19-11-12	0.53	1.06	5.3
18-6-12	18-3-6	0.56	1.12	5.6
16-8-8	16-4-8	0.63	1.26	6.3
15-15-15	15-5-5	0.67	1.34	6.7
13-3-9	13-25-12	0.77	1.54	7.7
12-12-12	12-4-4	0.83	1.66	8.3
10-10-10	10-20-10	1.00	2.00	10.0
10-5-5	10-10-20	1.00	2.00	10.0
6-12-12	6-2-0	1.67	3.34	16.7
5-10-10	5-10-5	2.00	4.00	20.0

New Soil Test Report

Table to Determine Total Amount of Fertilizer to Apply Based on Actual Nitrogen Recommended:

Fertilizer Nitrogen % (First number of fertilizer grade on bag)	Nitrogen Recommended: 0.1 lb. N/100 sq. ft	0.15 lb. N/100 sq ft	0.2 lb. N/100 sq. ft	1.0 lb. N/1000 sq. ft
	Total lbs. fertilizer to apply / 100 sq. ft			Total lbs. fertilizer to apply/1000 sq. ft
45	0.22	0.33	0.44	2.2
37	0.27	0.40	0.54	2.7
36	0.28	0.42	0.56	2.8
33	0.30	0.45	0.60	3.0
32	0.31	0.46	0.62	3.1
30	0.33	0.50	0.66	3.3
28	0.36	0.54	0.72	3.6
27	0.37	0.56	0.74	3.7
25	0.40	0.60	0.80	4.0
24	0.42	0.63	0.84	4.2
22	0.45	0.68	0.90	4.5
21	0.48	0.72	0.96	4.8
20	0.50	0.75	1.00	5.0
19	0.53	0.80	1.06	5.3
18	0.56	0.84	1.12	5.6
16	0.63	0.95	1.26	6.3
15	0.67	1.00	1.34	6.7
13	0.77	1.15	1.54	7.7
12	0.83	1.25	1.66	8.3
10	1.00	1.50	2.00	10.0
8	1.25	1.88	2.50	12.5
6	1.67	2.50	3.34	16.7
5	2.00	3.00	4.00	20.0

Calculating Fertilizer Rates

Steps (cont'd)

- Closest matching fertilizer blend: 25-0-12
- Apply according to nitrogen needs
  - 0.2 lb N/100 sq ft
  - 0.8 lbs of 25-0-12 fertilizer will supply 0.2 lb N
- 300 sq ft to be fertilized
  - 3 x 0.8 ≅ **2.4 lbs of 25-0-12** for 300 sq ft
    - or about 5 cups of 25-0-12
    - most fertilizers weigh about 1/2 lb per cup

Application Methods

There are a variety of fertilizer application methods

- Broadcast prior to planting
- Band placement
- Sidedressing
- Starter solutions
- Foliar fertilizers

Broadcasting

- Safest
- Easiest
- Spread evenly on soil surface
- Work in 4-6"

Band Placement

- Fertilizer placed near row at time of planting
- Can get "fertilizer burn" if placed too close
- Place fertilizer
  - 2-3" below seed
  - 2-3" to the side of seed

Sidedressing

- Fertilizer placed beside plant after emergence
- Primarily used for nitrogen
- High rates may cause burn

Starter Solutions

- Important for vegetable transplants
  - Hastens establishment
- Apply when transplants are set in the ground
- Mix 2 tablespoons 10-20-10 or 15-30-15 per gallon water
- Apply one cup on soil around roots of each transplant
- Higher rates may cause burn

Foliar Fertilizers

- Not satisfactory for N, P, K
  - Can't apply large amounts without burning foliage
- Use as supplement only
- If needed, can be used for micronutrients
  - Chelated iron

Nutrient Deficiency Symptoms

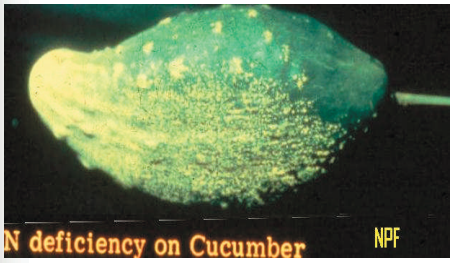
Master Gardener Core Course

Nitrogen Deficiency

N deficiency – Corn

N deficiency – Corn

N deficiency – Cucumber



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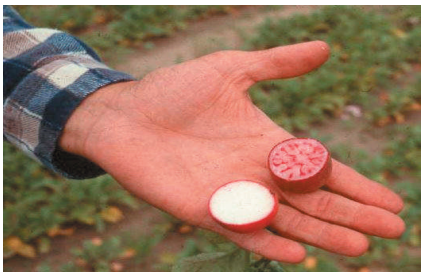
N deficiency – Potato

Carl Rosen, U of MN Extension 146

N deficiency – Radish

Carl Rosen, U of MN Extension 147

N deficiency – Radish



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N deficiency – Cauliflower

180 lb N/acre 120 lb N/acre

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N deficiency – Cauliflower

60 lb N/A

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Phosphorus Deficiency

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P deficiency - Cabbage

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P deficiency – Corn

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Potassium Deficiency

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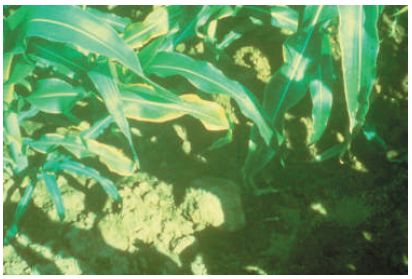
K deficiency – Corn



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K deficiency – Corn

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K deficiency – Cabbage

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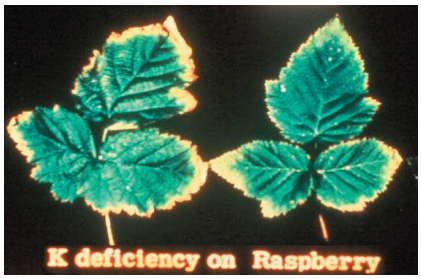
K deficiency – Peas

Carl Rosen, U of MN Extension 158

K deficiency - Raspberry



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K deficiency – Turf

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K & P deficiency – Cabbage

-P

-K

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Secondary Nutrients
Sulfur – Calcium - Magnesium

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S deficiency - Snap Bean

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Ca deficiency - Celery

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Ca deficiency - Tomatoes

Blossom End Rot

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Ca deficiency - Lettuce

Tip Burn

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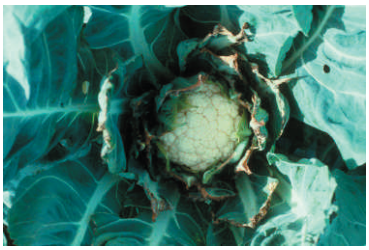
Ca deficiency - Cauliflower



Tip Burn

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Ca deficiency - Cauliflower

Tip Burn

Carl Rosen, U of MN Extension 168

Ca deficiency - Cauliflower

Tip Burn

Carl Rosen, U of MN Extension 169

Ca deficiency - Cauliflower

Black Rot: Tip Burn Source of Infection

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Mg deficiency - Cabbage

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Mg deficiency - Corn

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Mg deficiency - Grape

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Micronutrients
Boron – Manganese – Molybdenum – Zinc – Iron

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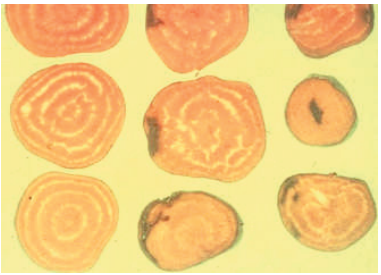
B deficiency - Beets



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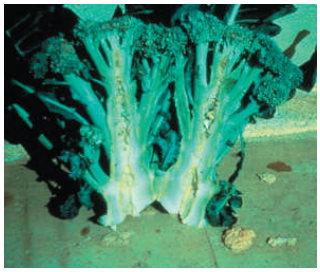
B deficiency - Broccoli



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B deficiency - Cauliflower

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B deficiency - Cauliflower

Carl Rosen, U of MN Extension 178

B deficiency - Cauliflower

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B deficiency - Cauliflower

Carl Rosen, U of MN Extension 180

B toxicity - Tomatoes

Carl Rosen, U of MN Extension 181

B toxicity - Tomatoes

Carl Rosen, U of MN Extension 182

B toxicity - Broccoli

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Mn deficiency - Bean

Carl Rosen, U of MN Extension 184

Mn deficiency - Raspberry

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Mo deficiency - Cauliflower

Whiptail: Low pH soil (<5.5)

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Zn deficiency - Snap Bean

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187

Fe Chlorosis - Navy Bean

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188

Fe Chlorosis - Blueberry

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189

Fe Chlorosis - Blueberry

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190

Fe Chlorosis

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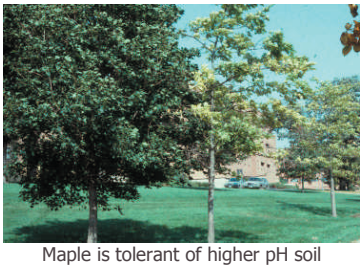
191

Fe Chlorosis - Pin Oaks



Maple is tolerant of higher pH soil

Carl Rosen, U of MN Extension

192

Excess Fe - Blueberry

Carl Rosen, U of MN Extension

193

Excess Salt/Fertilizer - Tomatoes

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194

Herbicide Injury - Zucchini

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195

Round-up injury - Cabbage

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Varietal purpling - Sweet Corn

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197

Herbicide damage - Strawberry

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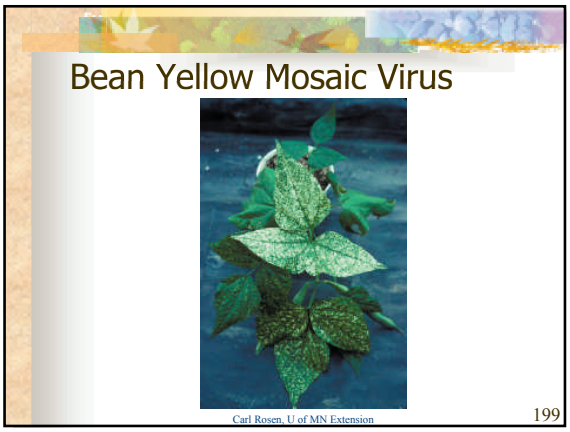
198


Bean Yellow Mosaic Virus
Carl Rosen, U of MN Extension
199

"That's the total harvest from your garden this year. Congratulations on your first $100-a-plate dinner."

University of Minnesota
Soil Testing Laboratory

SOIL TEST REPORT
Lawn and Garden

Client Copy
Department of Soil, Water, and Climate
Minnesota Extension Service
Agricultural Experiment Station

JOHN Q PUBLIC
1900 SANDY LANE
MINNEAPOLIS MN 55451

Page	**1**
Report No.	**10**
Laboratory No.	**10000**
Date Received	**10/13/98**
Date Reported	**10/13/98**

Sample/Field Number: 1A

SOIL TEST RESULTS

Estimated Soil Texture	Organic Matter %	Soluble Salts mmhos/cm	pH	Buffer Index	Nitrate NO3-N ppm	Olsen Phosphorus ppm P	Bray 1 Phosphorus ppm P	Potassium ppm K	Sulfur SO4 -S ppm	Zinc ppm	Iron ppm	Manganese ppm	Copper ppm	Boron ppm	Calcium ppm	Magnesium ppm	Lead ppm
Coarse	**2.5**		**5.1**	**6.8**			**80**	**120**									

INTERPRETATION OF SOIL TEST RESULTS

Phosphorus (P) PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPF
5 Low | 10 Medium | 15 High | 25 V. High

Potassium (K) KKKKKKKKKKKKKKKKKKKKKKK
25 Low | 75 Medium | 125 High | 150 V. High

pH **********
3.0 4.0 5.0 6.0 7.0 8.0 9.0
Acid | Optimum | Alkaline

Soluble Salts
0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
Satisfactory | Possible Problem | Excessive Salts

RECOMMENDATIONS FOR: Vegetable garden

LIME RECOMMENDATION: 14 LBS/100 SQ.FT.
TOTAL AMOUNT OF EACH NUTRIENT TO APPLY PER YEAR:*

NITROGEN	PHOSPHATE	POTASH
0.2 LBS/100 SQ.FT.	0 LBS/100 SQ.FT.	0.2 LBS/100 SQ.FT.

THE APPROXIMATE RATIO OR PROPORTION OF THESE NUTRIENTS IS: 10-0-10

Use a fertilizer with the percentage of nutrients closest to the above ratio. Apply according to the instructions on the fertilizer bag or container, or determine the amount required from the instructions given on the back side of this report. Since meeting the exact amount required for each nutrient will not be possible in most cases, it is more important to apply the amount of nitrogen required and compromise some for phosphate and potash.

If a fertilizer contains phosphate and/or potash, it can be mixed in the spring or fall into the top 4-6 inches of topsoil. If a fertilizer containing only nitrogen is used, it should be applied in the spring, tilling or raking it into the surface. Nitrogen is easily leached through soil.

For sweetcorn, tomatoes, cabbage, and vine crops such as squash and cucumbers, an additional application of 1/6 lb. nitrogen per 100 sq. ft. may be desirable at midseason. This can be accomplished by applying 1/2 lb. (about one cup) of 34-0-0 fertilizer. Throughly water fertilizer into the soil.

