

REFERENCE MANUAL FOR ONTARIO MASTER GARDENERS



2nd Edition, 2014

REFERENCE MANUAL FOR ONTARIO MASTER GARDENERS

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CHAPTER 1: INTRODUCTION AND ACKNOWLEDGEMENTS

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INTRODUCTION AND ACKNOWLEDGEMENTS

This gardening manual, which provides the advanced gardener with a broad range of gardening information, was produced by the Master Gardeners of Ontario Inc. Many thanks are owed to the Maryland Master Gardeners as well the Home and Garden Information Center, University of Maryland Cooperative Extension Service for allowing us to use and adapt their Handbook. Many individuals have contributed their time to the production of this document. The first version of this manual was created in 1999 by many members of the Education Committee lead, at the time by Lenore Ross; their hard work is greatly appreciated.

Staff at the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) initiated this effort and provided administrative and computer support throughout the 1999 version of the project. Without their help we would not have this resource. For reasons that are not clear, the document was not distributed at that time and remained lost until one hard copy recently surfaced. The present Education Committee has taken on the task of updating and distributing a new version of the original document.

This is a first published edition of the Reference Manual for Ontario Master Gardeners and although much care has been taken to ensure accuracy and consistency, there will be errors and omissions. If you discover errors or have any general comments, please forward these to the Education Committee through the Board of Directors, info@mgoi.ca.

OUR PLAN GOING FORWARD

The Education Committee has had the manual retyped and have edited the various chapters. In respect for the Master Gardeners who spent so many hours creating this useful and well written document, we have kept the original text as much as possible adjusting only for out-dated material. The most obvious changes required were in the area of pesticide use.

In time, we intend to improve and replace most of the graphics illustrations since we are not restricted to black and white drawings as the original authors were. For now, we have scanned the figures from the print version and inserted them into the new document. Because these are not originals, they are not as good quality as we would want. We will also be making the document compatible with modern electronic formats that are friendlier to smaller screens such as tablets.

SUSTAINABLE GARDENING IN ONTARIO

Ontario gardeners want and need accurate information on planting and caring for their properties. We are coming to understand that the decisions we make each day may have consequences beyond our garden gate. For example, carelessly sprayed herbicides may damage a neighbour's landscape plants.

On a larger scale, our erodible soils, misapplied fertilizers and overused pesticides may enter a nearby tributary and ultimately affect the health of both ground and surface waters. In fact, the recognition is growing that homeowners can be major contributors to the nutrient pollution threatening animal and plant life. The educational programs of the Ontario Master Gardeners are designed to answer home horticulture questions and help residents adopt environmentally-sound practices.

The sustainable garden and landscape is successful and productive because it relies more heavily on inherent resources (e.g., backyard compost) and diversity of natural systems (e.g., attracting beneficial insects) than on purchased fertilizers and pesticides. This handbook advocates a sustainable gardening approach that includes four major principles:

- **Soil Building/Erosion Prevention** – through regular additions of organic matter and protection of topsoil.
- **Nutrient Recycling** – through backyard composting, cover crops and locally available manure.
- **Using Appropriate Plants** – choosing hardy, disease-resistant species and varieties.
- **Practicing Low-Impact Gardening** – using drip irrigation, organic mulches, etc.

USING THIS HANDBOOK

This edition of the Ontario Master Gardener Handbook represents a significant step in the education of new Master Gardeners and serves as a resource for all Master Gardeners. The handbook includes basic information and practical tips on a wide range of subjects. Your handbook is not a textbook or comprehensive gardening “how-to”. Consult the reference lists at the end of each chapter for more detailed treatment of the subjects.

Our primary goal is to provide the reader with the rudimentary tools to facilitate the identification and solution of pest and plant problems. To this end we have added an extensive Integrated Pest Management (IPM) chapter which includes 30 self-help diagnostic keys.

Your handbook is divided into three broad sections:

- Section I - Core Subjects - **Chapters 2-9**
- Section II - Major Plant Groups - **Chapters 10-17**
- Section III - IPM/Diagnostic Keys - **Chapter 18**

TROUBLESHOOTING A PROBLEM

To diagnose plant problems based on observed symptoms, turn to the Table of Contents and locate the appropriate diagnostic keys in **Chapter 18**. The keys are not exhaustive; only the most common problems are listed. The first two keys in **Chapter 18** are abiotic (environmental, cultural) keys for woody and herbaceous plants. When diagnosing plant problems always refer to the abiotic keys along with the specific biotic (insect/ disease) keys. The IPM chapter also includes keys for diagnosing transplant and seedling problems and keys for indoor, structured and biting and stinging pests.

We emphasize an integrated pest management perspective throughout the handbook. **Chapter 18** provides a detailed treatment of this common sense approach, including recommended cultural practices that will help you prevent plant problems. Specific non-chemical controls are also listed in the diagnostic keys.

We hope you find your handbook easy to use and helpful in your Master Gardener activities and in your own backyard.

CHAPTER 2: BOTANY

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GARDEN BOTANY

INTRODUCTION

Botany is the study of all plant life. It includes the study of mosses, ferns, palms, deciduous and evergreen trees and shrubs, herbaceous flowers, grasses, and vines. Although the study of botany is a science unto itself, applied plant sciences, such as horticulture, use the basic principles of botany. As Master Gardeners you will use the principles of botany in gardening and for diagnosing plant problems.

STRUCTURE AND DEVELOPMENT

All living organisms are made up of cells. The functions of the cells are carried out in the cytoplasm or in sub-compartments called organelles.

Living plant cells have (Figure 2-A):

- A rigid **cell wall** that gives shape to the cell and provides the structural support of the plant. Only plants have cell walls.
- A **cell membrane** that controls what enters and leaves the cell.
- **Cytoplasm** which is the liquid inside the cell.
- Various **organelles** including the **nucleus** which contain the genetic material, **chloroplasts** for photosynthesis and a **vacuole** for storage.

Plant cells can have specialized functions and there are many different cell types found within plants.

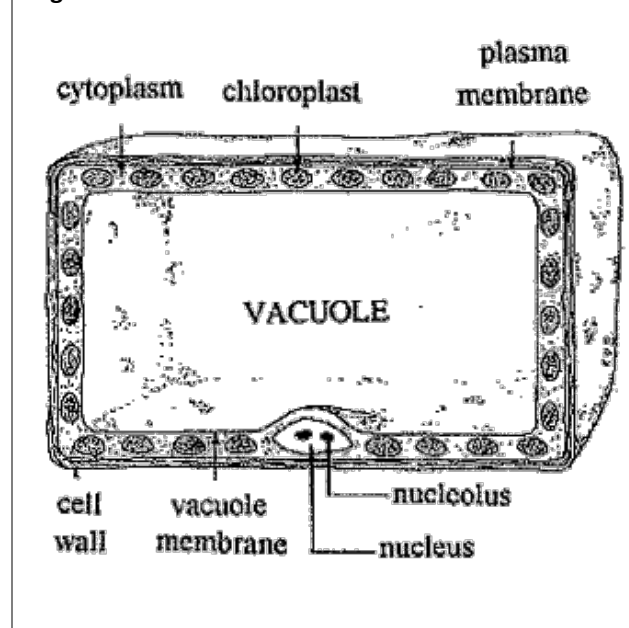
Tissues

Plant cells are organized into tissues. Tissues have specialized forms and functions. The important tissues of higher plants are the meristematic, epidermal, vascular, and ground tissues.

- **Meristematic** tissues are areas of cell division where growth takes place. Meristematic tissues produce thin-walled cells that mature into other tissue systems. For example, vascular cambium is a lateral meristem that allows radial growth in dicots. Apical meristems are located in buds and shoot tips. Root meristems are located at root tips.

- **Epidermis** is the outermost covering of the plant and forms the surfaces of leaves, stems and roots. The exterior cell wall of dermal tissues frequently has a waxy coating or cuticle to reduce the plant's water loss to the surrounding environment. Dermal cells can also become modified to produce hairs or spines. In woody plants, bark arises from the periderm (a meristematic region).
- **Vascular tissues** consist of the **xylem** and **phloem** cells which are, respectively, the water and food-conducting systems of a plant. Both xylem and phloem cells are tube-like and arranged in columns. The xylem carries water and nutrients from the roots to all plant parts. The phloem transports the food that the plant has produced through photosynthesis to other parts of the plant.
- **Ground** tissues include many of the different cells found between the two dermal layers and surrounding the vascular tissues. These include cells which provide support to the plant and others which produce and store the food created by photosynthesis.

Figure 2-A: GENERALIZED PLANT CELL



Seeds

Flowering plants (angiosperms) and cone-bearing plants (gymnosperms) begin their lives as seeds (see Figure 2-B). A seed contains a miniature plant in an arrested state of development and its initial food source.

- **Seed coat** - the outermost protective covering for the seed.
- **Endosperm** - the food source for the germinating plant until the plant emerges from the soil and can produce its own food in the sunlight.
- **Embryo** - the young plant.

Embryos have several parts:

- **Cotyledons** (seed leaves)-an additional food source for the germinating embryo which may begin photosynthesis before the true leaves emerge
- **Plumule** -forms the stem and true leaves
- **Radicle** -develops into the roots

Germination

Germination is the emergence of a plant from a seed. There are five steps in germination:

- Water is taken up (imbibition).
- Metabolic activity intensifies.
- The embryo grows and expands.
- The radicle forces its way out through the seed coat.
- The shoot emerges.

All plant species have one or more mechanisms for blocking or delaying germination until seeds are dispersed and growing conditions are likely to be favourable. Treatments used to overcome these mechanisms are known as conditioning and the actual techniques vary with species. Many species have more than one blocking system and each must be removed in proper sequence for germination to proceed.

- Chemical blocking systems are the most common and can be destroyed by a method appropriate to the particular species; for example, drying fresh seed, providing light to the germinating seed, providing various temperature cycles.
- Seeds may also have some physical or mechanical system for delaying germination, typically a thick or impervious seed coat. Such species can be treated by physically producing a hole in the seed coat with either a small file or by rubbing the seed between sandpaper. Care should be taken to avoid damaging the embryo side of the seed.

ORGANS OF A PLANT

Just as tissues are organized groups of cells that are similar in appearance and function, organs are groups of tissues that accomplish a similar function. Plants have two principal organ systems; the shoot system, including the stems and leaves, and the root system.