County: HENNEPIN. For additional information, contact your county extension educator, ROBERT MUGAAS at (612) 374-8400

University of Minnesota
Soil Testing Laboratory

SOIL TEST REPORT
Lawn and Garden

Client Copy
Department of Soil, Water, and Climate
Minnesota Extension Service
Agricultural Experiment Station

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ST PAUL MN 55113

Page	**1**
Report No.	**6**
Laboratory No.	**99106**
Date Received	**10/15/98**
Date Reported	**10/27/98**

Sample/Field Number: 1B

SOIL TEST RESULTS

Estimated Soil Texture	Organic Matter %	Soluble Salts mmhos/cm	pH	Buffer Index	Nitrate NO3-N ppm	Olsen Phosphorus ppm P	Bray 1 Phosphorus ppm P	Potassium ppm K	Sulfur SO4 -S ppm	Zinc ppm	Iron ppm	Manganese ppm	Copper ppm	Boron ppm	Calcium ppm	Magnesium ppm	Lead ppm
Medium	**3.8**	**0.5**	**7.6**			**23**	**15**	**70**									

INTERPRETATION OF SOIL TEST RESULTS

Phosphorus (P) PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
5 Low — 10 Medium — 15 High — 25 V. High

Potassium (K) KKKKKKKKKKKKK
25 Low — 75 Medium — 125 High — 150 V. High

pH **********
3.0 4.0 5.0 6.0 7.0 8.0 9.0
Acid — Optimum — Alkaline

Soluble Salts ****
0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
Satisfactory — Possible Problem — Excessive Salts

RECOMMENDATIONS FOR: Home Lawn

LIME RECOMMENDATION: 0 LBS/1,000 SQ.FT.

Grass watered Clippings removed

TOTAL AMOUNT OF EACH NUTRIENT TO APPLY PER YEAR:*

NITROGEN	PHOSPHATE	POTASH
3 LBS/1,000 SQ.FT.	0 LBS/1,000 SQ.FT.	3 LBS/1,000 SQ.FT.

THE APPROXIMATE RATIO OR PROPORTION OF THESE NUTRIENTS IS: 10-0-10

Use a fertilizer with the percentage of nutrients closest to the above ratio. Apply according to the instructions on the fertilizer bag or container, or determine the amount required from the instructions given on the back side of this report. Since meeting the exact amount required for each nutrient will not be possible in most cases, it is more important to apply the amount of nitrogen required and compromise some for phosphate and potash.

*CAUTION! Do not apply more that 1 lb. nitrogen per 1000 sq. ft. in one application to avoid burning the grass, unless a slow release form or organic fertilizer is used. It is recommended that up to 50 percent of the nitrogen be of the slow release form.

-Apply 1/3 of the above total between May 20 and June 20.
-Apply another 1/3 of the above total between August 10 and September 10.
-Apply the remaining 1/3 of the above total between October 10 and October 31.

Grass clippings left on the lawn is a sound practice because they recycle nutrients.

County: RAMSEY. For additional information, contact your county extension educator. DOUG FOULK at (651) 704-2080

appendix

4

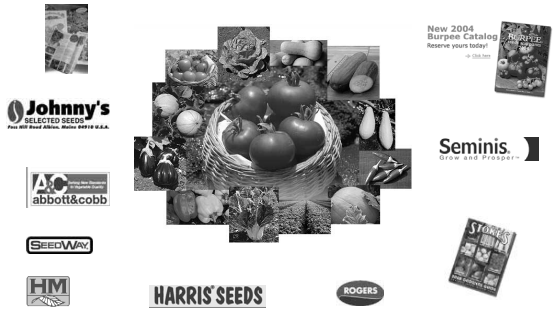
vegetables

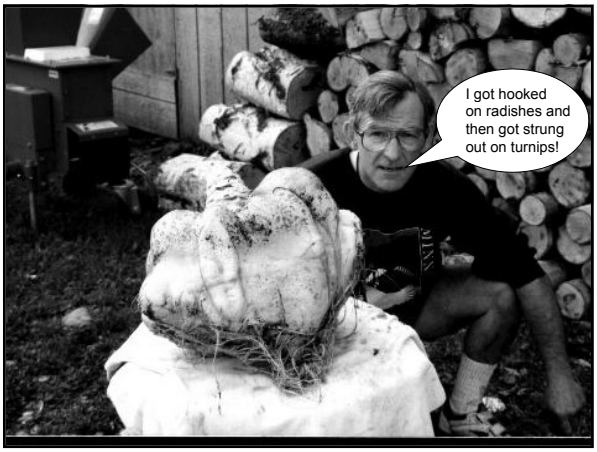
Principles of Vegetable Production

Dr. Vince Fritz
Professor
Horticultural Science
(vafritz@umn.edu)

University of Minnesota Extension Service

We Are Salivating Over Our Catalogs!





Take comfort In knowing there is help!

They didn't know they had a problem!

Plan Your Success!

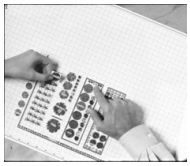
Work Requirements

Preferred Vegetables

Consumption Preferences

Space Requirements

Crop Rotation Strategies



Your Garden Map!

Your Plan Needs a Good Location!

Well drained soil	*Compacted soil*
Little or no slope	*Close to road or driveway*
Good sun exposure	*Close to Buildings*
Close to water source	*Close to black walnut trees*
Protected from wind	

Preparing the Soil!

Soil should be friable, well drained, and high in organic matter

High clay content will cause problems with seedling emergence and drainage

Compost, peat, and other soil amendments can improve garden performance

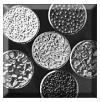
Take a soil test!!

Seeds and Maintaining Seed Quality

Try to buy only what you need

Method of storage has a great impact on viability (ex. garage, basement, refrigerator)

Conduct a germination test before planting

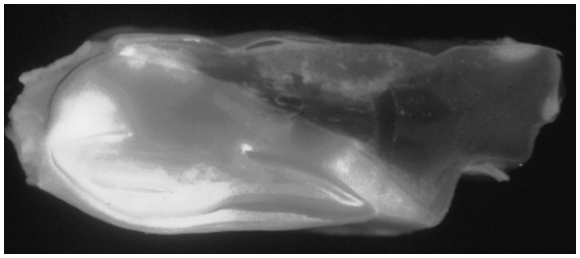


Vegetable Variety Selection

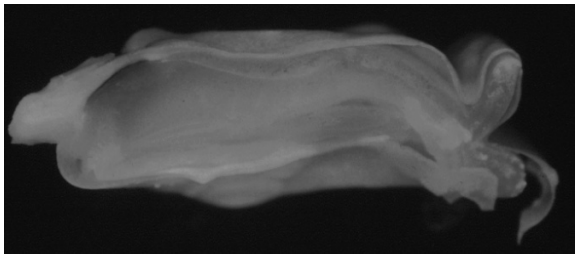
Genetic Types

su	*- Normal sugary*	*sweet*	*creamy*
se	*- Sugary enhancer*	*sweeter*	*creamy*
sh2	*- Supersweet*	*sweetest*	*crunchy*

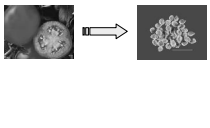
Water Movement During Imbibition (High Quality Seed)



Water Movement During Imbibition (Poor Quality Seed)



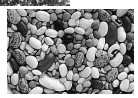
Saving Seed from the Crop

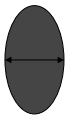


Open pollinated varieties	Hybrid varieties
Quickly dry and package	Diseased fruit
Select healthy fruit	Crops that may be cross-pollinated
Buy new seed for crops known to have poor quality	Plant poor quality seed

Methods of Planting

A general rule of thumb is that planting depth should be 4 -5 x the lateral width of the seed.

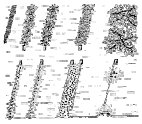




What Happens if I Plant Too Deep or Shallow?

Too Shallow	Too Deep
Susceptible to desiccation	Poor emergence
Poor root development	Delayed emergence
Poor plant stature	Susceptible to soil pathogens
Influenced by mild soil moisture fluctuations	Less competitive with weeds

Methods of Direct Seeding



Row planting

Equidistant or Broadcast planting

Hill planting

Direct Seeding

Prepare a furrow with a uniform depth

Evenly distribute the seed

Firm the soil over the furrow after planting

Water lightly, but thoroughly

Transplanting
Beating the Short Season

Ensures the most efficient use of space

Improves uniformity

Enables the growing of long season vegetables

Good fit for slow germinating vegetables

Overcomes vernalization effects in some vegetables

Transplanting, Contd.

Improves competitiveness with weeds

Gives greater control in scheduling your harvest

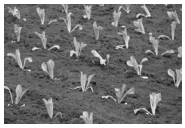
Caution !

Avoid transplant shock – "harden" plants

Transplant in evening or on a cloudy day

Know which crops do not transplant well

Avoid excessive wind



Transplant Only Healthy Plants

Annuals

Most vegetable transplants are 3-4 weeks old

Transplants should appear stocky (not spindly or leggy)

Transplants should be free of any obvious disease and have a well developed root system but not root bound

Dig a hole just large enough to accommodate the roots and plant slightly deeper than before
(Caution! – danger of moisture wicking)

Transplant Only Healthy Plants

Perennials

"Buyer beware" of mail order catalogues that sell varieties that do not do well in Minnesota

Do some homework to familiarize yourself with the disease and insect problems of the crop

Asparagus, one of the most common perennials in the home vegetable garden, are usually planted as 1-2 yr. old crowns

Roots should appear healthy with good color

Transplant Only Healthy Plants

Check crowns for viable buds

Until planting, store the crowns in a cool place and keep the roots moist but not wet

Use good transplanting principles when placing them in your garden

Now - The Garden is Planted
- But Don't Forget About It! -

Water thoroughly (1-2"/week)

Water is the most essential to plant growth (nutrient uptake, root growth)

Monitor regularly with a rain gauge

Critical Watering Times For Some Vegetable Crops

Crop	Stage of Development
Asparagus	spear / fern growth
Broccoli / Cabbage	head development
Cauliflower	head development
Beans / Peas	pod filling
Carrot	emergence / growth
Sweet Corn	silking / tasseling / ear growth
Cucumber	flowering / fruit development
Eggplant / Tomato	flowering / fruit development
Lettuce	emergence / head development
Melons	flowering / fruit development

Intensive Gardening Methods

Isn't This Just More Work??!

Maximize yield

Create the best plant environment

Less labor requirements

Basic Methods
- *Raised Beds*
- *Interplanting*
- *Vertical Gardening*
- *Succession or Relay Planting*

Why Use Raised Beds?

Making the Bed

Mobile or permanent

Usually 3-4 ft. wide

Mix topsoil with composted manure and other amendments

Final height of 8-12"

Great for equidistant planting configurations

Vertical Gardening

What is it?

Use of trellises, nets, strings, cages, or poles to maximize crop growth and quality

How to use it

Vining crops are prime candidates ("space hogs") (ex. melons, cucumbers, mini pumpkins)

Monitor soil moisture closely

Protection from excessive wind is really important

Interplanting

What is it?

The growing of two or more vegetables in the same space at the same time

Key relationships between different crops to consider

Length of growing season
Growth patterns
Potential negative effects on growth
Preferred season of production
Light, nutrient, and moisture requirements

Interplanting, Contd.

How to use it

Accomplished by alternating rows, different plants within a row,or a randomized planting

Some Examples

Carrots and Radishes
Radishes and Broccoli
Cabbage and Spinach

How do these crops uniquely relate to each other?

Succession and Relay Planting

What are they?

Succession

Planting of one crop in a space that was previously vacated by an earlier crop

Relay

Overlapping plantings of one crop

Based on planting intervals
Based on relative maturities (heat units)

Growing Vegetables in Containers

(Is Space Really Limiting?)

Grow vegetables that:

Take up little space
Bear fruit over a long period of time
Have a dwarf type growth habit

Light exposure on your deck or patio should be 8 – 10 hours of direct sunlight

Aluminum foil and other things can be used to direct more sunlight to the plant

Growing Vegetables in Containers, Contd.

Key points to remember:

Protect plants from excessive heat, wind, and rain

Be certain that pots and planter boxes are large Enough to provide adequate moisture for a couple of days

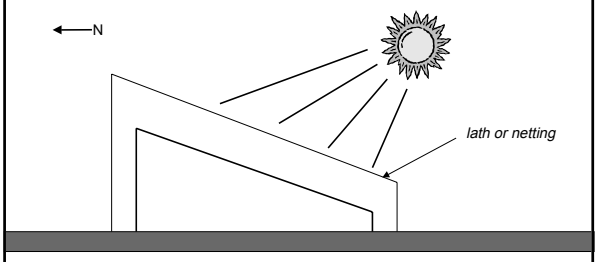
Extending the Growing Season Using Cold Frames or Hot Beds

Why Use Them?

Commonly used to harden off plants grown in a greenhouse

Can also be used to produce cool season vegetable transplants

Basic Anatomy of a Cold Frame



Building Materials Needed

Wood (no creosote or pentachlorophenol treated lumber)
Strong sturdy sashes (plastic, glass, lexane)
Simple system for draping lath or netting if needed

Key Points when Considering a Cold Frame

Does not require any outside energy source

Underground heating cables significantly improves performance (Hot Bed)

Locate in an area with good drainage

Protect from excessive winds (personal experience)

Provide ventilation if outside temperatures exceed 45 F

Installing Heating Cables to Make a Hot Bed

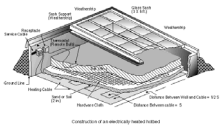
Dig out an area 8 - 9" deep

Lay cable in 6 - 8" loops being careful not to cross over

Cover with 2" of sand

Lay down hardware cloth to protect from damage

Cover with another 4 - 6" of soil



Row Covers

Mulches

Key Benefits

? trap solar radiation and soil moisture

? lightweight and reusable

? can ventilate during day

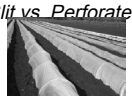
? can heat during night

? protect against insects (But…)

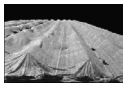
Row Covers

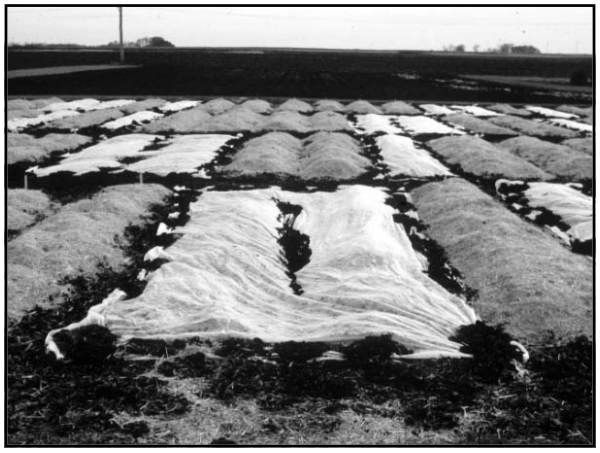
supported *vs.* **Floating**

Hoops required
Removal is time critical
Polyethylene fabric
(Slit vs. Perforated)



Crop supported
Raises with crop
Spunbonded





Row Covers

Caution!

Application is crop dependent ! !

VS.

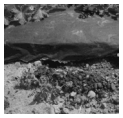
Mulches

Principally used to increase soil temperature and provide weed control

Black plastic is the predominant material used in the U.S.

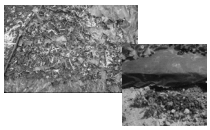
Clear plastic is superior in soil warming capabilities however, herbicides are required for weed control

Paper mulches continue to develop



Mulches

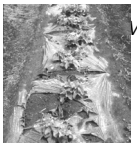
RETRIEVABLE	vs.	DEGRADABLE
High labor requirements		*Low labor requirements*
Reusable		*Disposable*
Special equipment needed		*No equipment needed*
Disposal problem		*Environment friendly*
		Calibration concerns

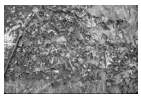


Mulches

Types of Degradability

Photodegradable	Biodegradable
UV light	*Microbe activity*
Unpredictable	*Slow process*
Crop dependent	
Residual degradation products	
Covered edges don't degrade	

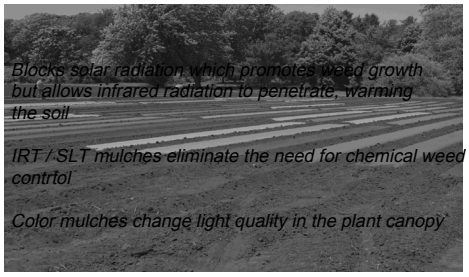




Newer Mulches

IRT (Infrared Radiation Transmitting)
SLT (Selective Light Transmission)

Colored Mulches



Blocks solar radiation which promotes weed growth but allows infrared radiation to penetrate, warming the soil

IRT / SLT mulches eliminate the need for chemical weed contrtol

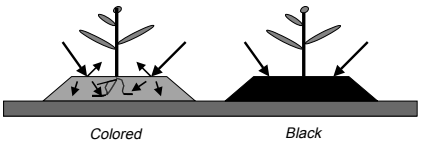
Color mulches change light quality in the plant canopy

Cucumbers on Green IRT Mulch

Watermelon on Green IRT Mulch

Peppers on Green IRT Mulch

How Are Colored Mulches Different?



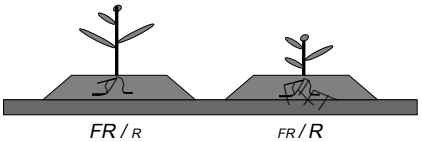
What is the Mechanism?

$$Pr \underset{\text{Far Red}}{\overset{\text{Red}}{\rightleftharpoons}} Pfr$$

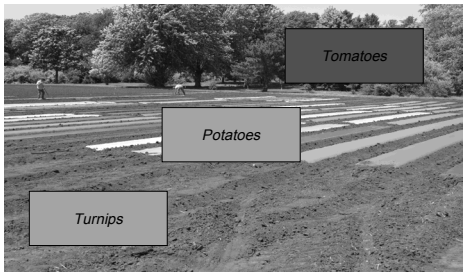
"Phytochrome"

How Are Colored Mulches Different?

How does phytochrome impact plant growth?



Future of Colored Mulches



Asparagus (Asparagus officinalis)

- A perennial crop
- Planted through either transplants or 1-2 yr. old crowns
- Can continue to produce for 15yrs. and longer provided it is well cared for

Establishing the Planting

- Choose a site with good drainage and full sun
- Dig a trench 12-18" deep, trenches 4-5' apart
- Enrich top soil with composted manure, etc.
- Refill trench with 2" of enriched top soil
- Space crowns 18" apart with crown slightly elevated above the remaining root system

Establishing the Planting

- Cover crowns with 2" soil
- As plants grow, continue to add soil over the crowns (Why?)
- Weed the planting in early spring to avoid damage to any emerging spears
- Refrain from harvesting until the third year of production (Why?)

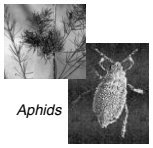
Harvesting Guidelines

- In first year, harvest for only ~4 weeks (Why?)
- Wait an additional year if transplants were used
- Once 4yrs. old, the typical harvest lasts 6-8 weeks
- Snap, don't cut the spears just below the soil surface when they are 6-8" tall

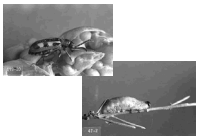
Postharvest Care

- Promote excellent fern growth
- Monitor for insect problems
- Cut the fern down when it yellows, before the berries fall off, creating a "perennial" weed problem
- Mulch with leaves, compost, etc.

Monitor for:



Aphids



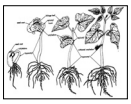
Asparagus Beetle

Fusarium 'Dieback'

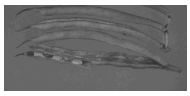
Beans (Phaseolus vulgaris)

- Bush snap bean is the most common garden type (green, wax, purple, etc.)
- Romano types are very desirable to the home gardener
- Other types of "beans" include scarlet runner and yard long beans

Growing and Harvesting

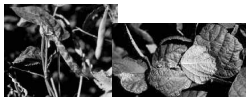


- After planting, avoid soil crusting
- Keep maturing pods off of soil surface to avoid mold problems
- Harvest before the "meat" between seeds becomes white and cottony in appearance



Monitor for:

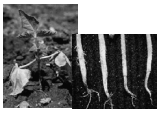
White Mold



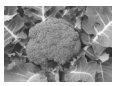
Bacterial Brown Spot

Rhizoctonia

Fusarium



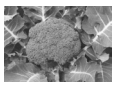
Pythium



Cole Crops (Brassica oleracea)

(cabbage, broccoli, cauliflower, Brussels sprouts)

- Cool season crops
- Require timely nitrogen feedings for sustained growth
- Rooting system is often shallow and fibrous
- Sensitive to soil moisture fluctuations especially when plants are small



Broccoli (Brassica oleracea var. italica)

Growing and Harvesting

- Use of transplants is the best method to establish the planting
- Seedlings 3-4 weeks old are transplanted 18 and 30" apart, within and between rows, respectively
- Due to the shallow and fibrous root system, extreme care should be taken when cultivating
- Harvest the head before it begins to get loose and flower buds swell or turn yellow

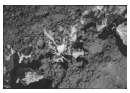
Cabbage (Brassica oleracea var. capitata)

- Use transplants to establish planting
- Seedlings 3-4 weeks old are transplanted 15-18" and 30" apart, within and between rows, respectively
- Heads are harvested when they are firm

Caution! - Watch out for cracking or splitting heads which occurs from excessive water uptake near maturity

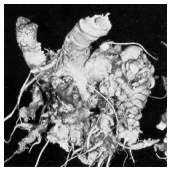
Cauliflower (Brassica oleracea var.botrytis)

- Establish through the use of transplants
- Space seedlings similar to other cole crops
- Once curd formation has begun, blanching is necessary to produce the white curd
- Some self-blanching varieties are available



Caution! – Watch out for small curd formation called "buttoning" , brought on by stress

Monitor for:

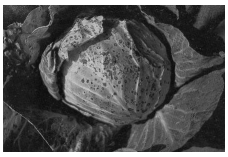


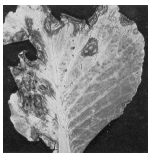
Club Root

Downy Mildew

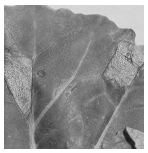
Fusarium Yellows

Monitor for:



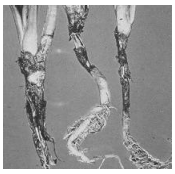


Alternaria Spot

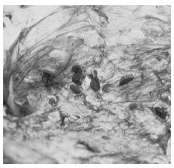


Black Leg

Monitor for:



Rhizoctonia (damping off)

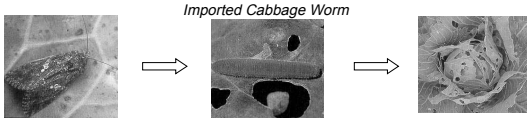


Sclerotinia (white mold/rot)

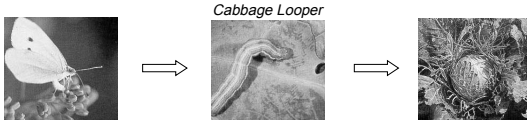
Monitor for:

Diamondback Moth

Imported Cabbage Worm

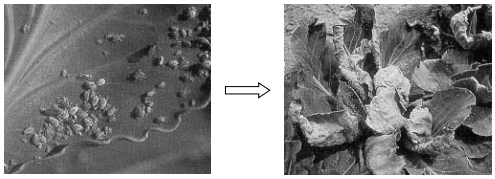


Cabbage Looper

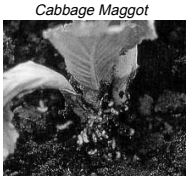


Monitor for:

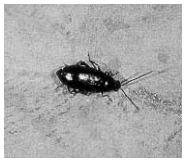
Cabbage Aphid



Cabbage Maggot



Flea Beetle



Sweet Corn (*Zea mays* var. rugosa)

- *Three main genetic types*
- *Isolation requirements are essential to maintain quality for some genetic types*
- *Plant in multiple rows instead of single, long rows for better pollination*
- *Some varieties do not do well in cold spring soils*

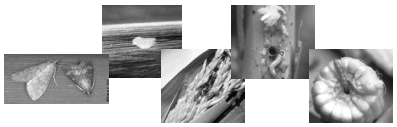
Growing and Harvesting

- *Isolation is critical to maintaining sweet corn quality (accomplished by space or time)*
- *Establish by direct seeding*
- *Plant seed in furrow 8-9" apart and in 30" rows*
- *Can be transplanted*
- *"Supersweet" varieties will not perform well if planted too early in the spring (soil temps. <55ºF)*
- *Use a successive planting strategy to ensure a constant harvest (approx. every 3-4 leaf stage)*

Growing and Harvesting

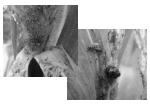
- *Maintain at least 250ft. between supersweet varieties from other sweet corn genotypes or field corn*
- *About 3 weeks difference in projected harvest is also effective in preventing cross pollination*
- *Ready to harvest at about 21 days after silking and tasseling (thumb nail test)*
- *Protect quality by rapid cooling after harvest (Why?)*

Monitor for:



European Corn Borer

Corn Earworm



Aphids

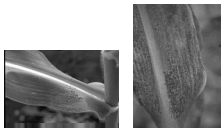
Monitor for:

Redwinged Blackbirds

Raccoons

Monitor for:

Common Smut



Common Rust

Caution! – Poor tip fill can be due to poor pollination brought on by silk clipping, planting too close, poor fertility, and weather

Lodging

Tomatoes (*Lycopersicon esculentum*)

- *Most popular vegetable in the garden*
- *Each plant can yield up to 15 lbs. of fruit*
- *Types and sizes are endless and can be either determinate or indeterminate in growth pattern*
- *Great for containerized gardening*

- *Self pollinated (very efficient)*
- *Spontaneous mutations have produced a variety of colors*

Growing and Harvesting

- *Establish planting using transplants*
- *Avoid producing spindly plants (What causes this?)*
- *Harden off the transplants for about 2 weeks (How?)*
- *Plants should be 6-7 weeks old when placed in the garden (after danger of frost)*

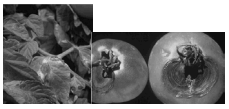
- *Plant seedlings deep so they are well covered by the soil (roots will be produced along the buried stem)*
- *With peat pot transplants – tear one side of the pot to encourage root growth*

Growing and Harvesting

- *Space staked or trellised plants 24" apart in rows 3 ft. apart (reduces fruit rot)*
- *Prune staked plants to 1 or 2 main stems*
- *Remove other suckers*

- *Cages also work well*
- *Ventilation between plants is important (Why?)*
- *Harvest when vine-ripe and before cracking*
- *Leave pedicel on fruit (Why?)*

Monitor for:

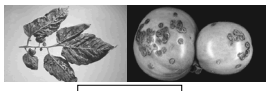


Early Blight

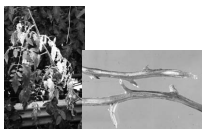
Verticillium

Late Blight

Monitor for:

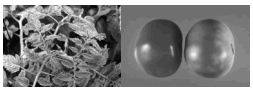


Bacterial Spot



Fusarium Wilt

Bacterial Speck



Tobacco Masaic Virus

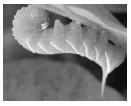
Monitor for:

Aphids

Whiteflies

Colorado Potato Beetle

Flea Beetle



Hornworm

Watch for:

Blossom End Rot

Sunscald

Walnut Wilt

Fruit Cracking

Potatoes (Solanum tuberosum)

- White, yellow, red, and purple varieties
- Russets, white, and yellow flesh
- Grow for either a new crop or a full season storage crop
- Vegetatively grown
- Stores well

Growing and Harvesting

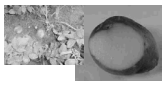
- Establish planting with seed pieces (2 oz.)
- Use only certified seed (Why?)
- Seed potatoes should be firm and not yet sprouted and have at least 1 eye
- Plant in furrows cut side down, 3-5" deep 8-9" apart in rows spaced ~36" apart
- Build soil around plants as you cultivate to protect future tubers from sun exposure

Growing and Harvesting

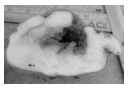
- Harvest when most tubers have reached 2" in diameter
- Remove the vines and allow to set 1-2 weeks for skin set to be completed (bruising will also be reduced)
- After harvest, heal (suberize) potatoes by storing at a minimum of 50ºF for 2-3 weeks
- Afterwards, store at 40ºF

Growing and Harvesting

Cautions!