Figure 2-B: DETAILS OF A SEED

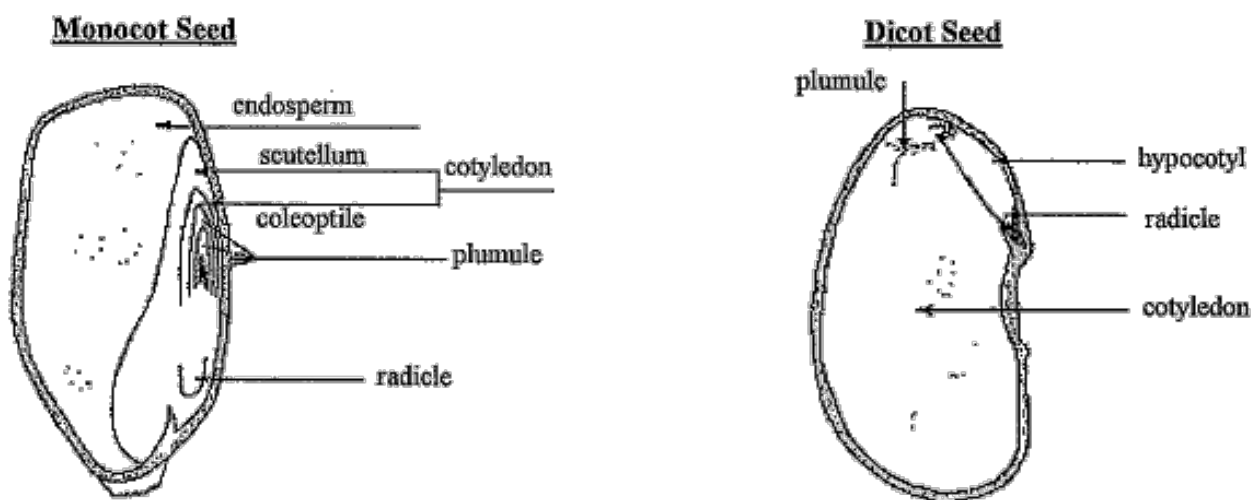
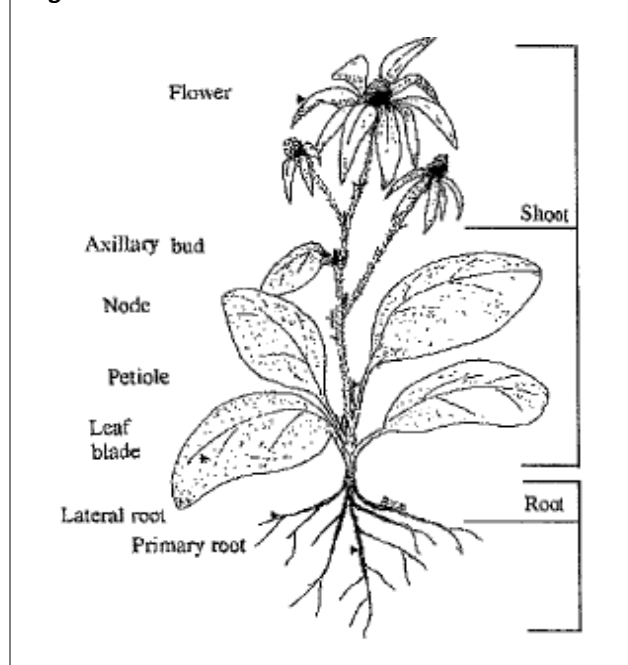


Figure 2-C: ROOT AND SHOOT TERMINOLOGY



Parts of a stem include (**Figure 2-C**):

- **Terminal bud** - the growing tip
- **Nodes** - meristematic areas where leaves and buds are attached
- **Lateral (axillary) buds** - if they grow they will form branches
- **Internodes** - regions between the nodes

The major tissues in the stem are (**Figure 2-D**):

- **Epidermis** - the outermost layer of cells on the surface of the stem
- **Cortex** - tissue between the epidermis and the vascular system
- **Xylem** - for transport of water and minerals upwards from the roots
- **Phloem** - for transport of food and hormones throughout the plant
- **Vascular cambium** (a meristematic tissue found only in dicots) - cells between the xylem and phloem; a site of cell division and active growth (**Figure 2-E**)
- **Pith** - in the center of the stem

Stems

The stem supports the leaves and provides the structure for and contains vascular tissue for the transport of water, minerals and food (sugar) up and down the plant. Together with the leaves, the stem forms the shoot system

There are two classes of flowering plants, monocots (grass-like plants) and dicots (broadleaved herbs and trees). One difference between them is the arrangement of the tissues in the stem. In dicots, xylem and phloem are in bundles arranged in a ring. In monocots, the vascular bundles are randomly distributed through the stem.

Figure 2-D: CROSS-SECTION OF A MONOCOT AND HERBACEOUS DICOT STEM

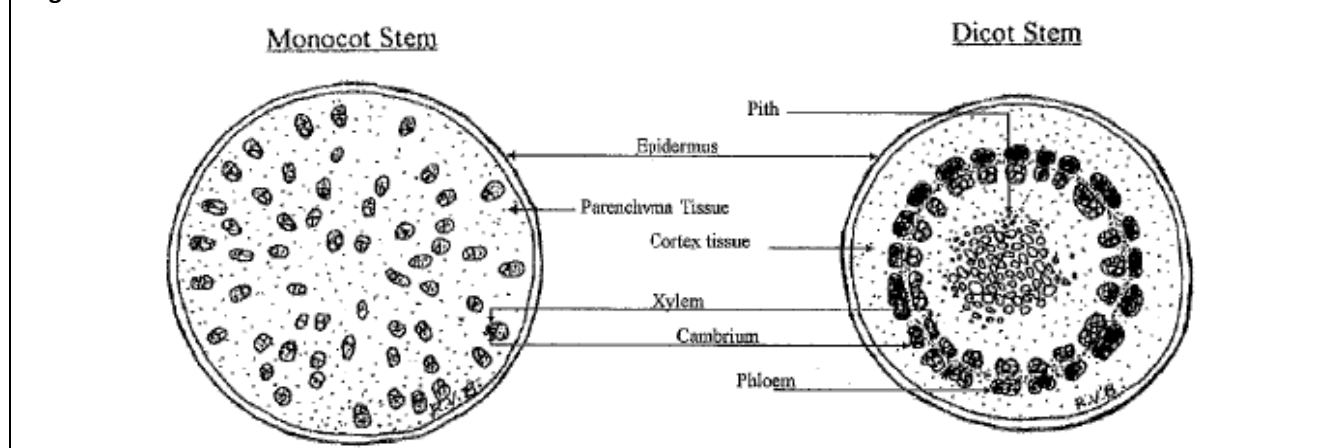
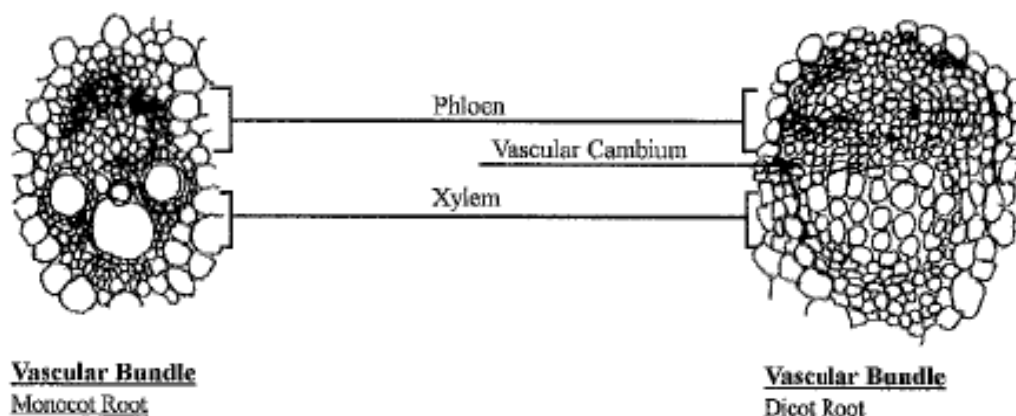


Figure 2-E: ENLARGEMENT OF A MONOCOT AND DICOT VASCULAR BUNDLE

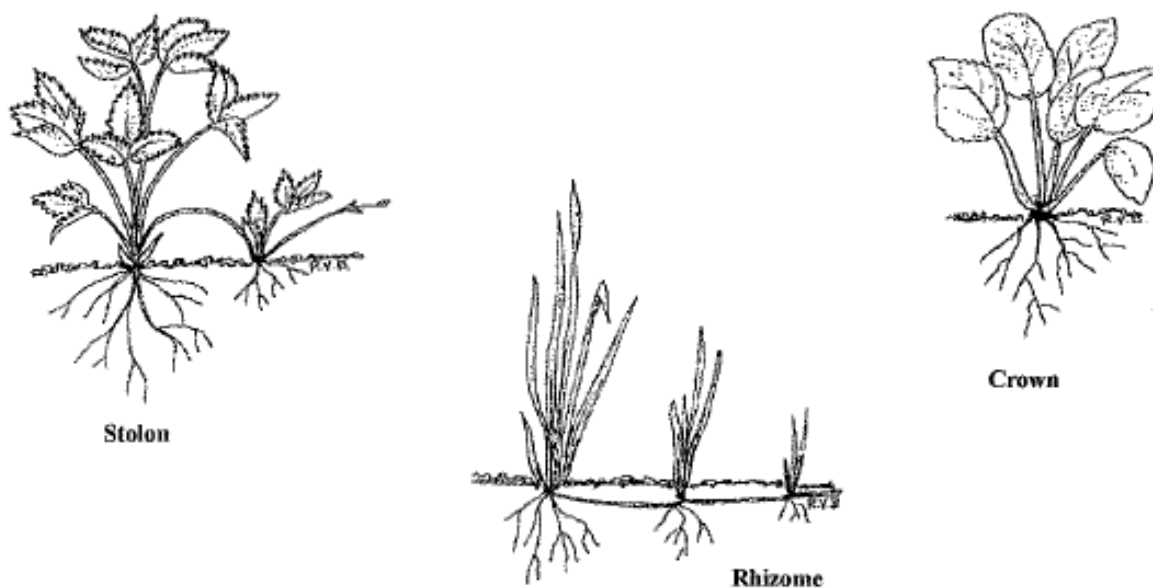


Stems of monocots and herbaceous dicots grow vertically, but rarely increase in diameter. Stems of woody dicots, however, exhibit radial growth in addition to vertical growth. As the meristematic cells of the vascular cambium divide and enlarge they force the stem to expand outwards. New xylem cells are formed to the inside and new phloem cells are formed to the outside. Xylem cells formed in the spring when water is plentiful become quite large, but cells formed later in the season when water is less abundant stay small. This is the reason for the formation of annual rings in woody plants.

The old xylem in the central portion of the stem is not functional, and the old phloem is crushed by the newly formed cells pressing outwards. Only a very narrow ring of cells inside the bark is alive and functional. That is why ropes or wires placed too tightly around a stem will eventually squeeze the vascular tissue, prevent transport, and girdle the plant.

Stems can be modified in several ways and include both above ground modifications and below ground structures. Stems can always be distinguished from roots by the presence of nodes (see **Figure 2-F**).