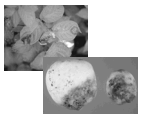
- Green skin is due to sun exposure
- Hollow heart is due to soil moisture fluctuations
- Black walnut wilt



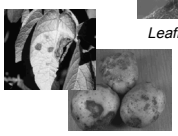
Monitor for:

Colorado Potato Beetle

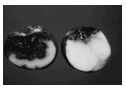
Leafhoppers



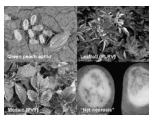
Late Blight



Early Blight



Soft Rot



Viruses

Flea Beetle

Wilts

Eggplant (Solanum melongena)

- Warm season vegetable
- Many types
- Prime candidate for plastic mulch and row covers

Caution! – Poor fruit set is due to high temperatures during flowering and dry conditions

Growing and Harvesting

- Establish planting using transplants
- Seedlings should be 8-10 weeks old
- Effective hardening of the plants is crucial
- Plant 15-18" apart in 30" rows
- Pinch main growing point when 6-8" tall to encourage branching (if not trellised)
- Harvest when fruit is 8-9" long and glossy

Peppers (Capsicum annuum)

- Endless number of types and colors
- Warm season crop
- Effective "hardening" period is crucial in establishment
- Very slow seed germination rate

Growing and Harvesting

- Establish planting using transplants
- Seedlings should be 7-8 weeks old
- Plant 15-18" apart within the rows spaced 30" apart
- Production could be enhance with plastic mulch and row cover systems
- Harvest as either immature or mature fruit

Caution! – Blossom end rot can be due to soil moisture fluctuations, high night temperatures, and excessive fruit set

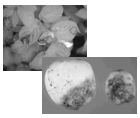
Melons (Cucumis melo)

- Warm season crop
- Muskmelon, cantaloupe, watermelon, honeydew, etc.
- Monoecious flowering habit
- Requires "pollinators" for effective fruit set

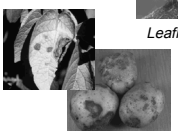
Monitor for:

Colorado Potato Beetle

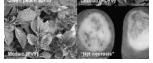
Leafhoppers



Late Blight



Early Blight



Soft Rot

Viruses

Flea Beetle

Wilts

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- Warm season crop
- Muskmelon, cantaloupe, watermelon, honeydew, etc.
- Monoecious flowering habit
- Requires "pollinators" for effective fruit set

Growing and Harvesting

- Establish planting using transplants
- Transplants 2-3 seedlings into hills spaced 2-3 feet apart in rows 5 feet apart
- Yield potential is improved on plastic mulch and fruit remain clean
- Can be trellised but each fruit should be supported
- Keep the belly of the fruit from becoming wet for extended periods (boards, plastic, trellising, straw, etc.)

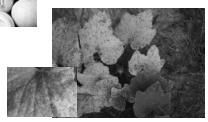
Growing and Harvesting

- Fruit quality is maximized at "full slip"

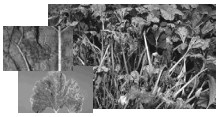
- After harvest, plunge the fruit into cold water and store at 40ºF from 4-10 days

Monitor for:

Fusarium Wilt

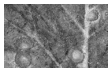


Powdery Mildew

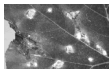


Downy Mildew

Bacterial Wilt and the Spotted and Striped Cucumber Beetles



Alternaria Leaf Spot



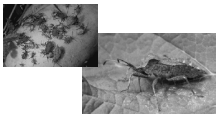
Angular Leaf Spot

Monitor for:

Flea Beetles

Cucumber Beetles

Vine Borer



Squash Bug

Onions *(Allium cepa)*

- Yellow, white, and red colors
- Pungent and sweet types, green onions
- Bulbing is initiated by daylength
- Shallow rooted
- Candidate for raised beds and broadcast seeding

Growing and Harvesting

- Establish planting by direct seeding , the use of sets, or transplants

- Plant 12 seeds per foot in rows spaced 12-14" apart
- Protect from 'blow out' (What is this?)
- Plant sets 1-2" apart in rows 1-2" deep
- Planting sets too early in the spring will cause bolting to occur

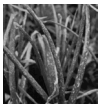
Growing and Harvesting

- *Use only 'long day' varieties!*
- *Harvest when 2/3 of the tops have fallen*
- *'Curing' is essential to long term quality storage (What is this?)*
- *Sweet varieties do not store as well as pungent varieties*

Caution! – Split or double bulbing is due to dry conditions
Small bulbs are due to planting too close or too late

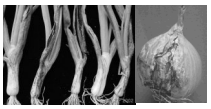
Monitor for:

Alternaria Purple Blotch

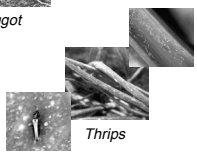


Botrytis

Onion Maggot



Smut



Thrips

Squash and Pumpkin

(Cucurbita sp.)

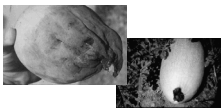
- *Warm season vegetable crops*
- *'Winter' varieties and types are numerous*
- *Many 'summer' varieties and types*
- *Monoecious flowering habit*
- *Requires pollinators*

Growing and Harvesting

- *Establish planting using transplants*
- *Seedling age should be 3-4 weeks old*
- *Older seedlings that are hardened off will not transplant well and growth will slow*
- *Plastic mulches are commonly used*
- *Plant in a area sheltered from wind*
- *Squash store easily in cool areas / protect from frost*

Growing and Harvesting

- *Flower drop due to heavy fruit set (or male flowers)*
- *Blossom end rot due to soil moisture fluctuations*



Cucumbers *(Cucumis sativus)*

- *Warm season vegetable*
- *Monoecious flowering habit*
- *Slicers and picklers*

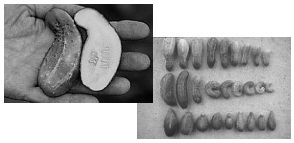
- *Parthenocarpic and gynoecious varieties*
- *Performs well on plastic mulch*
- *Sandy soils work very well*
- *Spreading plant growth habit however some bush types are available*

Growing and Harvesting

- Establish planting by direct seeding
- Plant seeds and later thin to 9-12" apart when seedlings are 5" tall
- If trellised, plant 4-5 seeds per foot in rows spaced 30" apart
- Responds well to plastic mulch systems
- Due to "apical dominance", multiple harvests maximize yield potential (What is this?)

Growing and Harvesting

- Misshapen fruit due to low fertility, poor pollination, and big fluctuations in temperature



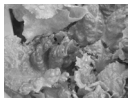
Lettuce (Lactuca sativa)

- Cool season crop
- Many types (bibb, romaine, leaf, etc.)
- Easy to grow
- Bolts in high temperatures
- Head types are difficult to grow due to heat stress
- Practice succession planting for continued harvest

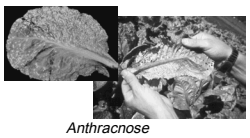
Growing and Harvesting

- Establish through direct seeding (can transplant)
- Plant 10-20 seeds per foot in rows spaced 8-12" apart, later, thin seedlings to 4-8" apart
- Candidate for raised beds and broadcast seeding
- Use frequent and light waterings
- Use other crops to shade during heat of the day

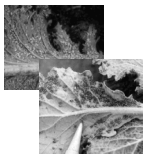
Caution! – Tip burn is due to variation in soil moisture, onset of bolting, and high temperatures



Monitor for:



Anthracnose



Aphids

Sclerotinia

Botrytis (Gray Mold)

Stem and Leaf Rots

Cole Slaw Anyone??

?s ?s

?s ?s

appendix

5

fruits

Growing Fruit in Minnesota Home Gardens

2002 Version

Instructor: Doug S. Foulk

Site Selection and Preparation

- Gentle slope allows air drainage
- Valleys are frost pockets
- Hilltops are too windy
- Eastern exposure good for drying foliage
- Southern exposure allows quick start
- Northern exposure delays bloom in spring
- Full sun is a must!
- Prepare soil the year before planting
- Remove sod/Control perennial weeds
- Test soil
- Adjust pH, usually 5.5 to 7
- Add organic matter
- Add N, P, K if necessary

Strawberries

Three *Strawberry* Types

- Junebearing: One large, concentrated crop
  - ***Earliglow, Mesabi, Winona***
- Everbearing: Two crops—spring & fall
  - ***Ft. Laramie, Ogallala***
- Day-neutral: Nearly continuous crop
  - ***Tribute, Tristar***

Planting *Strawberries*

- Site:
  - Good soil drainage
  - pH 5.3-6.5 optimum, 5-7 acceptable
- Purchase virus-indexed plants
- Plant in early spring
- Keep dormant stock moist until planted
- Plant placing ? crown above soil line.

Spacing Systems

- Matted Row
  - plants set in 18-24” apart
  - space rows 3-4’ apart
  - rows end up 12-24” wide
  - allow rows to fill in with runners
- Spaced Matted Row
  - Same as above, except…
  - maintain **6” spacing** between all daughter plants

- Hill System
  - for day-neutrals
  - plants set 6-12” apart
  - single, double or triple rows
  - all runners removed

Winter Mulch

- Crown can be damaged at temperatures colder than 20ºF…*above* zero!
- Serious damage is likely at temperatures colder than 15ºF.
- Flowering is reduced in winter-damaged plants.
- Apply mulch in late fall after a few frosts, or when low temperatures near **20ºF**.
- Use 4-6” straw, chopped leaves, pine needles, etc. 2-3” wood chips work well.
- Apply mulch over early snow, if necessary.

Removing Winter Mulch

- Remove mulch in spring when new growth can be seen.
- Leave mulch around plants to cool soil and protect fruit.
- If cold weather returns, recover plants with mulch or rowcover material.

Renovation

- **Why?**
  - Reduces runnering and helps maintain optimum plant density.
  - Controls row width.
  - Can be used to control foliar diseases.
- **When?**
  - Within 2 weeks after harvest is completed.

Steps in Renovation

1. Remove all foliage.
2. Narrow the bed width to 6-12”.
3. Fertilize the planting: 3/4-lb ammonium nitrate (33-0-0) per 100 feet of row.

What causes button berry?
Tarnished Plant Bug

- Monitor in spring ***as buds form*** using a white paper plate…
  - Threshold: > 5 nymphs/5-10 clusters.
  - Pesticide of choice: Malathion.
  - Spray ***before*** 10% bloom and/or after petal fall
  - Avoid mowing near bloomtime.

What’s leaving holes in the fruit?
Slugs & Their Control

- Improve air circulation at ground level:
  - Avoid mulch?
  - Remove all weeds
- Iron Phosphate Product
  - Slug-go
  - Escar-go
- Slug traps, eggshells, other home remedies are of variable effectiveness.

What's making my fruit rot?
Gray Mold Prevention

- Keep the leaves, flowers, and fruit dry:
  - Plant in full sun in well-drained soil or in a raised bed.
  - Keep plants well spaced and rows narrow.
  - Control weeds.
  - Water early in the day and/or use drip irrigation.
  - Remove all leaves and fruit at renovation; dispose or till into the soil.

What's making my fruit rot? Pt. 2
Leather Rot Prevention

- Mulch
- Sanitation
- Well-drained, uncompacted soil
- Narrow rows, good spacing

Strawberry Harvest & Storage

- Pick berries that are red to the tip.
- Pick with cap & stem on fruit and place in a shallow container.
- Store lightly covered in refrigerator; do not wash until ready to use or process.

For More Information

- FO-5625, ***Strawberries for the Home Garden***
- FS-1148, ***Strawberry Diseases***
- FO-0675, ***Home Fruit Spray Guide***

Raspberries

- Three types grown in MN:
  - *Rubus ideaus* (Red/Yellow)
  - *R. occidentalis* (Black)
  - *R. ideaus* x *R. occidentalis* (Purple)

- Two fruiting types:
  - Summerbearing (Floricane-Fruiting)
    - ▲ Includes Red, Purple and Black cultivars
  - Fallbearing (Everbearing or Primocane-Fruiting)
    - ▲ Includes Red and Yellow cultivars

Site Selection for Raspberries

- pH 5.5-7.5 (6.0-6.8 is optimal)
- Well-drained soil or raised bed
- Full sun, but sheltered from direct winds
- **Summerbearing** types benefit from a **later** spring warm-up
- **Fallbearing** types benefit from an **earlier** spring warm-up

Planting Systems for *Raspberries*: HEDGEROWS

- Red or Yellow: 2-3' apart in rows 6-8' apart
- Maintain 12-15" row width

Planting Systems for *Raspberries*: HILLS

- Plant 4-5' apart in each direction
- (Optional) Set a stake at planting time in the 'center' of each 'hill'
- Maintain each hill at a 1' diameter

Planting *Raspberries*

- prune canes to 8" if necessary
- set plants w/ growing point just below soil surface
- Fertilize w/ nitrogen only (ammonium nitrate, urea) when growth begins: 1/4 cup in 18" band around each plant
- When: as early as the soil can be worked
  - Earlier planting = more/larger primocanes in 1st year
- Purchase virus-indexed plants

Trellising *Raspberries*

- Advantages:
  - Minimizes wind damage
  - Improves light penetration & air circulation
  - Makes harvest easier

Renovating *Raspberries*

- For **Summerbearing Red Raspberries**:
  - Remove spent canes after crop is produced
  - Remove any weak or broken primocanes.
- For **Fallbearing Red Raspberries**:
  - For **summer AND fall crops**: same as for summerbearing red raspberries.
  - **For a large fall crop ONLY**: prune all canes at ground level in late winter/early spring.

What's wrong with my plants?
Fungal Cane Diseases

- Anthracnose
- Spur Blight/Cane Blight
- Prune annually
  - prune at least 3 days before anticipated rain
  - remove or destroy all prunings
- Apply lime sulfur in spring before leaves are 1/2 inch long.
  - 1 1/3 cups per gallon water

What's wrong with my plants?
Viruses

- A **virus** can cause:
  - stunting
  - yellow, crinkled or twisted leaves
  - crumbly berries
  - symptoms that show up mid-season or later
- Virus-infect plantings must be removed.

Why are there bugs in my berries? Picnic Beetles

- Also known as sap beetles
- Will attack other crops, including strawberries
- Attracted to overripe fruit
- Sanitation is best defense

What are these white patches? Heat Injury

- Caused by hot, sunny weather
- Causes drupelets to turn white/off-white

Raspberry Harvest & Storage

- Ripe fruit separates easily from the plant.
- Fruit is delicate: handle gently, place in shallow containers and refrigerate immediately.

For More Information

- FS-1108, ***Raspberries for the Home Garden***
- FS-1152, ***Raspberry Diseases***

Grapes in Minnesota

- 2 Types Grown:
  - French Hybrid Types
    - vinifera X American types
    - Most require winter protection
    - For wine
    - Hardiest Cultivars:
      - Kay Gray
      - St. Croix
      - Frontenac
  - American Types
    - V. labrusca in parentage
    - For table or juice
    - Hardiest Cultivars:
      - Beta
      - Bluebell
      - Worden
      - Valiant

Site Selection for *Grapes*

- Grapes want SUN & WARMTH
  - South, SE, or SW slope
  - South side of a structure
  - Sandy to loamy soil
- Soil pH should be 6-7
- Avoid:
  - North-facing slopes
  - Low-lying areas
  - Poorly drained soils
  - Areas near 2,4-D use

Training Systems for *Grapes*

- J System
  - For cultivars that require winter protection.
- 4 Arm Kniffen
  - For cultivars hardy enough to be left on the trellis over winter.

Training Hardy *Grapes*

- First Year
  - Prune newly planted vines to 2-3 buds.
  - Train canes to grow upward.
- 2nd Year
  - Install trellis (if not already installed) before growth begins.
  - Choose strongest cane for trunk.
  - Allow vine to grow past top of trellis; prune just above this point when >1/4" in diameter.
- 2nd Fall or Late Winter
  - Entirely remove any canes not being kept.
  - Prune remaining canes to 2 buds each.
- Thereafter
  - Prune each fall or late winter to leave 4 canes
    - 5-7 (wine) or 10-15 (table) buds per cane
  - Also leave 4 renewal spurs at pruning

What's wrong? Black Rot

- Infects shoots, tendrils, petioles, new leaves, and berries
- Berries turn brown, shrivel, turn black, & become covered with pycnidia
- American types generally more resistant
- Sanitation
- Fungicides from 4-6" stage to color change

What's this mold? Mildews

- 2 Types: Powdery & Downy
- D.M. a problem in wet weather; P.M. when warm & humid.
- American types generally more resistant
- Improve air circulation
- Fungicides

Grape Harvest

- Rely on your taste buds
- Use pruners to harvest
- Store fruit in vented plastic bags in refrigerator
- Do not wash fruit until ready to use

For More Information

- FO-1103, ***Growing Grapes for Home Use***
- ***Growing Grapes in Minnesota***, available from the Minnesota Grape Growers Association. Info: http://mngrapes.com/
- BU-7090, ***Small Fruits: Insect & Disease Management for Backyard Fruit Growers in the Midwest***

Blueberries

- Two commercial species found in NE U.S.:
  - Highbush (*Vaccinium corymbosum*)
  - Lowbush (*V. angustifolium*)
- And when you cross the two species, you get...

Half-high *Blueberries*

- U of M Cultivars:
  - Northblue
  - Northsky
  - Northcountry
  - St. Cloud
  - Polaris
  - Chippewa
- Non-U of M:
  - Patriot
  - Bluetta

Site Preparation for *Blueberries*

- Acid soil is required! pH 4.0-5.0 is optimum
  - Acidify soil the year before planting
  - Amend soils with a pH of 5.5-7.0 with:
    - acid peat
    - elemental sulfur
    - iron sulfate (apply at 6 times the rate of elemental sulfur; use no more than 9 lbs/100 sq. ft. per application)
- If pH is >7, acidify in stages

Planting *Blueberries*

- Planting two or more cultivars results in:
  - Larger berries
  - Greater number of berries
  - Earlier harvest
  - More uniform ripening
- Spacing:
  - 2-3 feet for hedge
  - 4 feet for max fruit
- Apply mulch

Basic Care for *Blueberries*

- Fertilize annually in spring
  - 1st 3 years: 2 oz. (1/4 cup) ammonium sulfate per plant
  - Thereafter: 4 oz. (1/2 cup) per plant
- Frequent, shallow irrigation
- Winter protection is beneficial
  - snow
  - 1/4" bird netting
- Bird netting also may be necessary to protect your harvest

Pruning *Blueberries*

- First 5 Years:
  - remove dead/damaged wood only
- Thereafter:
  - remove oldest wood annually

Blueberry Harvest & Storage

- Fruit will not ripen all at once.
- Hold the fruit cluster in your hand and gently roll your thumb over the berries.
- Blueberries may be placed in deep containers.

For More Information

- FS-3463, ***Blueberries for Home Landscapes***

Currants & Gooseberries

- Half-day sun tolerant
- Tolerates wide pH range
- Prefers later spring warm-up
- Prefers moist, well-drained soils
- But what about white pine blister rust?
  - European black currants & wild gooseberries are main hosts
  - Still…U of Wisconsin recommends staying 1000 feet from white pines or wild currants/gooseberries!

Planting *Currants & Gooseberries*

- Space at least 3 feet apart in rows at least 6 feet apart
- Plant deeply: cover 2-3 buds of lower canes
- Provide 2-4 inches of mulch at planting

Caring for *Currants & Gooseberries*

- Provide N annually (1/8-1/4 cup ammonium nitrate per plant)
- Prune in early spring
  - 1, 2 & 3 year-old plants: Keep 4-5 most vigorous new canes each year; remove only weak & damaged wood.
  - Thereafter: Prune out oldest wood & weakest wood to maintain 9-12 canes of 1-3 year old wood.

Disease Control for *Currants & Gooseberries*

- Anthracnose & Septoria Leaf Spot
  - Sanitation—remove all fallen leaves
- Powdery Mildew
  - maintain good air circulation
  - apply sulfur fungicide if necessary

For More Information

- FS-1122, ***Currants and Gooseberries in the Home Garden***
- A1960***, Growing Currants, Gooseberries & Elderberries in Wisconsin***; available at: http://www.uwex.edu/ces/pubs/berricat.html

Apples

- Use "Apples for Minnesota" to get started
- Consider:
  - Intended Use
  - Flavor Preference
  - Disease Resistance
  - Season of Ripening
- Two different cultivars necessary
  - 2nd tree within 100 feet

Cultivars

- Oriole (unknown parentage, 1949)
  - Mid-August
  - Fine fresh, great flavor in pies
  - Stores a couple of weeks
- State Fair (Mantet X Oriole, 1978)
  - Mid-late August
  - Crisp and juicy
  - Classic "apple" flavor
  - Stores 2-4 weeks
- Zesta (State Fair X MN 1691, 1998)
  - Late August
  - Great sugar-acid balance; tops in many taste pan• els
  - Moderately resistant to fireblight
  - Stores nearly 2 months
- Chestnut Crab (Malinda O.P., 1946)
  - Early September
  - Crispy, highly flavored
  - A good kid-sized apple
  - Russet is part of normal appearance
  - Resistant to cedar-apple rust
  - Stores a few weeks
- Sweet Sixteen (MN 447 X N. Spy, 1978)
  - Mid-late September
  - Large and sweet
  - Very aromatic, with cherry/bubblegum notes
  - Somewhat resistant to fireblight
  - Stores about 1 month
- Honeycrisp (Macoun X Honeygold, 1990)
  - Late September
  - Well-balanced, aromatic
  - Juicy, uniquely crisp texture
  - Stores up to 6 months
- Honeygold (Golden Del. X Haralson,'72)
  - Sweet, well-balanced flavor
  - One of the best all-purpose apples
  - Stores 3 months
  - Resistant to cedar-apple rust
  - Keepsake (MN 447 X N. Spy, 1979)
  - Mid-October
  - Very aromatic
  - Light yellow, firm, crisp flesh
  - Flavor mellows in storage
  - Somewhat resistant to fireblight and cedar-apple rust
  - Stores up to 5-6 months
- Liberty
  - Late Sept.-early Oct.
  - Coarse, crisp, juicy texture
  - Fine, mild flavor
  - Stores up to 2 months
  - Resistant to apple scab!
  - Also try: William's Pride

Rootstock Selection

- Why dwarfing rootstocks?
  - Take up less space
  - Easier to manage pests
  - Bear fruit earlier
  - No ladders
  - Can plant multiple cultivars
- M26 a good, hardy choice; Avoid M7.
- Also:
  - P 22
  - Bud 9

Planting

- If bare-root: keep cool & moist until planted; soak roots 4-8 hours before planting.
- If potted: At planting, spread the roots or make several vertical cuts through roots.
- Why we still plant apple trees deeply:
  - root suckering
  - burr knots
  - anchorage
- Therefore: the graft union should be 2-3 inches above the soil line.
- Do NOT add fertilizer at planting time!

Planting: *Staking*

- M7 or larger does not require staking.
- M26: stake for 3-5 years (can use shorter stake).
- M9, Bud 9, P22: stake for the life of the tree.
- Suitable materials:
  - 3/4" conduit
  - 2x2" lumber
- To secure the tree, use:
  - tape
  - fabric strips

Planting: Mulch

- Prevents rootzone competition until established
- A Method to Try: 2-ring mulch donut
  - inner ring: pea gravel (2-3' diam.)
  - outer ring: rotted hay, wood chips, etc. (at least to dripline)

Pruning and Training at Planting

- If **unbranched**, prune trunk to 30-40" tall.
- Ensure that branch angles of newly-developing scaffold branches are wide enough.
- If **branched**, leave desirable branches.
- Do not tip branches.

- You want 4-5 branches spaced evenly around the tree.
- If branches are poorly spaced, remove them and prune as for an unbranched tree.
- If a branch is well placed, but has a narrow branch angle, use a **spreader** to widen the angle.

Mineral Nutrition

- Fertilize annually with N-containing fertilizer.
- Apply liquid fertilizer to mulched trees.
- Rule of thumb: Apply 1 oz. actual N for each year of tree age *not to exceed 16 oz.*
- Be sure to include lawn fertilizers in your annual calculations!
- To calculate the amount of fertilizer to apply: Divide **actual N needed** by the **%N in the fertilizer**.
- Example for 3-year old tree:
  - Ammonium Nitrate: 33-0-0
  - 3 oz/ .33 = 9 oz.
  - Therefore, apply 9 oz. ammonium nitrate!
- Shoot growth on **nonbearing** trees: 12-18”
- Shoot growth on **bearing** trees: 8-12”
- If growth is *less*: increase N by 25%.
- If growth is *more*: withhold N for one year.

Training and Pruning

- The primary goal of training and pruning an apple tree is to **maximize light penetration to as much of the tree as possible.**

***General Rules of* Pruning**

- Prune apple trees annually, in mid-late winter—just before bud break is the optimum time.
- Suckers are best removed in late summer—they are less likely to quickly regrow.
- Watersprouts may be removed throughout the summer if dry weather is forecast.
- Prune young trees to develop a strong structure, bearing trees to maintain continuous production.
- **Heading** cuts result in vigorous vegetative growth, delay fruiting and increase shading problems!
- **Thinning** cuts are preferable to **heading** cuts!

***First Dormant* Pruning**

- If the tree was **unbranched** at planting: Select 4-5 properly spaced branches.
- If the tree was **branched** at planting: Select second set of “scaffold” branches.

Once scaffold branches have been selected...

- Remove:
  - Dead or broken branches
  - Suckers
  - Watersprouts
  - Downward-growing branches and spurs
- Thin:
  - Areas with too many twigs, especially toward the top of the tree

Thinning: Another Way to “Prune”

- Why thin fruit?
  - Reduces limb breakage
  - improves size, color, quality
  - prevents biennial bearing
    - ▲Thinning: Another Way to “Prune”
- How?
  - By hand, in 2 stages
  - First thinning: within 40 days of full bloom
    - ▲1 fruit per cluster
  - Second thinning: after June drop
    - ▲thin fruits to 4-8 inches apart

Harvest

- How to tell when ripe?
  - Background color
  - No coating left on teeth
  - Development of aroma
- To harvest:
  - Cradle apple in palm
  - Lift and twist in one motion OR
  - Use two-handed method

Storage

- Cool as soon as possible after harvest.
- Apples store best at 33-34° and >80% humidity.
- In refrigerator, store in loosely covered container OR plastic bag with holes.
- Large amounts benefit from non-frost free unit.

What’s wrong with this apple?

- Damage:
  - Infested fruit can be recognized by the shrunken, discolored dimples
  - Interior has brown “tracks”

Answer: Apple Maggot

- Description:
  - 2/3 size of common housefly
  - Wings/body have black/white bands
  - Larvae are headless, legless cream-colored maggots 1/3” long when full-grown
  - Adults emerge around July 1st, feed briefly, then mate in early July. Adults continue to emerge through September, especially after ?” or more rain or irrigation.
- Control and Management:
  - Method 1: Apply carbaryl, phosmet or diazinon July 1st, then at least twice more according to label directions.
  - Method 2: Hang a red sphere treated with Tangletrap® in the tree and begin spray program only when adult flies are caught.
  - Method 3: Hang 1 treated red sphere per 100 apples and remove dead flies often to maintain a glossy surface. Renew treatment every 2

weeks. *Least effective method*

- Method 4: Bagging. Enclose individual fruits in plastic bags, either regular or Ziploc, around July 1st. Staple the opening securely closed and cut off the bottom corner of bag.

For all methods: Pick up all fallen fruit immediately!

What's wrong with this apple?

Damage: Tunnel from outside of fruit to the core, missing seeds and nearby tissues. Orange sawdust material at calyx end.

Answer: Codling Moth

Description:

- Adult moths have shiny golden-brown wing tips.
- Larvae are creamy white to pinkish with a dark head. They have legs and pro-legs.
- Egg-laying occurs at about petal fall.

Management and Control:

- Apply diazinon or methoxychlor (botanical alt: ryania) at petal fall and once more 7-10 days later.
- Reduce the number of unsprayed apple, pear and hawthorn trees within 100 yards.
- Pick up and dispose of windfalls.
- Clean up brush piles.

What caused these crescent-shaped scars?