Figure 2-F: STEM MODIFICATIONS



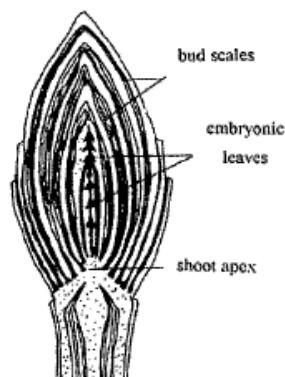
- **Crowns** have internodes so short that the leaves form a rosette as in strawberries and cabbage.
- **Vines** have adapted elongated stems or tendrils for climbing or creeping (for example, ivy).
- **Stolons** are horizontal stems (fleshy or semi-woody) that lie on top of the ground (for example, strawberries or spider plants).
- **Rhizomes** are similar to stolons, but grow underground (for example, iris or johnsongrass).
- **Succulent** stems have extensive parenchyma tissue for water storage.
- **Tubers** and **corms** are underground stems modified for storage (for example, potatoes or gladiolus).

The greatest use of stems is wood for fuel, lumber, and pulp. From pulp we make paper and synthetic fibers such as rayon, viscose, cellophane and linoleum. From bark we get corks and the spice, cinnamon. Stems we eat include Irish potatoes, asparagus, kohlrabi, and cauliflower, which is not a flower but is a proliferation of stem tissue. Sugar cane is a source of sugar and molasses. Many stems contain latex, gums, oils and waxes from which we get products such as rubber and chewing gum. Drugs such as quinine and mescaline come from the stems of *Cinchona* and peyote. Sassafras and ginger are rhizomes used for flavouring foods.

Buds

A bud is an undeveloped shoot from which embryonic leaves or flower parts arise (**Figure 2-G**). Examples of buds include leaf buds and flower buds. As mentioned earlier, buds may be located at the terminals (stem tips) or laterally, in leaf axils. The Brussels sprouts we eat are enlarged axillary buds formed at nodes along the plant's stem. Capers and cloves are the immature flower buds of plants we use.

Figure 2-G: DETAILS OF A BUD



Leaves

Leaves are borne on the stems and function in food production and gas exchange (**Figures 2-G and 2-H**). Parts of a leaf include:

- **Blade** - the broad, flat part of the leaf
- **Margin** - the edge of the blade
- **Petiole** - the stem-like structure that attaches the blade to the stem
- **Midrib** - the central vein that extends up the center of the blade from the petiole

Characteristics of leaves aid in plant identification. Leaves at the nodes may occur in pairs **opposite** one another. Leaves may also occur **singly** at each node and **alternately** from side to side along the stem, or there may be several leaves at each node arranged in a **whorl**. Leaves may be **simple** or **compound**. The blade of a compound leaf is divided up into smaller units called leaflets. If all of the **leaflets** radiate from a single point, the leaf is palmately compound (hand-like). If the leaflets are arranged in two rows on either side of the midrib, the leaf is pinnately compound (feather-like). Leaves and leaflets come in many sizes and shapes and have numerous differences in leaf margins. All of these characteristics are critical in plant identification.

Figure 2-H: DETAILS OF A LEAF PETIOLE AND STEM

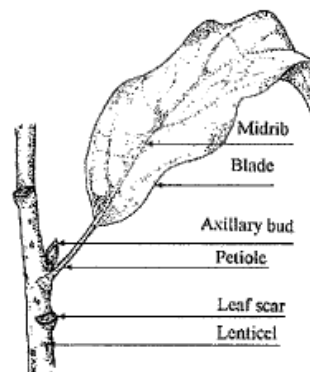


Figure 2-I: LEAF ARRANGEMENT

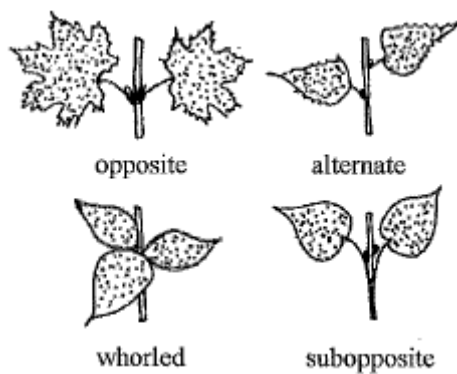


Figure 2-J: LEAF VENATION

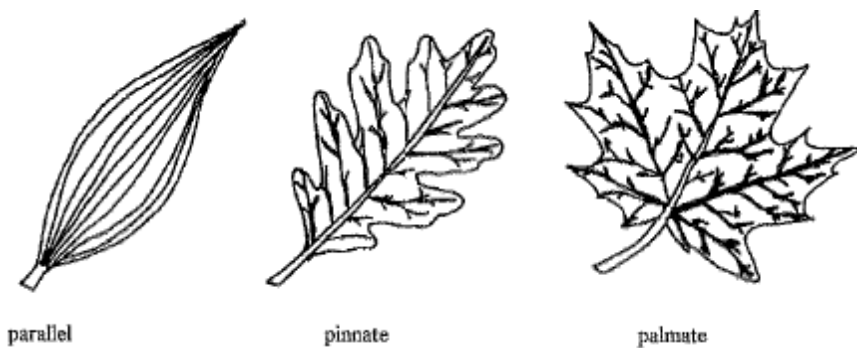


Figure 2-K: COMPOUND LEAVES

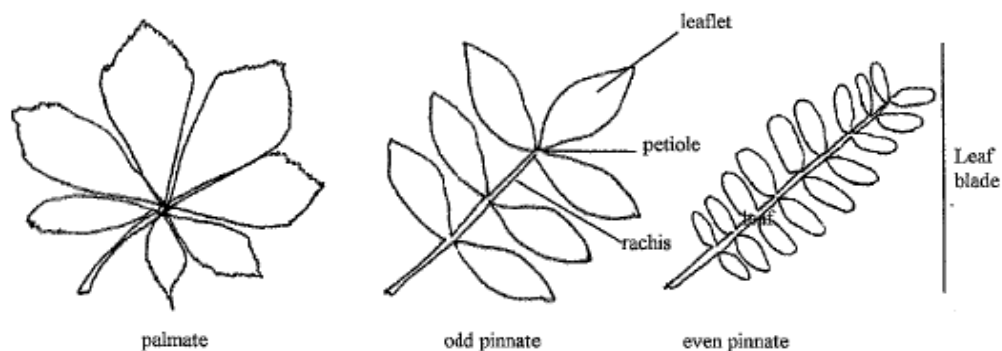


Figure 2-L: LEAF SHAPES

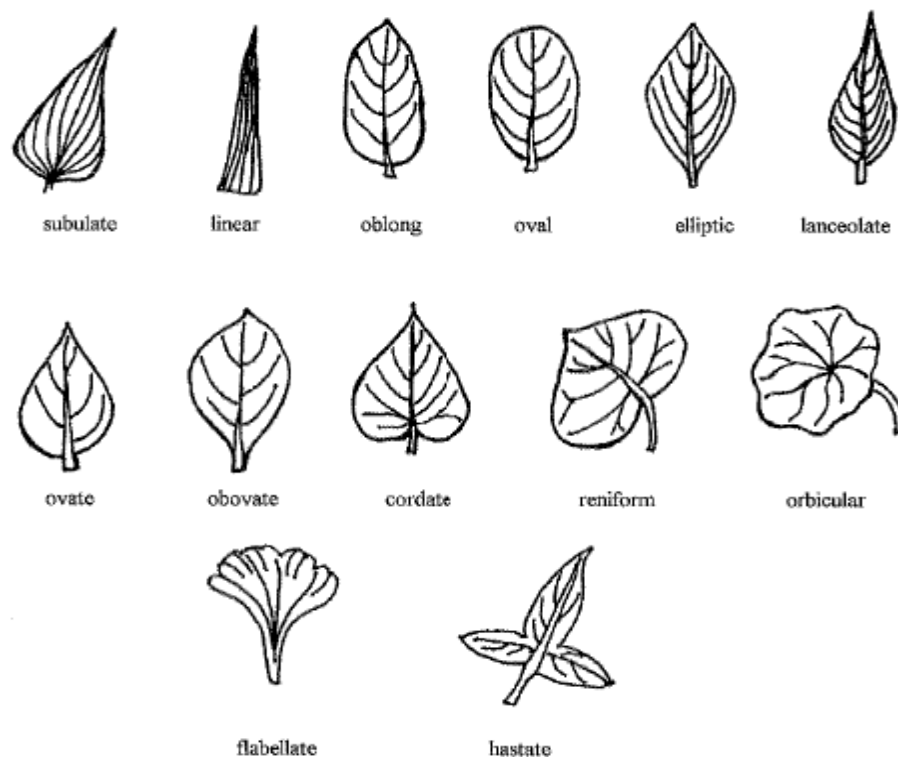
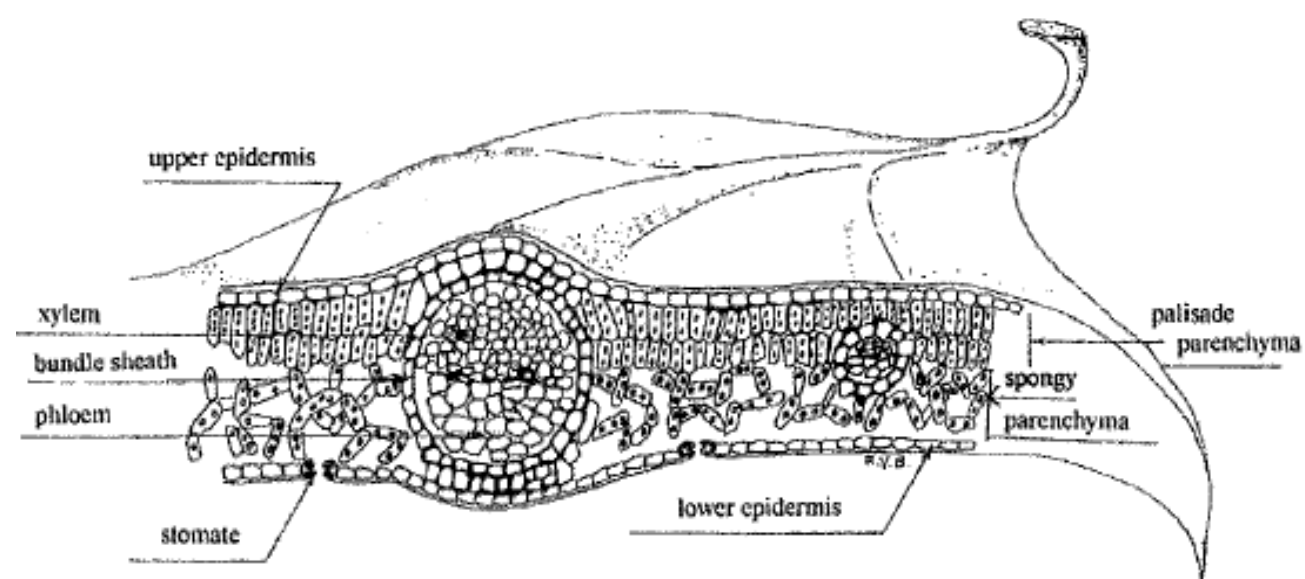


Figure 2-M: DETAILS OF A LEAF IN CROSS SECTION



The internal anatomy of a leaf blade can be described as a "sandwich" (**Figure 2-M**):

- **Upper and lower epidermis** - the pieces of "bread" in the sandwich
- **Cuticle** - a waxy layer coating the epidermis to prevent desiccation
- **Mesophyll cells** - two layers that form the middle of the "sandwich" where photosynthesis takes place. The upper layer is called the palisade layer and the lower, more loosely arranged layer, is called the spongy layer. The open arrangement of the spongy layer allows for free exchange of gases such as water vapor, carbon dioxide and oxygen.
- **Stomata** - tiny openings in the epidermis where gases such as carbon dioxide and water vapor diffuse in and out of leaves. Each stoma is bordered by a pair of guard cells. Opening and closing of the guard cells permits the plant to control the rate of gas exchange in the leaf

Plants in harsh environments have leaves with modifications for their special needs. In arid regions leaves are thickened for water storage, and leathery with sheltered stomata, so they lose less water. Aquatic plants have leaves with very large air spaces to keep them afloat

Legumes often have leaves or parts of leaves modified as tendrils for climbing. Leaves of cacti are reduced to spines for protection of the stem. Carnivorous plants have leaves designed to trap insects. Leaves of plants found in deep shade are often only a few cells thick but with a very large surface area to trap all available light

People take advantage of leaves in a variety of ways. Trees in the landscape provide shade as well as beauty. We eat the leaves of spinach, lettuce, and cabbage and the petioles of celery and rhubarb. Herbs and flavourings come from leaves of thyme, tarragon, peppermint and wintergreen. Many dyes (e.g., henna) are extracted from leaves. Fibers for ropes and twine come from leaves. Eighty percent of the world's production of cordage comes from species of Agave. Manila hemp and flax provide fibers for fine textiles. In many parts of the world, leaves are used as thatching for buildings. Oils from leaves have been used for scenting soaps and perfumes (e.g., lavender, patchouli), as mosquito repellents (e.g., citronella), and medicines (e.g., eucalyptus oil and camphor). Leaves have a long history of use as drugs, narcotics and poisons (e.g., digitalis, cocaine, belladonna, and nicotine). Many beverages are made from brewing leaves (e.g., tea) or fermenting juices from leaves (e.g., tequila).

Roots

Roots are responsible for the uptake of water and nutrients in the soil (**Figure 2-C and 2-N**). The extensive root system (both its spread and depth) anchors the plant in the soil. Roots can also serve as a carbohydrate storage system for the products of photosynthesis. An important difference between roots and stems is that roots have no nodes and never bear leaves or flowers.

The primary root originates at the lower end of the embryo:

- **Taproot** - formed when the primary root continues to elongate downward
- **Lateral or secondary root** - a side, or branch root that arises from another root
- **Root hairs** - projections of epidermal cells of roots responsible for the actual uptake of water and mineral absorption
- **Adventitious roots** - roots formed on stems

The tip of a root produces a carbohydrate-rich slime which enables the root to penetrate the soil. The root tip has three major parts:

- **Meristem** - where cell division occurs at the tip of a root. The meristem is protected by a layer of cells called the root cap.
- **Zone of elongation** - where cells increase in size. By elongating, these cells push the roots through the soil.
- **Zone of maturation** - where cells undergo changes to become specific tissues (i.e., Epidermis, cortex or vascular tissue).

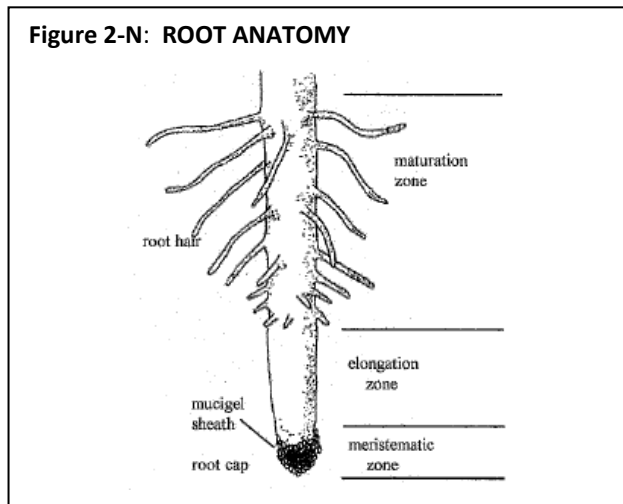
The tissues of a mature root are arranged in rings (**Figure 2-O**):

- **Epidermis** - the outermost layer of cells surrounding the root
- **Cortex** - cells that move water from the epidermis into the vascular tissue and occasionally, store food
- **Endodermis** - regulates which substances get into the xylem and phloem for transport
- **Pericycle** - a layer of cells between the endodermis and the vascular tissue. Cells of the pericycle can divide and form lateral roots.
- **Vascular tissue** - located in the center of the root. It conducts food and water through the root. Phloem and xylem of the roots is continuous with phloem and xylem of the stem.
- **Vascular cambium** - tissue between the phloem and xylem of woody dicots. It divides and produces xylem cells to the inside and phloem cells to the outside.

There are two types of root systems:

Tap root system - one main root that grows downward from which thinner lateral roots grow. It may be fleshy (carrot) or woody (walnut tree).

Fibrous root system - numerous similarly sized roots develop and branch repeatedly at the base of the stem (grasses).



Many plants have modified roots for specialized functions. Aerial roots originate along the stem and serve a variety of functions. They may be used for climbing (e.g., ivy) or photosynthesis (e.g., orchids). Prop roots of corn provide additional support for the stem and in banyan trees they support the branches. Mangroves have roots modified for gas exchange. Roots with a spongy interior grow above the water surface and aid in oxygen transport to submerged roots. Contractile roots are common on flowering bulbs. After maturing, the roots abruptly shorten and pull the bulb deeper into the soil. The most common modification, and the one of greatest interest for humans, is for food and water storage.

People have been using roots for thousands of years. Most familiar to gardeners are beets, carrots, radishes, turnips, sweet potatoes and rutabagas. Cassava may be less familiar, except as tapioca, but it yields more starch per hectare than any other crop, with less labour and millions of people in the tropics depend on it. Other important root crops are sugar beets, and roots from which we get sarsaparilla, licorice and the insecticide, rotenone.

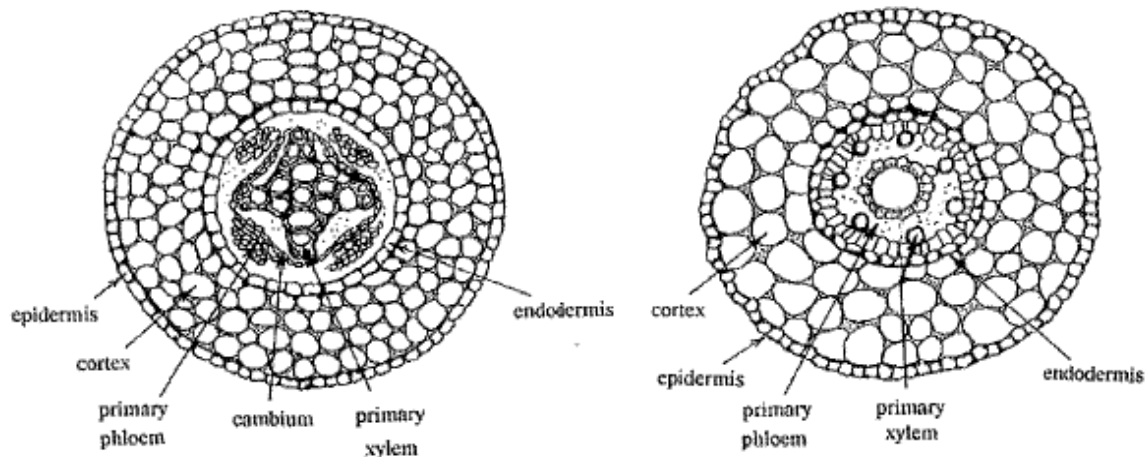
Flowers

The function of a flower is sexual reproduction. The flower is generally the showiest part of the plant. Its attractiveness, colour and fragrance are devices to attract pollinators. Fly-pollinated flowers usually have a foul odour. Moth-pollinated flowers open at night and are usually white with a strong, sweet scent. Markings on petals signal insects how to approach, where to land and mark the entrance to the flower. Bee-pollinated flowers reflect ultraviolet light which is visible to insects but not to humans. Many flowers reward or bribe their pollinators with nectar or intoxicating fluids. Flowers often match the body forms of the animal that performs the pollination (bees, hummingbirds, bats) with landing platforms or nectaries at the ends of long tubes that only the desired pollinator can reach. Some male insects are tricked into transferring pollen by flowers resembling and smelling like females of their species. Other flowers resort to kidnapping and hold their pollinators hostage until the pollinator has been thoroughly coated with pollen. Wind pollinated flowers are less showy, and because success is less certain, they produce copious amounts of pollen. The flower can be considered a specialized stem with leaves.

The parts of a typical flower are illustrated in **Figure 2-P**:

- **Receptacle** - support for the rest of the flower parts
- **Sepals** - the outer row of leaves that enclose an immature flower. Calyx is the term that describes the collection of sepals.
- **Petals** - coloured sets of modified leaves that may attract insects for pollination. Bracts are coloured, modified leaves located below and surrounding the flower and are often mistaken for flower petals (dogwood, poinsettia). The corolla is the collection of petals and the perianth is made up of both the calyx and corolla.
- **Stamens** - the male reproductive organs. The stamen is made up of the filament, anther and pollen. Stamens produce pollen grains which contain sperm nuclei.
- **Carpels** - the female reproductive organs composed of the ovary, style and stigma. The ovary contains the egg cells. A flower may contain several individual carpels, or carpels may be fused into a single pistil.

Figure 2-O: ROOTS CROSS-SECTION

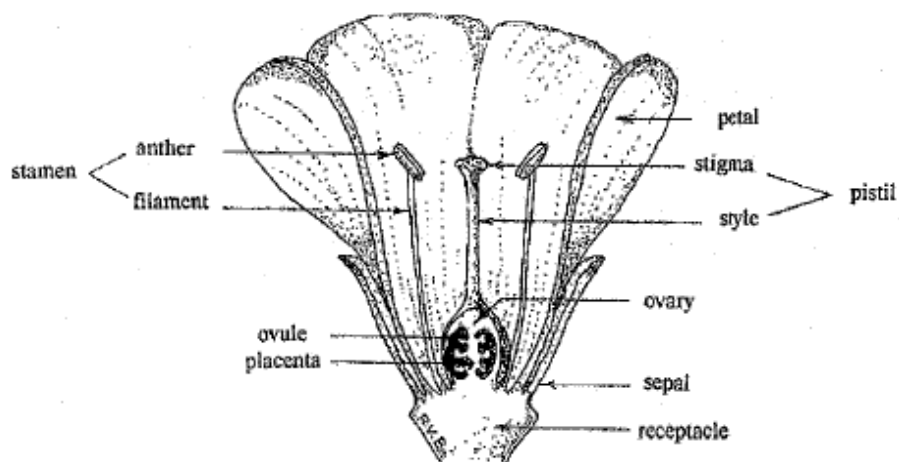


A complete flower contains pistils, stamens, petals and sepals. An incomplete flower lacks one of the above organs. A staminate flower has only male organs and a carpellate flower has only female organs. **Dioecious** plants have staminate and pistillate flowers on separate plants (holly, willow). Monoecious plants have both staminate and pistillate flowers on the same plant (squash, corn).