Answer:
Plum & Apple Curculios

Description:

- Native pest with many hosts.
- Adult weevils are less than 1/4" long and are gray-brown to dark brown (reddish if A.C.).
- Larvae grow to 1/4" and are pale and grub-like.
- Curculios damage young fruit through feeding and egg-laying.

Control and Management:

- Beginning at petal fall, look for crescent-shaped scars.
- If found, treat with diazinon or methoxychlor twice. The same spray can control both curculio and codling moth.
- Dispose of windfalls ASAP.
- Organic methods: padded stick, chickens.

Why are my apples blackened and cracked?

Answer: Apple Scab, the most serious disease of apples in Minnesota

Infection is dependent upon temperature and continuous leaf wetness:

- at 61-75º: 6 hours
- at 52º: 9 hours
- at 41º: 21 hours
- Daylight is necessary for initiation of infection!

Control and Management:

- Grow 'Liberty!' Otherwise...
- Remove or thoroughly shred all fallen leaves.
- Begin treatment program at "pink" stage or after 3 infection periods, whichever comes first.
- If no lesions are found at the end of June, discontinue sprays.

Control and Management:

- Method 1: ASAP after any infection period, apply captan, thiophanate-methyl or sulfur. Maintain coverage through June, then assess.
- Method 2: Use above fungicides every 7-10 days through June, then assess.

What are these bright yellow lesions?

Answer: Cedar Apple Rust

Control and Management:

- Method 1: Plant 'Liberty,' 'Chestnut Crab' or 'Keepsake.'
- Method 2: Remove all galls on eastern red cedars and junipers near your trees in spring.
- Apply captan or thiophanate-methyl after a rain beginning at 1/2" green tip. Repeat until petal fall.

Why is my apple tree wilting?

Answer: Fire Blight

A problem in warm, wet weather.

Spread by rain and insects.

Can enter through flowers, wounds, and possibly stomata.

Control & Management:

- Plant 'Sweet Sixteen,' 'Zesta' or 'Keepsake.'
- Prune out infected shoots 12" below visible infection; disinfect pruners between cuts in 10% bleach solution.
- Avoid excessive N.

Why are my apples sooty?

Answer: Sooty Blotch/Flyspeck

For More Information:

"Apple Rootstocks: A Primer"
www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Mar0100.html

FO-1111, ***Apples for Minnesota and Their Culinary Uses***

H200A, ***Apple Russeting***

P220A, ***Apple Scab***

P221B, ***Black Rot Canker***

P222C, ***Cedar Apple Rust***

P223F, ***Fire Blight***

P226S, ***Sooty Blotch and Flyspeck on Apple and Pear***

P244A, ***Disease Resistant Apple Varieties***

FS-1007-A, ***Apple Maggot Management in Home Gardens***

appendix

6

Pathology

This article is published on the American Phytophathological Association's Education Center Web page at:
http://www.apsnet.org/education/IntroPlantPath/Topics/plantdisease/top.htm
Please visit the online version of this article to view color photos.

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Plant Disease Diagnosis

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A plant pathologist or a student taking plant pathology is often asked by friends or associates the following questions. What is wrong with my plant; followed by, what can I do to get rid of the problem? It may be too late to help the specific plant when the question is asked, but proper diagnosis may be extremely important in preventing the problem on other plants or in preventing the problem in the future.

How does a plant pathologist or a plant pathology student go about diagnosing plant problems? The diagnostician must have very good observation skills, and s/he also needs to be a good detective. It is important to keep an open mind until all of the facts related to the problem can be collected. The possibility of multiple causal factors must also be considered.

Control measures depend on proper identification of diseases and of the causal agents. Therefore, diagnosis is one of the most important aspects of a plant pathologist's training. Without proper identification of the disease and the disease-causing agent, disease control measures can be a waste of time and money and can lead to further plant losses. Proper disease diagnosis is therefore vital.

Often, plant pathologists have to rely on symptoms for the identification of a disease problem. For example, Dr. Shoe is asked by Ms. Green to examine azaleas in her nursery. When Dr. Shoe gets to the nursery, he observes that the azaleas in Greenhouse 1 are wilted. When he removes plants from their pots, the roots appear to be rotten. Ms. Green wants to know right away what she should do with the azaleas in Greenhouse 2 where no wilting is currently being observed. Dr. Shoe is asked to make recommendations even before he has looked at plants in the second greenhouse. Because similar symptoms can be produced in response to different causal agents, the use of symptoms alone is often an inadequate method for disease identification. The identification of the disease-causing agent may take a week or more. What can Dr. Shoe do for Ms. Green now?

One of the most important things is for Dr. Shoe to use his powers of observation. He needs to ask many questions related to the azalea's care and culture in order to eliminate or identify possible causes of the problem. He also needs to consider various environmental and cultural factors. As a result of his questions and observations he may:

* Be able to identify a disease and disease-causing agent,

* Be able to narrow the problem down to several possibilities which will require further study in the laboratory before he can make a final diagnosis, or

* Be completely baffled by the problem.

Regardless of the outcome, Ms. Green still expects a recommendation as to what she should do now.

This article presents the various steps/activities which are associated with accurate plant disease diagnosis. The process may vary with different diseases and conditions but the overall process is relatively consistent. The steps all require careful observations and questions. The steps include:

Know What is Normal

Proper plant identification. Identification of affected plants is one of the first steps in diagnosing a plant disease. Both scientific and common names of the plant should be noted. Common names should not be relied upon since some distinctly different plant species may have the same common name, and the common name used in one area may be used for a completely different species in another area. The common name "vinca" has been used to describe plants belonging to two different genera, *Vinca*, a perennial, and *Catharanthus*, an annual. Another example is "monkey grass" which is used to describe *Liriope* and *Ophiopogon (mondo grass)*. An example from forestry is "*cedar*" which is used to describe eastern red cedar *(Juniperus)*, western red cedar *(Thuja)*, Port Orford cedar *(Chamaecyparis)*, incense cedar *(Libocedrus)*, and Atlas cedar (*Cedrus*). Obviously the use of common names can cause confusion in identification and recognition of problems.

In addition to knowing the common and scientific names of an affected plant, it is important to know the specific variety or cultivar, whenever possible. A great variation in susceptibility to a specific disease may occur within different cultivars of a plant species. For example, when we look at the susceptibility of wheat to wheat stem rust caused by *Puccinia graminis* f. sp. *tritici*, we know that all wheat cultivars are not susceptible to all races of *P. graminis*. The major control measure for this disease is based on planting wheat cultivars each year that are resistant to the pathogen races that are predicted to be present during the growing season. Tomato cultivars having the "Better Boy" genetic background are generally resistant to root-knot nematodes while those with the genetic background of the variety "Rutgers" are susceptible, so knowing the genetic background of a cultivar can be important. Knowing the cultivar and its susceptibility to various diseases can narrow down the possible disease agents to consider.

Knowing the identity of the plant species affected allows the pathologist to utilize various resources that contain lists of plant diseases associated with specific plants. These lists are very helpful in suggesting possible pathogenic agents. An example of such a list is found on the American Phytopathological Society (APS) web site as a part of its the online resources
(http://www.apsnet.org/online/common/top.asp). Once you select the plant of interest, you will see a list of bacterial, fungal, nematode, parasitic plants and viral diseases associated with the specific plant. *Westcott's Plant Disease Handbook* is useful because specific symptoms are associated with each disease[7]. APS Press has published a list of fungal diseases and hosts[4]. This book followed a previous publication by USDA[12], but the APS Press publication only includes fungal pathogens. The original USDA publication, while now somewhat outdated, included fungal, bacterial, viral and nematode pathogens, as well as physiological problems. Other resources are available which include the APS Press Compendium series on diseases and disorders for specific plant species, such as roses[8] or diseases for specific regions, such as Florida, USA[2]. In some cases these lists of plant diseases may suggest potential disease possibilities or they may lead the diagnostician to rule out other diseases. One factor to keep in mind, however, is that these lists are often incomplete or the disease may be new and unreported on the plant or in a specific region. The best possible option is to utilize several different resources since one may not have a complete index of potential diseases on a specific plant.

Recognize healthy plant appearance. It is important to know the normal appearance of the plant species you are investigating. Each plant species has special growth habits, colors and growth rates. If you do not know what to expect of the plant you cannot recognize when something is wrong. Does the plant normally have new foliage that is yellow or red and becomes darker green as the foliage ages? Many ornamental shrubs have been developed and marketed for the ornamental value of such brightly colored new growth. These plants are highly prized for this coloration; however, if an individual does not know that this coloration is the normal appearance of the plant, s/he may think that the plant is diseased. It is important to know what the normal appearance of a plant is before you decide there is a problem. It is also important to remember that appearance can vary with different cultivars. Some plant cultivars have naturally yellow to pale green leaves (e. g. new hosta cultivars, herbs like golden oregano, and coleus varieties) which at first glance appear to have symptoms of under-fertilization, root stress or soil pH problems.

Once the "normal" appearance of the specific plant is determined, several comparisons can be made between the problem plants and healthy plants. Compare characteristics such as overall size, shape, and coloration; leaf shape, size, coloration, and distribution; root distribution and coloration; and bark, stem or trunk texture and coloration. It is also important to note normal events, such as leaf drop, that may occur in a healthy plant. For example, some holly species normally drop leaves in the spring.

The affected parts of the plants should also be noted. Are there symptoms on the roots, leaves, stems, flowers, or fruit? Is the entire plant involved? Is only one limb or side of a plant involved? Answers to these questions can assist in the identification of the problem.

Check for Symptoms and Signs

Identify characteristic symptoms. Describing the characteristic symptoms exhibited by a specimen can be very difficult to do accurately. Because of this, it is often difficult, if not impossible, to determine what is wrong with a plant when a person is describing symptoms over the phone. As a test of this you may want to take a plant exhibiting symptoms and have three different individuals describe the symptoms that they observe on a sheet of paper. Next, compare the descriptions. Do the descriptions vary significantly? Could you visualize the symptoms by the way any one of the individuals described the diseased plant? Symptoms can often be grouped as follows; for definitions of terms, see the APSnet Education Center Illustrated Glossary (http://www.apsnet.org/education/IllustratedGlossary/top.htm):

* **Underdevelopment of tissues or organs**. Examples include such symptoms as stunting of plants, shortened internodes, inadequate development of roots, malformation of leaves, inadequate production of chlorophyll and other pigments, and failure of fruits and flowers to develop.

* **Overdevelopment of tissues or organs**. Examples include: galls on roots, stems, or leaves, witches' brooms, and profuse flowering.

* **Necrosis or death of plant parts.** These may be some of the most noticeable symptoms, espe cially when they affect the entire plant, such as wilts or diebacks. Other examples include shoot or leaf blights, leaf spots, and fruit rots.

* **Alteration of normal appearance.** Examples include mosaic patterns of light and dark green on leaves, and altered coloration in leaves and flowers.

Diseases also involve a progression of symptoms that can vary significantly. The progression of symptoms is one of the most important characteristics associated with problems caused by biotic agents. Diseases can result in primary and secondary symptoms. For example, decayed roots on a tree may be a primary symptom while the toppling over of the tree or windthrow is a secondary symptom. At later stages of a disease, secondary invaders may also obscure the original disease symptoms so that symptoms observed at the later stages of the disease are not typical of the symptoms developed in response to the original pathogen.

It is important to look for a progression of disease symptoms in plants exhibiting problems. In some cases, such as improper herbicide usage, symptoms observed may be similar to spots present as a result of an infectious agent. The difference is that with herbicide injury, the symptoms usually appear suddenly and there is no observable progression of symptoms. The spots may also follow spray patterns of the herbicide. Herbicides, such as 2,4-D, can cause leaf distortion which may be confused with viral diseases. However, when new leaves form, they will generally be free of symptoms, indicating a lack of symptom progression.

Identify symptom variability. Variations in symptoms expressed by diseased plants may lead to an improper diagnosis. These variations can result from a couple of factors. It is possible that there is more than one problem present, and in some cases there may be more than one pathogen infecting a plant. Symptoms associated with these infected plants may be significantly different from the symptoms expressed in response to each of the different pathogens acting separately. The disease symptoms exhibited by multiple pathogens infecting a plant may be either more severe or less severe than if the plant were infected with just one of the pathogens. This is commonly seen in multiple infections due to viruses. An example of this is shown in Figure 1 which shows peach seedlings infected with single or multiple viruses. The seedling on the left is infected with both *Prune dwarf virus* and *Prunus necrotic ringspot virus*. The seedling in the middle is infected with *Prune dwarf virus* alone and the seedling on the right is infected with *Prunus necrotic ringspot virus* alone.

Figure 1. Peach seedlings infected with various viruses alone or in combination. Peach seedlings infected with both *Prune dwarf virus* and *Prunus necrotic ringspot virus* (seedling on left), infected with *Prune dwarf virus* (seedling in middle) and infected with *Prunus necrotic ringspot virus* (seedling on right). (Used by permission of S. Scott)

Look for signs of biotic causal agents. Signs of plant disease agents are the observable evidence of the actual disease-causing agent. Signs may include the mycelia of a fungal agent, fungal spores, and spore-producing bodies. Indications of insects causing problems may include the actual insect, insect frass, mite webbing, and insect eggs. Signs are much more specific to disease-causing agents than are symptoms and are extremely useful in the diagnosis of a disease and identification of the agent causing the disease. The use of a hand lens and a knife can be valuable for a diagnostician in the field. Cutting into the bark of ornamental plants and trees at the soil surface may lead to the observation of mycelial mats of root rot fungi such as *Armillaria* spp. (Figure 2). Bacterial ooze can be observed by cutting stems and placing them in water (Figure 3). Masses of different spores such as rust spores (Figure 4) on leaves can also be important in disease diagnosis. Powdery mildews are typically diagnosed by the observation of the gray to white mycelia and conidia observed on the surface of leaves and flowers (Figure 5).