Pollination takes place when the pollen grains are transferred from the anther to the stigma. After pollen lands on the stigma it sends a pollen tube down the style. The male sperm nucleus travels through the pollen tube to the ovary.

Fertilization occurs when the male sperm nucleus unites with the female egg inside the ovary. The fertilized egg develops into an embryonic plant in a seed, and the ovary develops into the fruit.

Figure 2-P: FLOWER ANATOMY



Fruit

Fruit is the mature ovary and contains the seeds. The fruit's function is to protect the seeds until they are ready for dispersal. Fruits and seeds dispersed by wind have wings, parachutes, or are as fine as dust. Seeds like coconuts are buoyant and are dispersed by water. Adaptations for animal dispersal are legendary. Fruits are nutritious but seeds pass unharmed through the animal's digestive tract. Other seeds hitchhike by using adhesives, hooks or barbs to attach themselves to fur, feathers or skin. Cockle burrs were the inspiration for one of today's most useful products, Velcro®.

Fruits may be either dry or fleshy when ripe. **Dehiscent** - dry fruits open at maturity and release their seeds (e.g., legumes). **Indehiscent** - dry fruits remain closed at maturity (e.g., nuts).

The fruit wall (**pericarp**) of a fleshy fruit has three layers. The outermost layer is called the **exocarp**. The middle layer is the **mesocarp**, and the inner layer is the **endocarp**.

Fruits may be simple or compound.

- **Simple fruits** are formed in individual flowers with one carpel or pistil (**Figure 2-Q**). A peach is formed from a single ovary. An apple is formed from five fused ovaries in one pistil.
- **Compound fruits** may be either aggregate or multiple fruits (**Figure 2-R**).

Figure 2-R: TYPES OF FRUITS

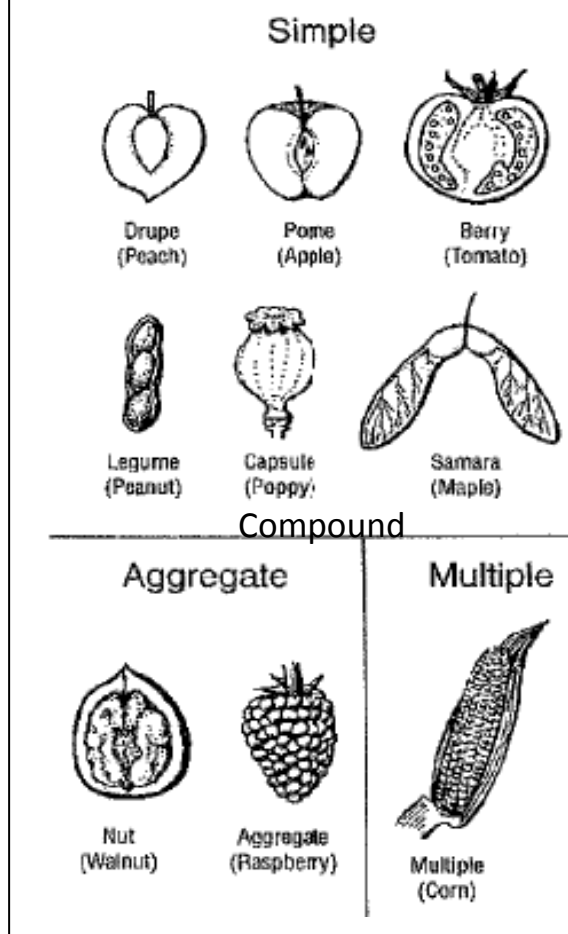
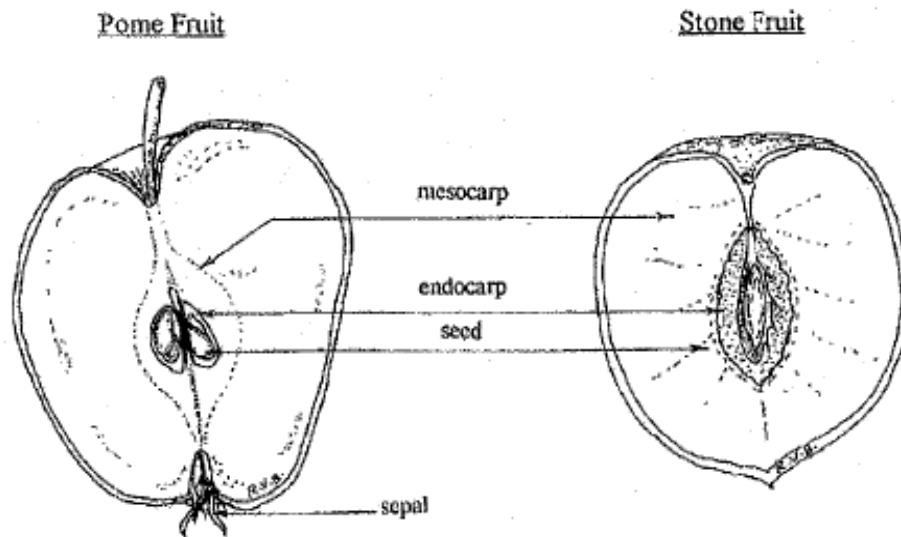


Figure 2-Q: EXAMPLES OF FRUIT



- **Aggregate fruits** form if a flower has several separate female organs all of which stay together as a unit (e.g., black raspberry). A strawberry is a unique type of aggregate fruit. The fruit of a strawberry is actually an indehiscent, dry fruit called an achene. The fleshy part of a strawberry is not formed by an ovary, but is an enlarged receptacle.
- **Multiple fruits** result if the female organs of several flowers stay together to form a fruit (e.g., pineapple).

We are accustomed to eating fruits and seeds, but we also eat flowers (e.g., broccoli) or flower parts (e.g., the receptacle and bracts of asparagus). Allspice, nutmeg, and pepper are spices derived from fruits. Beverages such as coffee, wine and beer are fruit products. Trade in coffee is second only to oil in terms of billions of trade dollars. Fruits and seeds have uses besides food. Fibers from cotton fruits are used for textiles. Morphine and codeine are drugs extracted from the latex of immature poppy fruits.

PLANT NAMES AND CLASSIFICATION

There are an estimated 5 million different organisms living on earth, of these only about 1.5 million have been named. Approximately 266,000 of these are plants. Each organism is assigned to a species. In flowering plants, species are classified by their flower structure: the numbers of flower parts and their arrangements. In the absence of flowers, leaves can sometimes be used to identify the plant because each species usually has a leaf blade with a characteristic shape (e.g., oval or pointed), margin (e.g., smooth or toothed), and texture (e.g., smooth or hairy) (**Figure 2-5**). Similar species are grouped together within a genus (pl. genera). Related genera form families. The genus and species to which the organism belongs forms the organism's name. The genus is a singular, latinized noun which is always capitalized. The species is usually an adjective and is written in lower case. When written, both the genus and species names are italicized or underlined.

Further distinctions of individual plants can be made with subspecies (ssp.), variety (var.) and cultivar (cv.) designations. Subspecies and variety names are written in lowercase and either italicized or underlined along with the genus and species names. A cultivar refers to a particular variation in a plant that is found and maintained in cultivation.

Hybrids are the offspring of two different species, cultivars or even genera of plants. Hybrids are indicated by an "x" between the genus and specific epithet.

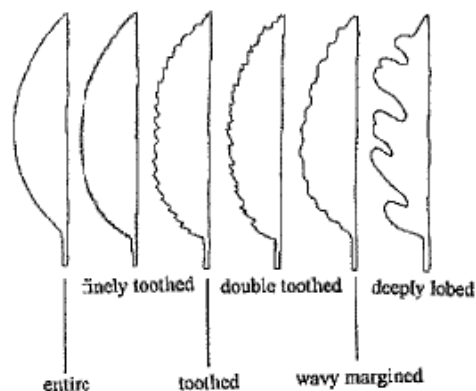
Gardeners are most familiar with flowering plants, but there is a great deal of diversity in the plant kingdom. Flowering plants reproduce sexually with flowers. The products are seeds which are encased in fruits.

Gymnosperms (the name means naked seeds) produce seeds which have no fruit around them. Conifers and cycads (sago palms) are gymnosperms that bear seeds in cones. Seeds of other gymnosperms have fleshy seed coats (e.g., yews and ginkgos). Mosses and ferns are plants that are dispersed by spores. Mosses are so simple they even lack vascular tissue. This is one of the reasons they are limited to moist environments.

Families of flowering plants fall into one of two categories: **Monocots** (Monocotyledons) and **Dicots** (Dicotyledons). Monocots include such familiar plants as grasses, most flowering bulbs, palms, and orchids. Dicots are the broad-leaved herbs, shrubs and trees. Monocot seedlings, as their name implies, have only one cotyledon and dicot seedlings have two cotyledons.

Monocot leaves are long and narrow. They often lack petioles; they wrap around the stem instead. The veins of monocot leaves are arranged parallel to one another extending from the base to the tip of the leaf. Dicot leaves are much shorter and broader than monocot leaves, and their veins are usually branched into a network. Monocots have sepals, petals, stamens and carpels in multiples of three. Dicots have flower parts in multiples of four or five.

Figure 2-5: TYPES OF LEAF MARGINS



As mentioned earlier, monocots and dicots differ in the internal anatomy of their stems and roots. Because the vascular bundles of monocots are scattered randomly and lack vascular cambium (**Figures 2-D and 2-E**), monocots are not capable of radial growth.

For gardeners, the most important difference between monocots and dicots is probably their response to herbicides. Physiological differences between the two groups render monocots resistant to compounds that kill the broad-leaved dicots.

The best way to identify an unknown plant is with a taxonomic key. Keys are usually arranged as a series of questions, each of which has two possible answers. Each answer leads to a new question until the plant is identified. It is important to know the identity of a plant when diagnosing problems, because symptoms of diseases and pests are unique for each species.

ECOLOGY

Coping With Adversity

Plants have adapted to life under a variety of harsh environmental conditions. Water and nutrient availability is often a limiting factor for growth. Dry spells are common in some climates either because of drought or because water is frozen in the soil and is unavailable. Plant growth is also limited by very high and very low temperatures because cells can function only in a narrow range of temperatures.

Plants often avoid these adverse conditions by going dormant. **Annuals** survive these seasonal cycles as seeds. Each year, they grow, flower and set seed before the plant dies. **Biennials** germinate and form vegetative and storage structures in their first season. The stored food provides the energy for new growth the following season, and then the plant flowers and sets seed. **Perennials** live several years and have evolved a variety of survival mechanisms including leaf and stem modifications and periods of rapid growth. Some store food and water in modified underground stems and roots. **Bulbs** are short stems protected by thick fleshy leaves. **Corms** are short, swollen stems covered by dry, scale-like leaves. **Tubers** are swollen tips of rhizomes. The "eyes" of a white potato are the axillary buds. **Tuberous roots** can be differentiated from tubers because they have no nodes or internodes (e.g., sweet potatoes and dahlias).