Figure 2. White mycelia of *Armillaria* growing under bark of peach tree. (Used by permission of G. Schnabel)

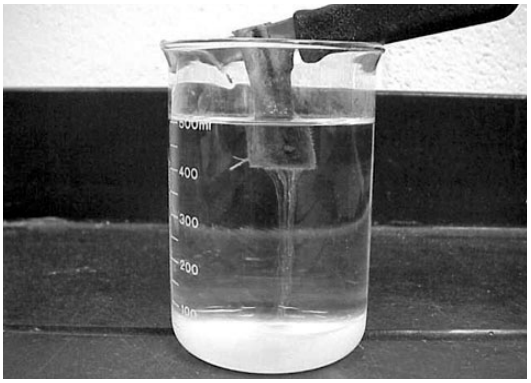

Figure 3. Bacterial ooze from cut tomato stem infected with *Ralstonia solanacearum.* (Used by permission of M. Williamson)

Figure 4. Stem rust on barley. caused by *Puccinia graminis.* (Courtesy B.Steffenson)

Figure 5. Powdery mildew on apple blossom cluster caused by *Podospaera leucotricha.* (Courtesy K D. Hickey)

Dissecting and compound microscopes are useful for the observation of specific spores and spore structures, and can lead to further identification of possible disease agents. Knowledge concerning the use of microscopes and a hand lens is vitally important to the diagnostician. Signs of plant disease agents can often be overlooked unless careful observations are conducted. Signs are not visible when taking a quick ride by plants looking through the windshield of a truck and may not even be visible to the naked eye.

Identify Plant Part Affected - Are symptoms associated with specific plant parts?
It is important to note if the symptoms observed are associated with specific plant parts. For example, is a wilt observed correlated with a disruption of the vascular system which may be indicated by browning of the vascular system or are the roots of the plants abnormal including rots, decreased feeder roots, etc.; are necrotic lesions observed strictly on younger leaves? The symptoms of some diseases are most commonly seen on specific plant parts and this observation can be important in diagnosis.

Observe Patterns

Check distribution of symptoms. One of the first things that a diagnostician should note is how the diseased plants are distributed over the affected area. Are they distributed uniformly across an area or are they localized? Is there a definite pattern to the distribution? For example, does it occur only along the edges of a greenhouse near open windows, next to roadways or driveways, in low spots of a field, along a planted row, or is it affecting plants at random in a field? This distribution can be especially important in looking at the possibility of non-infectious problems, such as improper herbicide use or various soil factors[11]. A uniform pattern on an individual plant and uniform damage patterns over a large area are generally not associated with biotic agents, but are usually due to abiotic agents.

How prevalent is the problem? Are all plants affected? Infectious problems generally occur over time and there is a progression of symptoms. Rarely will all of the plants be affected. Generally, disease problems caused by biotic agents will be observed when they are causing problems on a low percentage of plants at least at the start of the disease, unless there were extenuating circumstances, such as the use of infected seeds. Even then, rarely will 100% infection be observed. When a problem appears in 100% of the plants, it more commonly results from factors such as soil conditions (deficiencies or toxicities), adverse climatic factors (cold temperatures, hail, drought, etc.), or toxic chemicals (improper pesticide use, growth regulators, air pollutants, such as ozone, etc.).

What has been the progression of symptoms on plants in the affected area? If the symptoms all appeared at the same time and there has been no further development of symptoms, this would indicate a possible episodic event such as a change in temperature or possible improper chemical usage. If however, the symptoms started in one area and slowly spread to other areas and the severity of disease symptoms changed over time, this would be more indicative of the presence of a biotic agent. Biotic agents can also include insects and mammals, such as voles, which may be feeding on plants in an area.

Check for host specificity. Is the problem occurring in only one plant species or are different plant species affected? If different plant species are affected, this suggests the possibility of a non-infectious problem which could be related to cultural or environmental problems. However, Phytophthora and Pythium root rots can cause problems on many different plant species; therefore, the fact that more than one plant species is affected does not completely eliminate infectious agents. If there is more than one species of plant involved, are these plants closely related and can they be infected by a common pathogen?

Ask Questions

Review the cultural practices and growing environment. It is vital that a diagnostician question the activities that have been conducted around the affected plants. The problem may not be due to anything that the grower has done; the problem could be related to what his/her neighbor has done. Information pertaining to the growing environment to which the affected plant has been exposed is a vital piece of the puzzle. It is especially important to document changes in the environment. Environmental factors to consider include: extreme temperatures (freezing and heat), rainfall, hail, lightning, prolonged drought, temperature inversions (important in possible air pollutant damage and pesticide drift) and prevailing winds. All of these abiotic factors can be important to the problem. Site factors such as soil type, possible drainage problems, and soil pH should also be evaluated.

Cultural and maintenance activities can be significant. What pesticides or other chemicals have been applied? At what rate and when were they applied? Who applied the chemicals? What equipment was used in its application? What other activities have occurred? Has someone been mowing in the area? Has the highway department been working along the roadway, possibly applying herbicides? Have any unusual occurrences or weather patterns been noted? Many times careful investigation by the diagnostician is required because, in some cases, someone may have done something improperly and may be unwilling to admit their error.

Laboratory Tests

Sometimes neither symptoms nor signs provide enough specific or characteristic information to decide the cause of an infectious plant disease. In such cases, it may be necessary to bring a sample back to the laboratory for further tests to isolate and identify the causal agent. This can be a time-consuming and labor-intensive process that takes specialized skills.

Incubation of plant material. One of the first steps when getting back to the laboratory may be to place a sample of the diseased tissue under conditions that will allow an infectious agent to grow and possibly induce sporulation. This can be accomplished by placing a leaf in a moist chamber[19,13]. A moist chamber can be a sterile petri dish containing a wet filter paper in the bottom of the dish and a triangle of glass tubing on which the sample is placed so that the sample is not directly on the wet filter paper but is exposed to humid conditions. This type of moist chamber will work for small and relatively flat specimens such as leaves. Plastic bags or boxes may be necessary for larger specimens. Saprophytes that are present on the specimen can also be encouraged to grow in a moist chamber and a brief surface swab with 70% isopropanol or 0.1-1% sodium hypochlorite may be useful in reducing these saprophytes. Moist chambers are generally incubated at room temperature.

Isolation and identification of biotic plant disease causal agents. Isolation of fungi usually requires that pieces of infected plant tissue be placed on various nutrient media[11]. The organism that grows out of this tissue is then isolated in pure culture[1,13]. Bacteria are often isolated by chopping up infected tissue in a small amount of sterile water. This water:bacteria suspension is then streaked onto a bacteriological medium such as nutrient agar. Several problems can occur when trying to isolate the plant pathogenic agent. The infected plant tissue may contain one or more saprophytes which have moved into the infected tissue. These saprophytes may outgrow the plant pathogen on the nutrient medium, obstructing accurate identification of the pathogen. In some cases where a specific plant pathogen is suspected, a medium selective for the suspected pathogen may be utilized. It is also beneficial to attempt to isolate the plant pathogen from the margins of the diseased tissue where the pathogen is more numerous or more active than saprophytes that quickly colonize the recently killed tissue.

Once an organism is isolated, is that organism the true cause of the problem? Conducting Koch's postulates[1], which involves the inoculation of healthy plants, may be necessary to conclusively answer this question, especially if the organism has not been previously reported as a plant pathogen on that host. Koch's postulates are seldom conducted for routine diagnoses, but may be extremely important for new diseases and for research. Inoculation of a healthy host and obtaining the symptoms originally observed in the field may be difficult. This may be due to problems in replicating the conditions through which the host was inoculated and also in reproducing the environmental conditions present when the host became infected. It is often impossible to replicate in the laboratory the original conditions present during the disease development.

Once an infectious plant pathogen is successfully isolated, the organism must be identified. There are estimated to be some 1.6 million fungal species[3,9], most of which are not infectious pathogens. Many fungi and bacteria have never been isolated and identified. The characteristics upon which their identification is based are often complex and specialized training is necessary to be able to identify these fungi and bacteria. Diagnosticians with experience are often able to identify the most commonly isolated organisms. Identification of plant pathogenic nematodes also requires a trained individual.

Diagnostic tests for identification of biotic causal agents. A major problem in identification of biotic causal agents is the inability of some infectious pathogens to grow on artificial media. Viruses, as well as some fungi (e.g. powdery and downy mildew causing agents) and some prokaryotes (e.g. phytoplasmas), require a living host in order to grow. In cases where the plant pathogen is difficult or impossible to grow on artificial media, other methods may be used for their detection, such as the use of serological tests for viruses. Viral identification is often accomplished utilizing ELISA (enzyme-linked immunosorbent assay) which is based on the binding of an antibody produced to a specific virus with the virus in the infected plant material[1]. More tests are currently being developed using the polymerase chain reaction (PCR) for detection of specific organisms[5,10]. These types of reactions take specialized equipment and reagents, and the tests are not commonly done outside diagnostic and research laboratories. Other techniques used for the identification of viruses include negative staining and electron microscopy to view the viral particles in plant tissue or suspensions.

PCR and ELISA tests, as well as other laboratory tests, may be used for organisms that will grow on artificial media. Additional tests may include analysis of fatty acids of organisms, carbohydrate utilization (i.e. BIOLOG test), and enzyme activity testing (i.e. pectinase, isozyme patterns)[5].

Diagnostic tests for identification of abiotic plant disease causal agents. It is extremely important to look for abiotic factors that may be important in observed symptoms. Soil and water tests may be necessary to determine pH, nutrient composition, salinity, and other factors such as pesticide residues that may induce various symptoms. It may also be important to get samples of plant tissue analyzed for nutrient content to determine if there are macro- or micronutrient deficiencies or toxicities.

Final Diagnosis

Diagnosis is a form of hypothesis testing, where the hypothesis is simply the identity of the disease, and a good diagnostician goes through multiple iterations of the scientific method (seeking evidence through testing that supports or refutes the hypothesis that s/he generates). These hypotheses are generated through observations of the plant, environment, and information from the grower. When all of the information is successfully collected, literature sources should be consulted to determine what is already known about diseases and disease-causing agents associated with the identified plant. Information can be obtained from published resources including plant disease compendia, plant disease indexes, technical notes, commodity newsletters, online resources, and personal communication with plant disease experts. When no information is available on the specific plant, information on diseases and disease causing-agents of similar plants may be useful. There may also be rare cases where no information is available related to the disease. Then, extensive testing may be necessary to determine the identification of the plant pathogen. When this type of testing is required, it may take a long time to develop research-based control recommendations and control measures may have to be based on diseases of similar etiology. If these diseases have occurred in other areas of the world, control measures that have been previously developed in other areas may be useful.

The student should keep in mind that s/he is a detective. Causal agent identification and diagnosis of plant problems is just like a detective investigating an assault or murder case, only in this case, the victim is a plant. All clues should be investigated. Some clues may lead down blind alleys while others will lead down the correct path. It is important to note that there are exceptions that exist and these exceptions must be considered. It is the compilation of the information and clues that will ultimately lead to the most accurate diagnosis.

The figures that follow illustrate some of the common symptoms that may be produced by different types of problems. Images such as these symptoms and signs are often used in the diagnostic process. Studying these images may assist the diagnostician in narrowing down the possible diseases to consider and others which can be eliminated[6].

Commonly Observed Symptoms and Signs

Fungal leaf spots - spots usually vary in size. Generally are round and occasionally elongate on stems. Zones of different color or texture may develop giving the spot a "bull's eye" effect. Spots are not limited by leaf veins (Figure 6).

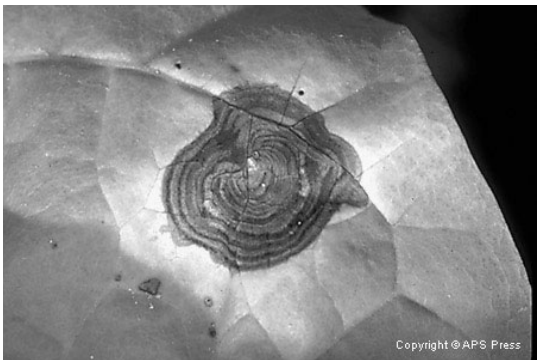

Figure 6. Target spot lesion on tobacco caused by *Rhizoctonia solani* . (Courtesy H.D. Shew and T.A. Melton)

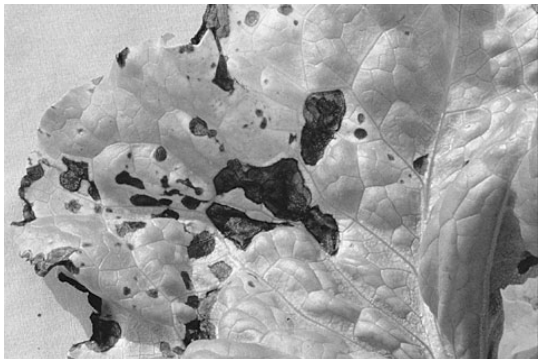

Figure 7. Bacterial leaf spot on greenleaf lettuce caused by *Xanthomonas campestris* pv. *vitians*. (Courtesy S.T. Koike)

Bacterial leaf spots - spots are often angular due to limitation by leaf veins. Color is usually uniform and no signs of plant pathogen are evident. Tissue may appear initially as being water soaked but may become papery as it dries (Figure 7).

Vein banding - Vein banding occurs when there is a band of yellow tissue along the larger veins of the leaf. This symptom is observed with viral diseases and is in contrast with nutrient deficiencies which may cause a dark green band along leaf veins (Figure 8).

Figure 8. Pea infected with *Red clover vein mosaic virus* exhibiting vein chlorosis and banding. (Courtesy R. O. Hampton)

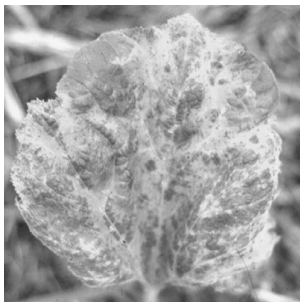

Figure 9. Mosaic symptoms exhibited on leaves of squash. (Used by permission of M. Riley, from files of W. Witcher)

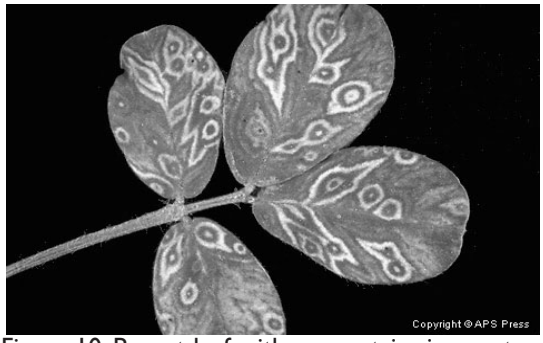

Figure 10. Peanut leaf with concentric ring spots caused by *Tomato spotted wilt virus* (TSWV). (Courtesy A. Culbreath, J. Todd, and H. Pilcher)

Mosaic and Ringspot - Mosaic (Figure 9) and ringspot (Figure 10) are used to describe an irregular patchwork of green and yellow areas over the surface of a leaf. In some cases leaves may also become distorted. Often these symptoms are associated with viral pathogens. There is not a sharp margin between the affected and healthy areas. Distinct margins may indicate a nutritional problem or genetic variegation.