Competition for Resources

In addition to water and suitable temperatures, plants require nutrients and sunlight. Competition for water and minerals is especially intense. Some plant species minimize competition for water and minerals by having root systems grow at depths different from neighbouring species. Other species such as walnuts and sunflowers eliminate competition from roots of neighbouring plants by engaging in chemical warfare. The roots of these plants produce compounds that are growth inhibitors or are toxic to roots of other plant species. Some of these compounds are even inhibitory to the plant's own seeds! This ensures that the plant's offspring do not grow up too close to their parents.

Ninety percent of tree species and most small vascular plants form mutualistic relationships with fungi which enhance their ability to acquire water and minerals. **Mycorrhizae** are plant roots that have fungi growing on their surface and even penetrating between their cells. The fungus gets carbohydrates and proteins from the plant's cells and the slimy coating around the root. In return, the fungus increases the absorptive surface area of the roots by several folds. Mycorrhizae are especially important for uptake of minerals such as phosphorus. Even in the presence of adequate phosphorus, plants without mycorrhizae have difficulty absorbing it. A wise gardener will use caution when treating plants with fungicides. This dependence of plants on fungi is of special concern for our coniferous forests. Their survival is threatened because mycorrhizal fungi are particularly sensitive to acid rain.

Vines compete with other plants for sunlight with climbing structures that elevate the leaves closer to the available sunlight. This is a distinct advantage in a dense forest setting. Some vines grip their supports with **tendrils** that are either modified leaves or modified stems derived from axillary buds. **Twining stems** wrap around their supports as a result of spiral growth patterns. Other plants have **holdfasts** or **adhesive disks** at the ends of short branches.

Defense

Animals can be a threat to a plant's survival. Plants have evolved several mechanisms to deter herbivores. **Thorns** are modified short branches that arise from axillary buds. **Spines** are modified leaves or parts of leaves. Cactus spines are really the remnants of rigid petioles and midribs. In holly leaves, the major veins terminate in marginal spines. Rose thorns are correctly called **prickles**. Prickles are short outgrowths from the epidermal tissue of stems, leaves and fruit.

Special epidermal hairs on stinging nettle protect the plant by causing a rash in animals that come in contact with them. Poison ivy also has evolved irritable compounds that ward off potential plant-eating animals. Deadly nightshade produces compounds that sicken and possibly kill animals that eat it.

PLANT GROWTH REGULATION

Plant Growth Regulators

A **hormone** is defined as a substance produced in one part of an organism that affects development in another part. Hormones are active at very low concentrations. The growth of plants is regulated by five classes of chemicals: auxins, gibberellins, cytokinins, ethylene, and abscisic acid.

Auxins promote cell division and cell elongation and induce adventitious root formation on cuttings. Auxins are responsible for **gravitropism** (growth response to gravity), **phototropism** (growth response to light), and apical dominance. **Apical dominance** is the suppression of lateral buds by auxin produced by the terminal bud. Removal of the terminal bud (pinching back a plant) eliminates the flow of auxin, and thus allows lateral buds to sprout. Auxins inhibit **abscission**, the dropping off of leaves, flowers, fruit, or other plant parts, and stimulate ethylene production. In some species, auxins promote flowering; in others, flowering is prevented. Auxins can cause fruit formation in the absence of fertilization (parthenocarp).

Gibberellins promote internode elongation and regulate the production of seed enzymes in cereals. They stimulate flowering in long-day plants and biennials. Like auxins, gibberellins cause parthenocarp and are often successful when auxins fail. The greatest use of gibberellins is in the production of seedless grapes. Single hormone treatments will more than double the size of Thompson Seedless grapes.

Cytokinins promote cell division. They enhance shoot growth and counteract the effects of auxins in apical dominance. Cytokinins also help tissues resist aging.

Ethylene is the only hormone which is a gas. It speeds the aging of tissues and enhances fruit ripening. Fruits such as apples and bananas produce large quantities of ethylene. Enclosing a green fruit, such as a tomato, in a bag with some apples will speed the ripening of the tomato.

Abscisic acid is involved in dormancy of seeds and buds and promotes abscission.

Growth Regulators

Chemical compounds have been developed which act as artificial hormones and mimic the activity of genuine hormones. These growth regulators are used by growers to promote fruit set, promote synchronous fruit ripening, or to promote fruit ripening after harvest. Some artificial hormones are potent herbicides.

Environmental Growth Regulation

Environmental factors such as light, temperature and water regulate the growth of plants. **Light** influences growth by its **quality** (wave length), quantity (1 lux = 0.1 foot candle) and **duration** (photoperiod). Photosynthesis in plants is most efficient at red and blue light wavelengths. Plants are adapted to certain intensities of light. Shade plants are easily "burned" in full sun, and some sun-loving plants become "leggy" when grown in the shade. The flowering of some plants is controlled by the length of the dark period at night. **Short-day plants** flower only when the dark period is long (poinsettia, chrysanthemum) and **long-day plants** flower when nights are short (spinach, petunias, marigolds). The flowering of **day-neutral** plants is independent of the night length (some strawberry cultivars).

Temperature is involved in seed germination, flowering and dormancy. Some plants, especially fruit trees, require a chilling period before they will flower (apples, peaches). Chilling is often necessary before bulbs will sprout (tulips, daffodils).

Water is important for the transport of food and nutrients within the plant. Water is consumed in photosynthesis and is also lost in transpiration. Water taken up by cells allows them to expand. Water within a cell presses the cell membrane against the cell wall and keeps the cell turgid (swollen and firm). When plants encounter a shortage of water they wilt. Wilting is the result of a loss of turgor pressure within the cell.

METABOLISM

The metabolism of a plant is the sum total of the physical and chemical activity that occurs inside cells. Plants are unique in that they can produce their own food molecules by the process called **photosynthesis**. Photosynthesis occurs in two phases. In the first phase, or light phase, the energy from sunlight is absorbed by chlorophyll (the green pigment in leaves) and is converted into chemical energy. During these reactions water molecules are split and oxygen is released. The second phase of photosynthesis is independent of light.

The chemical energy produced in the first phase is used to fix carbon dioxide into sugars. Sugar is then transported from the leaves to the rest of the plant. Sugars are linked together to form complex carbohydrates such as cellulose, or starch. Sugars can also be used to make other necessary molecules such as proteins, fats, oils, and DNA.

In the process of **respiration**, sugars are broken down completely to carbon dioxide and water to release their chemical energy. This chemical energy is then used to drive other metabolic processes.

The two processes of photosynthesis and respiration are summarized below.

Photosynthesis	Respiration
• Produces food • Stores energy • Occurs in cells that contain chloroplasts • Releases oxygen • Uses water • Uses carbon dioxide • Occurs in sunlight	• Uses food for plant energy • Releases energy • Occurs in all cells • Uses oxygen • Produces water • Produces carbon dioxide • Occurs in the dark and in light

Photosynthesis

*water + carbon dioxide (chlorophyll) → sugars + oxygen
(light energy)*

Respiration

starch + sugar + oxygen → water + carbon dioxide + energy

Water Movement

Transpiration is the movement of water up through the plant stem from the roots to the leaves. As water molecules evaporate from the surface of the leaves other water molecules move up to take their place. Ninety percent of the water taken up by roots is lost in transpiration (the remaining 10% is used in photosynthesis and growth). As the water is pulled up the xylem it carries minerals with it. The evaporation of the water from the leaf surface cools the leaf. Transpiration increases as humidity decreases or temperature increases.

Nutrition

Macroelements are nutrients used in the greatest quantity by plants, and occasionally their availability is limited. **Carbon, hydrogen, and oxygen** are components of sugars, protein, fats, DNA, etc. Hydrogen is also involved in the regulation of the pH (acidity) of cell sap. Plants get carbon from carbon dioxide, hydrogen from water and oxygen from the air. The rest of the macroelements are obtained from the soil. Proteins contain **nitrogen** and **sulfur**. **Phosphorus** is essential for the high energy molecules involved in all chemical reactions. **Potassium** is important for ion balance in the cell. **Calcium** is used in the cell wall. **Iron** is involved in the synthesis of chlorophyll and the function of some enzymes. **Magnesium** is an essential part of chlorophyll and also functions in some enzymes.

Microelements are needed in lesser amounts and are usually plentiful. All are obtained from the soil. **Boron** is important for the metabolism of carbohydrates.

Manganese is used in enzyme function, root growth, and chlorophyll synthesis. **Molybdenum** is involved in nitrogen metabolism. **Zinc** and **copper** are active in enzyme function. **Silicon** is found in cell walls. **Sodium** and **chloride** are used in photosynthesis and ion balance in cells. **Cobalt** is an essential part of vitamin B12.

Of all of the essential elements in plants, nitrogen is the one most often in short supply. The air we breathe is almost 80% nitrogen, but it is not in a form plants can use. Plants take up nitrogen as nitrate or ammonium. Some plants have developed interesting mechanisms for acquiring nitrogen. Carnivorous plants live in bogs with such acidic soil they cannot take up what little nitrogen may be present. Instead they get the nitrogen they need by capturing and digesting insects. Legumes such as peas and beans form mutualistic relationships with nitrogen fixing bacteria. The bacteria can convert atmospheric nitrogen into a useable form for the plant and in exchange the plant provides the bacterium with all the sugars it needs.

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Maryland Master Gardener Handbook.**

CHAPTER 3: SOILS AND FERTILIZERS

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SOILS AND FERTILIZERS

SOIL BASICS

Soil is not dirt! It is the dynamic "ecosystem" on which all plant and animal life depends. Formed from parent materials (bedrock and rock debris) broken down over long periods of time, soil is a combination of these weathered rock fragments and newly formed clay minerals mixed with decaying remains of plants and animals (organic matter). Air, water, soil animals and micro-organisms are the other components. Soil furnishes mechanical support, water, and nutrients for growing plants.

Soil is a critical natural resource that can be improved with thoughtful stewardship. A sustainable gardening ethic requires us to:

- Recycle nutrients so that last season's yard and garden waste becomes next season's plant food.
- Regularly incorporate organic matter to improve our soil's physical condition (tilth) and to leave our soil, at season's end, in better condition than we found it.
- Prevent soil erosion and nutrient run-off.

Soil scientists classify and describe soils by their components, texture, structure and other physical properties. This chapter will introduce these concepts, examine fertilizers, lime and soil-building techniques and close with suggestions for nutrient management and soil conservation at home.

ONTARIO SOILS

More than 250 types or series of mineral soils have been defined in Ontario. Since the 1920's, Pedologists or Soil Scientists have been describing and mapping the soils of each county throughout Ontario. This information is available through the provincial Ministry of Agriculture, Food and Rural Affairs (OMAFRA) for individual counties in [Soil Survey Maps and Reports](#). Although people are most familiar with mineral soils, there are also considerable areas within Ontario that are organic soils - those with approximately 30% organic matter by weight or more than 17% organic Carbon.

Organic soils are found in bogs and wetlands but are also important vegetable crop growing areas. Limestone, dolostone, shale and sandstone sedimentary rocks have most influenced the soils that have formed in southern Ontario.

In northern Ontario, the granites of the Precambrian bedrock of the Canadian Shield have the most influence on the composition of soils.

COMPONENTS OF SOIL

Mineral soils consist of four major components: mineral materials, organic matter, water and air.

Mineral Materials

Sand, silt and clay are the three major components of the mineral fraction of soil; and account for 45%-50% of the total soil volume.

- Sand and silt particles are derived mostly from quartz and feldspar; they are inert and form the soil's skeletal framework. Individual gravel and sand particles can be seen with the naked eye. A magnifying glass is necessary to see silt particles.
- Clay particles are derived from silica and aluminum oxides. They carry negative electrical charges and have a large effect on soil characteristics. Clay particles can be observed with an electron microscope.
- gravel - particles > 2.0 mm
sand - 2.0 mm to 0.2 mm
silt - 0.2 mm to 0.002 mm
clay - particles < 0.002 mm

Water and Air

Water and air are found in the pore spaces between the mineral and organic components. These pore spaces account for up to 50% of total soil volume. Air and water are essential for the growth and health of plant roots and soil microbes. Water is also responsible for plant rigidity (turgor) and is the solvent in which most plant nutrients are dissolved. Air and water are used continuously by plant roots and microbes and must be replenished. Soils differ greatly in their capacity to provide air and water to plant roots.

Soil porosity is a measure of the pore space volume of a given soil.

- Pore spaces are essential for the movement of air, water and plant roots.
- Sandy soils have large pore spaces which promote rapid drainage of water and leaching of nutrients and organic matter.
- "Tight" soils, high in clay, contain many tiny pore spaces which may impede root growth and water drainage.

- Increasing the organic matter content increases your soil's water-holding capacity and increases porosity.

Water in soil comes from precipitation, irrigation or groundwater. Falling rain enters the soil through cracks, holes, and openings between soil particles. As the water enters, it pushes air out. If air is unavailable to plant roots for too long, the plant will suffer from a lack of oxygen. Some water is used by plants, some is lost by evaporation, and some moves so deep into the soil that plant roots cannot reach it. If rainfall is intense or prolonged, some water may be lost to runoff.

Did you know?

Melons lacking in sweetness and flavour probably ripened in water-logged soil. Recent research has shown that oxygen-starved roots signal the plant to stop photosynthesizing plant sugars. Existing fruit sugars also break down, accounting for the lack of good taste.

Organic Matter

Soil organic matter consists of dead and decaying plants and animals. Organic matter is critical for gardening success for several reasons:

1. It improves the soil's physical structure or tilth.
2. It holds and slowly releases major and minor plant nutrients.
3. It increases the water holding capacity of the soil.
4. It increases the population of beneficial organisms in the soil.

BENEFITS OF SOIL ORGANIC MATTER

Improving Soil Structure

- Loosens tight soils by causing tiny clay particles to form larger aggregates.
- Lignin in humus helps sand particles stick together (granulation).
- Greatly increases capacity to hold water; humus is spongy with tremendous surface area; can hold 90% of its weight in water.
- Soil amended with organic matter warms up and dries earlier in spring and is easier to till.
- Increases pore space in soil which improves soil drainage and penetration of plant roots.

Increasing Soil Fertility

- Holds and slowly releases plant nutrients.
- Produces and releases important enzymes and vitamins taken up by plants.
- Increases earthworm and microbial populations.

In natural settings, plant nutrients are returned to the soil as plants die and decompose. Earthworms, insects, bacteria, fungi and other organisms digest and transform the organic matter into humus, the dark, fluffy end product which is fairly stable and homogeneous. Through this decomposition process, plant nutrients are released and made available for use by growing plants. The recycling of plant nutrients, driven by the soil's microbial inhabitants, is critical in maintaining fertile soils.

- Nearly all of a soil's organic matter content is in the top 30 cm.
- Sandy soils tend to have a lower percentage of soil organic matter than do clay soils.
- Organic matter is often higher in soils that have not been cultivated for a long time than in soils that are frequently tilled with little return of plant residues.
- Tilling increases the amount of air in soil, which raises the rate of organic matter decomposition.

SOIL LAYERS (HORIZONS)

Most Ontario soils have at least three distinct layers, or horizons, that collectively form the soil profile. Horizons often differ in colour, texture, consistency, or structure (see **Figure 3-A**).

Surface Soil

- Contains most of the organic matter and highest concentration of plant roots.
- Plants get most of their nutrients and water from the top 30 cm of soil.

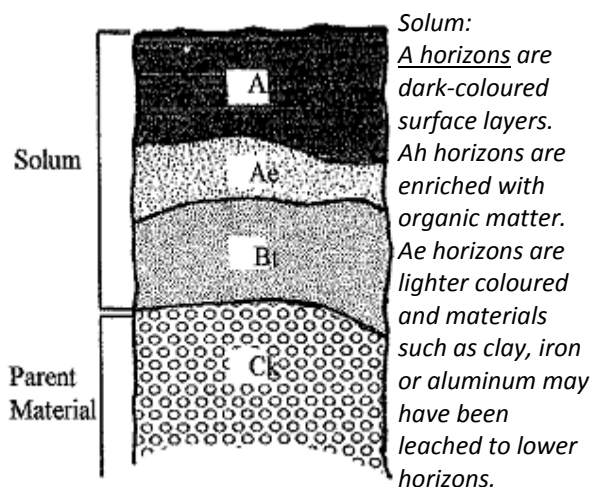
Subsoil

- Firmer and usually of a finer texture than surface soil because the very small clay particles are carried downward through the soil profile by gravity and rainfall.
- Lower in organic matter.
- Provides storage space for water and plant nutrients.
- Aids in regulating the soil temperature and air supply of plant roots.

Parent Material

- Made up of decomposed rock that retains characteristics of the bedrock.
- Influences the soil's texture, natural fertility, acidity, and depth.

Figure 3-A: SOIL PROFILE



PHYSICAL PROPERTIES OF SOIL

A soil's physical properties are those characteristics that can be seen with the eye or felt between the thumb and fingers. These properties evolve over time as climatic factors (such as rainfall and temperature) act upon the soil's parent materials. Physical properties are also affected by relief (slope and direction of the land surface) and vegetation (kind and amount, such as forests or grass). Characteristics such as texture, structure, internal drainage, and depth affect water and nutrient availability and root growth.

It is important to feel and observe your soils through the different seasons to better learn their physical properties. It is easy to add fertilizers to the soil to increase your vegetable harvest. Changing your soil's physical properties to increase yield is more difficult but ecologically more sustainable. That may involve breaking up a compacted soil layer or adding organic matter to increase pore space and improve friability.

COLOUR

Colour can tell you some important things about your soil's condition. Colour is determined by:

1. Organic matter content;
2. Drainage conditions; and
3. Degree of oxidation.

Surface Soil

- Colours vary from almost white, through shades of brown and gray, to black.
- Light colours indicate low organic matter content, while dark colours may indicate a high content.
- Light or pale colours are frequently associated with sandy soils from which minerals and organic matter are readily leached.
- Shades of red or yellow, particularly when associated with clay textures, usually indicate that subsoil material has been incorporated into the surface layer.
- Dark-coloured soils absorb and lose heat more rapidly than light-coloured soils. This means that darker soils will warm up and dry out more quickly in spring time but also be subject to greater variation in daily soil temperatures.

Subsoil

- Colours indicate the degree of iron oxidation in the soil.
- Red to brown colour of subsoils comes from iron coatings under well-aerated conditions.
- In wet soils with low oxygen levels the iron coatings have been chemically and biologically removed, and the gray colour of background soil minerals shows.
- Yellow and gray mottled subsoils indicate slow drainage and poor aeration.

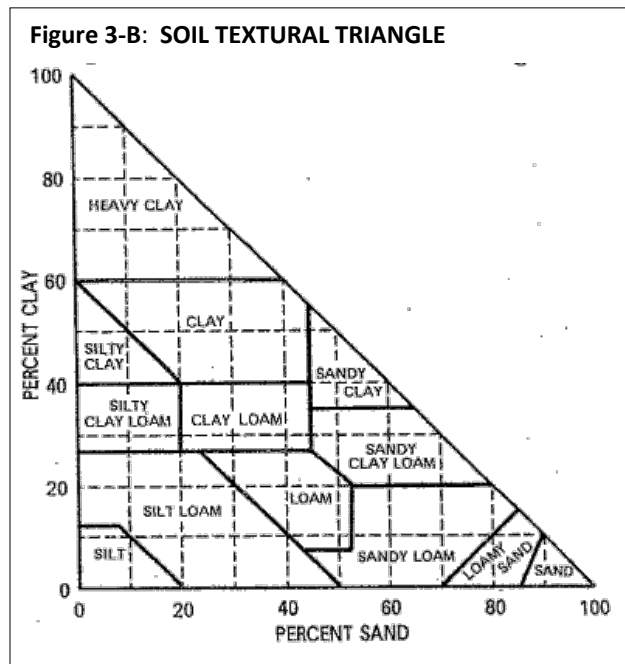
SOIL TEXTURE

The relative distribution of the different-sized soil mineral particles, sand, silt and clay, is referred to as **texture**. The arrangement of those particles determines the soil structure. Soil texture remains fairly constant through time while soil structure can be improved, principally through the incorporation of organic matter, or made worse through erosion and compaction.

Compare soil to the construction of a building. Think of "soil texture" as the lumber, brick and stone used to build it.

The "soil structure" would be the fitting together of the textural components with organic matter serving as the mortar and nails.

In each textural class there is a range in the amounts of sand, silt, and clay that can be present. For example, loam is a textural class of soil that contains 7%-27% clay, 28%-50% silt, and less than 52% sand (see **Figure 3-B**).



Source: Denholm, K.A., L.W. Schut, D.E. Irvine. 1993.
Field Manual for Describing Soils in Ontario.
 Ontario Centre for Soil Resource Evaluation, Guelph
 Agriculture Centre.

Principal Surface Soil Classes in Ontario

Most surface soils in Ontario fall into five general textural classes. Each class name indicates relative amounts of sand, silt, and clay in the soil.

1. Silt loam - Silt is the dominant-sized particle in silt loam, which feels quite smooth or floury when rubbed between the thumb and fingers.
2. Loam - When rubbed between the thumb and fingers, an approximately equal influence of sand, silt, and clay is felt.
3. Silty clay loam - When moist it becomes somewhat slick or sticky, or both. Noticeable amounts of both silt and clay are present in silty clay loam, but silt is a dominant part of the soil.
4. Sandy loam - Feels quite sandy or rough but contains some silt and a small amount of clay. The amount of silt and clay is sufficient to hold the soil together when moist.
5. Clay loam - Clay dominates a clay loam, which is hard when dry and slick and sticky when wet.