Leaf Distortion - Leaves of the infected plant may be distorted from their normal shape and size. Leaves may be elongated, smaller size, or thickened. This type of symptom can be associated with viral, fungal or bacterial infections (Figure 11) as well as insect and mite infestations.

Figure 11. Peach leaf curl caused by *Taphrina deformans*. (Courtesy J.W. Pscheidt)

Figure 5. Powdery mildew on apple blossom cluster caused by *Podospaera leucotricha* . (Courtesy K.D. Hickey

Powdery mildew - can affect leaves, stems, flowers and fruits with a white to gray surface coating of mycelia which can be rubbed off (Figure 5). Black specks may later develop in the mycelia. These specks are mature cleistothecia, the overwintering fungal structures which contain ascospores. Tissue may turn yellow, reddish or remain green under the mycelia and some leaf distortion may be observed especially on actively growing tissues.

Presence of Spores/Spore Structures - Several fungal diseases can be easily identified based on the presence of spores or spore structures on the leaf surface. Some examples of this are rusts which are often recognized by the rusty brown to black spores (Figure 4) and smuts which are identified by the black spores which often replace the seed structure (Figure 12).

Figure 4. Stem rust on barley. caused by *Puccinia graminis*. (Courtesy B.Steffenson)

Figure 12. Loose smut (on left) and false loose smut (on right) on barley, caused by *Ustilago nuda* (left) and *U. nigra* (right). (Courtesy P. Thomas)

Figure 13. Rhabdocline needle cast on Douglas Fir. (Courtesy E. Hansen)

Needle drop in conifers - Conifers normally retain their needles for several years but these needles will eventually be lost. This drop is gradual and production of new needles obscures the loss of older needles. Unfavorable growing conditions, such as drought, may cause an acceleration of needle drop. If the drop occurs in only older needles especially during unfavorable growing conditions, there is no need for concern. If new needles are lost then other factors may be involved such as needle cast fungus (Figure 13), nutrient deficiencies, or toxic chemicals.

Chemical spray or air pollutant injury - Spots associated with injury are relatively uniform in color and the interface between the affected and healthy area is usually sharp. Distribution on plant may be associated with where spray or pollutant comes in contact with the plant. (Figure 14)

Figure 14. Injury of beans caused by drift of the herbicide, paraquat. (Courtesy H. F. Schwartz)

Figure 15. Chlorotic and necrotic lesions on leaf tips due to fluoride toxicity (*Aglaonema commutatum* 'Maria') (Courtesy J. M. F. Yuen)

Leaf or Needle Tip Death - Death at the tips of needles and tips and margins of leaves often indicate unfavorable climatic conditions, toxic chemicals or root malfunction due to poor cultural practices. Air pollutants, soil chemicals, and excess fertilizer can cause tip burn. Drought and freezing may have a similar effect. All needles of a specific growth period are usually affected. Needles infected by foliar fungal diseases are generally more scattered and rarely are all needles of a particular growth period killed (Figure 15). Needles diseased by infectious agents are generally affected over varying lengths and are often straw yellow or light tan. Fungal fruiting bodies may also be observed.

Figure 16. Alfalfa leaves exhibiting scorching of the leaf edges due to sulfur dioxide injury. (Courtesy K. T. Leath)

Figure 17. Canker on apple caused by *Nectria galligena.* (Courtesy A. L. Jones)

Soil or air chemical injury - Chemicals which are absorbed from the soil by roots or absorbed from air through leaves may exhibit a burning or scorching of leaf margins (Figure 16). If severe, islands of tissue between the veins may also be killed. Dead tissue may drop out of the leaf leaving a ragged appearance. Other chemicals may cause a distortion of leaf shape and size.

Cankers - Cankers are localized necrotic lesions which are often sunken in appearance (Figure 17). Cankers can result from mechanical injury (e.g. trees which have been damaged by collisions with cars or lawnmowers), and various fungi or bacteria. In the spring, ooze may be observed on the surface of bacterial cankers and fruiting bodies may be observed on the surface of fungal cankers.

Fruit Decays and Rots - Various fungi and bacteria can cause rots of fruit. These are often distinguished by the color, lack of firmness of tissue, and signs of spores or fruiting bodies (Figure 18).

Figure 18. Brown rot of peach caused by *Monilinia fructicola*. (Courtesy J. M. Ogawa)

Figure 19. Mosaic symptoms on yellow crookneck squash. Normal appearance is completely yellow fruit. (Used by permission of M. Williamson)

Fruit Discoloration - Discoloration of fruit is often associated with viral infections (Figure 19). This discoloration may be similar to mosaic and ringspot symptoms observed on leaves (Figure 20).

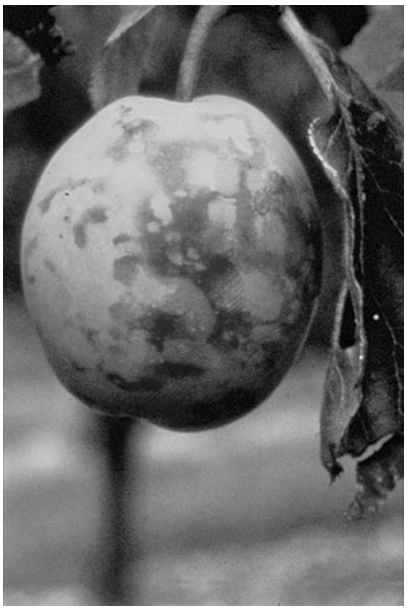

Figure 20. Ringspot symptoms on peach fruit due to *Plum pox virus*. (Courtesy A. N. Adams)

Figure 21. Verticillium wilt of cucumber caused by *Verticillium dahliae*. Courtesy W. D. Gubler)

Wilts - Wilts are characterized by a general loss of turgidity of leaves or possibly entire plants due to the loss of water (Figure 21). The loss is most often caused by a blocking of the water flow through the xylem. This blockage can be caused by the presence of various bacteria (*Erwinia, Ralstonia)* and fungi (*Fusarium, Verticillium)* in the xylem. Wilts may also be observed when there is a destruction of the root system due to nematodes or root-rotting fungi (*Armillaria, Phytophthora, Pythium)* or an acute water shortage in the soil.

Shoot dieback or blights - Sudden dieback of a shoot usually indicates climatic or chemical injury rather than parasitic problems. If the line between affected and healthy bark is sharp, a soil chemical should be suspected. If dieback is somewhat more gradual and there is a cracking or splitting of the bark and wood, cold injury should be suspected along with bacterial blights caused by *Pseudomonas* or *Erwinia*. A bacterial streaming test with phase and compound microscope and isolation may be required to determine if the blights/dieback is due to a bacterial agent (Figure 3). Gradual decline of shoots and retention of dead leaves is more indicative of a parasitic disease (Figure 22). The margin between the affected and healthy tissue is often irregular and sunken. There may also be small pin-like projections or bumps over the surface of dead bark. These bumps are spore-producing structures of the fungal causal agent.

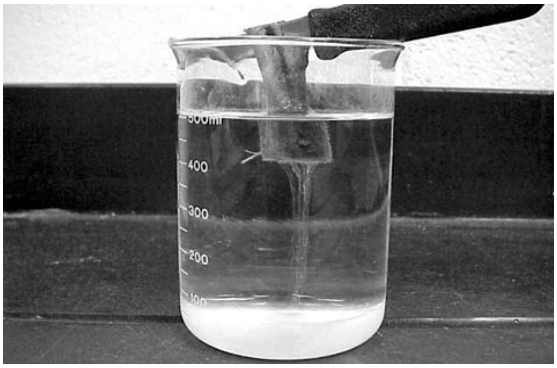

Figure 3. Bacterial ooze from cut tomato stem infected with *Ralstonia solanacearum*. (Used by permission of M. Williamson)

Figure 22. Shoot growth of apple with fire blight, *Erwinia amylovora*, showing typical shepherd's-crook at the tip of the shoot. (Courtesy A. L. Jones)

Dying branches of trees and shrubs - If scattered branches in a tree or shrub start to decline and eventually die, a canker disease or a shoot blight should be suspected (Figure 23). If branches die suddenly and, especially if affected branches are concentrated on one side of tree, weather conditions should be suspected (wind, snow, etc.) or animal or mechanical damage at the trunk base; however, this is not always the case. If symptoms develop over time on one side of a tree or plant then damage of the roots associated with one side may be suspected such as root rots due to *Phytophthora* spp.

Figure 23. Branch dieback of Monterey pine in California caused by pitch canker. (Courtesy L. D. Dwinell)

Figure 24. Crown symptoms caused by laminated root rot of Douglas-fir. (Courtesy W. G. Thies)

Death of tree and shrub top - If all or a major portion of a tree or shrub dies over a period of time, the diagnostician should suspect a problem with the roots (Figure 24). Examples are diseases caused by Armillaria root rot and Verticillium wilt. The decline may be gradual and may eventually affect the entire tree, but in some cases the death may occur on one side of the plant initially. If the decline is sudden, a toxic chemical in soil or weather extremes such as freezing or drought should be suspected.

Overall Stunting or Decline - These symptoms can be caused by several very different factors. Systemic viral infections can result in stunting or decline, but such viral infections are often accompanied by other aboveground symptoms such as shortened internodes. In many cases, overall stunting of a plant may be due to problems associated with the root system (Figure 25). The roots should be examined for rotting and possible mycelial growth, reduction in roots especially feeder roots, and the presence of galls (Figure 26). Root galls can result from fungal and fungallike agents (*Plasmodiophora brassicae*), nematodes (*Meloidogyne* spp. - root-knot), and bacteria (*Agrobacterium* sp.). Abiotic factors such as nutritional deficiencies, soil compaction and herbicide residues can also result in overall stunting or decline.

Figure 25. Healthy 'Mandalay' chrysanthemum (left) and plant infected with *Fusarium oxysporum* f. sp. *chrysanthemi* (right) which exhibits stunting without other observable symptoms. (Courtesy Penn State Univ.)

Figure 26. Crown gall on Euonymous caused by *Agrobacterium tumifaciens*. (Courtesy Robert L. Forster)

Damping-off - This term describes the rapid death and collapse of young seedlings. Often the seedlings will appear to be almost broken at the soil line (Figure 27). It may be observed in flats of plants begun in greenhouses and can result from infection of the seedlings by the fungal organisms Fusarium, Phytophthora, Pythium, Rhizoctonia, or Thielaviopsis (Figure 28).

Figure 27. Soybean seedlings exhibiting symptoms of Pythium damping-off. Note thinning and browning of stem growth near the soil line. (Courtesy X. M. Yang)

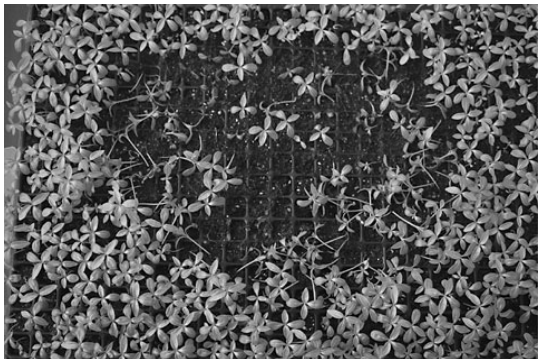

Figure 28. Damping-off of vinca (*Catharanthus roseus*) due to *Rhizoctonia solani*. (Courtesy R. L. Wick)

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Index of Basic Plant Care (usually Tree) Articles

Trees and Shrubs for the Drainage-Challenged Landscape
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Transplanting Basics for Balled and Burlapped Trees and Shrubs
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Jun1599.html#transplant

Winter Injury to Plants in the Landscape
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Sept1599.html#winter

Dormant Season Pruning for Mature Trees
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Dec0199.html#prune

Gardening Under Trees
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-May1500.html#trees

Preventing Storm Damage to Trees – Are Your Trees a Hazard?
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-June0100.html#trees

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Tree Legalities
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Premature Senescence and Leaf Shedding in Trees
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-July1501.html#shed

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http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Aug0101.html#crack

What Happens When Trees are Defoliated?
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-May1502.html#defoliate

Waterlogged Plants
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-July1502.html#soaked

Tree-ting Storm Damage
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-July1502.html#tree

Is Your Black Walnut Worth Big Bucks?
http://www.extension.umn.edu/projects/yardandgarden/YGLNews/YGLN-Sept0102.html#walnut

It Might Be Worth Saving
Transplanting Trees and Shrubs-Part I: Preparing for the Move
http://www.extension.umn.edu/projects/yardandgarden/YGLNews/YGLN-Oct0102.html#trees

It Might Be Worth Saving
Transplanting Trees and Shrubs-Part 2: Making the Move
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Snow Cover and Winter Injury to Woody Ornamental Plants
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Mar0103.html#woodies

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http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Oct0103.html#roots

Pruning By Study
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Mar0104.html

Shopping for Shrubbery
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Apr1504.html#trees

Why Are My White Pines Red?
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Apr1504.html#redpine

Why? Oh, Why Do We Prune Trees?
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-May0104.html#prune

Tree Cavities: To Fill Or Not To Fill?
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http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-June1504.html#fast

What's Wrong with My Maple?
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Sept0104.html#maple

When to Prune Deciduous Trees
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Dec0104.html#mums#prune

When Lightning Strikes Your Tree
http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-June1505.html

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http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-July1505.html#arborist

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