Other textural designations of soils can be seen in **Figure 3-B: Soil Textural Triangle**.

GET IN TOUCH WITH YOUR SOIL

Texture is determined in the field by rubbing or feeling moist-to-wet soil between the thumb and fingers. Pick up a handful of slightly moist soil to quickly determine the approximate texture of a soil. Hold it up to the sunlight. Do you see the glint of many or only a few grains of sand? Try to create a ribbon by pressing the soil between thumb and forefinger. Keep forcing the ribbon until it breaks. An 8 cm to 10 cm long ribbon indicates fairly high clay content.

ESTIMATING SOIL TEXTURE AT HOME

Fill a jar 2/3 full of water. Add soil until the jar is almost full. Then add 15 ml of water softener or dish detergent, seal lid tightly and shake vigorously.

Let the soil settle for two to three hours at least. The largest and heaviest sand particles will sink to the bottom, then the silt layer; then the extremely small clay particles on top. If the water in the jar does not clear within a few hours, wait overnight. Clay particles are so small that they can stay suspended for a long time.

Mark off the thickness of the different layers of settled soil on a piece of paper. You can estimate your soil texture by comparing the relative proportions (%) of the different layers and using the textural triangle.

SOIL STRUCTURE

Soil particles are grouped together in the soil formation process to create structural pieces called **peds** or **aggregates**. In topsoil, the structure is usually granular unless it is disrupted. Soil aggregates are rounded and vary in size from that of a pinhead to large peas.

Soil structure is closely linked with air and water movement. Strong structure (crumb-like) allows favorable movement of air and water, while poor structure slows it down. Water can enter topsoil that has a strong granular structure more rapidly than one with a weak structure.

Since plant roots grow in the same channels through which air and water move, a strong granular structure allows for extensive root development, while a weak structure discourages it. Water, air and plant roots move more freely through subsoils with a blocky structure than they do through those with a platy structure (aggregates are thin and closely packed together). A strong structure in surface soil is promoted by an adequate supply of organic matter but can be destroyed by compaction or by working the soil when it is too wet or too dry.

When you compress soil with your footsteps, a vehicle or rototiller, pore spaces collapse and air and water are forced out of the soil. In clayey soils, low in organic matter, such **compaction** may cause long-term damage to the soil structure.

TOO WET TO PLOW?

Eager gardeners sometimes till their garden soil when it is too wet. If the clay content is fairly high, such tilling can create large clods which do not easily break apart.

Pick up a handful of soil before tilling and form it into a ball. You're ready to till if the ball breaks apart easily when gently bounced in your hand.

Plant roots change soil structure. As they grow, roots tend to enlarge the openings in the soil. When roots die and decay, they leave channels for the movement of air and water. Humus from decaying roots serves as a cementing agent and helps form stable, granular aggregates. Besides the plants we see, bacteria, fungi, and other forms of life also grow in the soil. As they die they too, enrich the soil.

DEPTH

The effective depth of a soil for plant growth is the vertical distance from the surface to a layer that essentially stops the downward growth of plant roots. The barrier layer may be rock, sand, gravel, heavy clay, or a partly cemented layer. Terms used to express effective soil depth are:

- Very shallow - less than 25 cm.
- Shallow - 25 to 50 cm.
- Moderately deep - 50 to 90 cm.
- Deep - 90 to 150 cm.
- Very deep - 150 cm.

Deep soils hold more plant food and water, allowing for maximum root penetration and produce larger crops than shallow soils with similar textures.

Susceptibility to Erosion

Soils that have lost part or entire surface horizon through past erosion are usually harder to till and less productive than those with thick surface horizons. The principal reasons for soil erosion in residential landscapes are a lack of sufficient vegetative cover during the fall and winter months, and gardening on steep slopes. Grading and construction activities on new home sites often lead to soil erosion and compaction.

IMPROVING SOIL STRUCTURE

Poor soil is a chief complaint among both novice and experienced gardeners. Fine-textured, clayey soils tend to drain poorly, restrict root growth, and form impervious layers. Very sandy soils tend to be low in organic matter and require more frequent watering and feeding. Many symptoms of poor plant health can be traced, in part, to poor physical characteristics.

"CREATING" BETTER SOIL

Gardening in difficult soils (eroded, compacted, high clay content, new subdivision) can be most frustrating. In these situations it is best to create fertile soil by adding large quantities of topsoil and/or organic matter. It is important to remember that soil texture is a constant, unchanging characteristic of a soil. Soil structure, however, can be either improved or destroyed by human activities. Follow these tips:

- Begin with easily worked small spaces, borders and raised beds.

- Work toward a goal of having 20%-30% organic matter in the top 8-20 cm of the soil.
- Begin by incorporating 60 to 90 litres of available compost, leaf mold, grass clippings or peat moss into an area of 10 m² of soil. Or use 40 to 60 litres of aged horse, sheep or cow manure or 20 litres of chicken manure. Always add a nitrogen source when incorporating hay, straw or sawdust.
- Commercially available mixtures of topsoil and leaf compost make excellent "instant" gardens.
- Soils with organic matter content greater than 50% tend to dry out rapidly.

Regularly adding manures, compost, cover crops, and other organic materials can improve your soil's physical qualities (structure) and effectively raise the nutrient level, thus reducing the need for synthetic fertilizers. A desirable soil quality does not come about with the single addition of organic material as it requires a serious and continuous soil building program.

Table 3-1: CHOOSING SOIL AMENDMENTS

Homegrown Amendments	
Yard and Kitchen Waste Compost	Is produced by microbial decomposition of mixed raw organic materials. (Detailed instructions on composting are given in Chapter 4, "Backyard Composting")
Farmyard Manure	Should be composted prior to incorporation. Best to add in the fall. Add a source of nitrogen to manure containing large quantities of bedding.
Cover Crops	Versatile, inexpensive method of soil improvement. Also known as "green manures" (annual rye, oats, wheat and hairy vetch); are usually planted in the fall for spring incorporation. For very difficult soils, grow a mixture of legumes and grasses for 6-12 months, mowing prior to seed formation. (See Chapter 13 "The Vegetable Garden")
Leaf Compost	Many excellent products available; can be purchased in mixture with topsoil or home-made.

Cover crops benefit the soil by:

- Increasing organic matter content.
- Picking up and holding nutrients that might leach over the winter.
- Reducing erosion and loss of topsoil. Breaking up compacted soil and increasing porosity and tilth (especially rapeseed, rye and alfalfa).

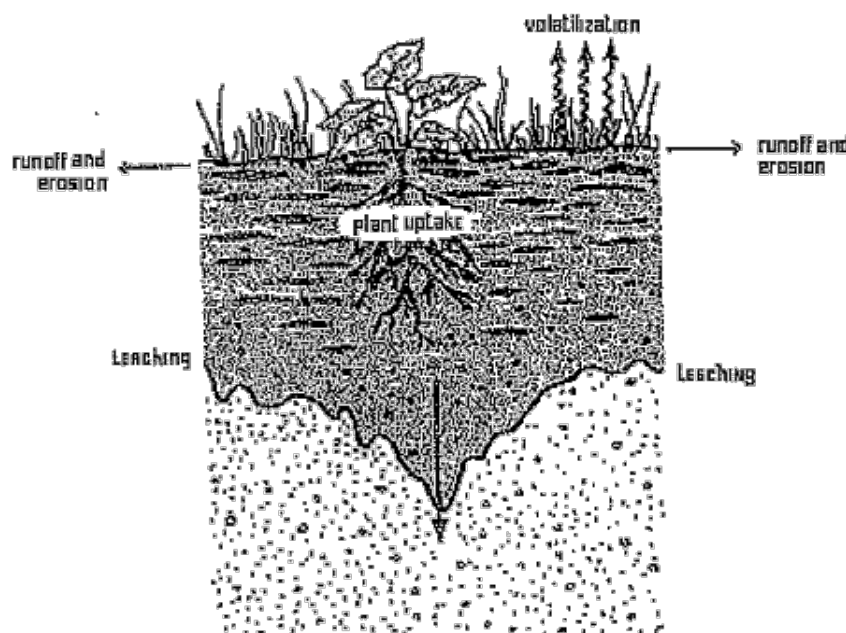
Purchased Materials	
Peat	Relatively expensive; very acidic, good for lowering soil pH.
Sand	Minimum of 50% by volume needed to improve water drainage and aeration of fine-textured soils. Can worsen the situation by causing clay to "set up" like concrete.
Gypsum	Calcium sulfate or "land plaster" causes clay particles to flocculate or form larger aggregates. Will not raise soil pH.
Uncomposted bark and wood mulch	Take a long time to break down. Will "rob" soil of nitrogen and may interfere with planting.
Topsoil	Use caution when purchasing this unregulated product. Sellers are not held to verifiable standards. Inspect closely and request information on origins.
Bio-solids Compost	Treated sewer sludge that is further composted. Some are labeled for use on food crops. Heavy metals content considered very low. Soluble salt content is high; material should be leached with water prior to planting.
Pearlite	A material that is mined from volcanic deposits and processed. Very light weight and porous. Used primarily in containers.
Vermiculite	Processed mica. A porous material with good water and nutrient holding characteristics. Used mainly in containers.
Calcined Clay	Processed and screened clay materials. Used where mechanical strength is required, e.g. Turface®.

PLANT NUTRIENTS

Plants need 17 nutrients for normal growth, but four elements - carbon, hydrogen, oxygen (from air and water) and nitrogen (in the soil) make up 95% of plant solids. Available forms of nitrogen are derived for plant use by organic matter decomposition. Five additional macronutrients from the soil's mineral fraction are required by plants in large amounts: phosphorus, potassium, calcium, sulfur and magnesium (see **Figure 3-C, Table 3-2, 3-3**).

Some plant nutrients move within the plant to satisfy deficiencies in the total plant. Such nutrients are said to be mobile (e.g., phosphorous). Other nutrients, once incorporated into the plant tissue, are fixed (not mobile) and cannot be used by other plant parts to meet deficiencies (e.g., calcium).

Figure 3-C: FATES OF NITROGEN IN SOIL



NITROGEN

Nitrogen deserves special attention because it has a major affect on the growth and yields of crop plants and can be a source of groundwater pollution. After carbon, oxygen and hydrogen, it is required by plants in the greatest amount (proteins are 16% nitrogen). It is found only in the organic fraction of soil and is easily leached in the nitrate form. An annual plant's need for N is usually greatest 3-4 weeks after seedling emergence or after transplanting.

Nitrogen exists in the soil in organic and inorganic forms (see **Table 3-2**). Nitrogen in your soil is continually transformed between organic and inorganic forms through biological and chemical reactions. These processes constitute the nitrogen cycle (see **Figure 3-D**).

Table 3-2: CHEMICAL FORMS OF NITROGEN COMMONLY FOUND IN SOIL

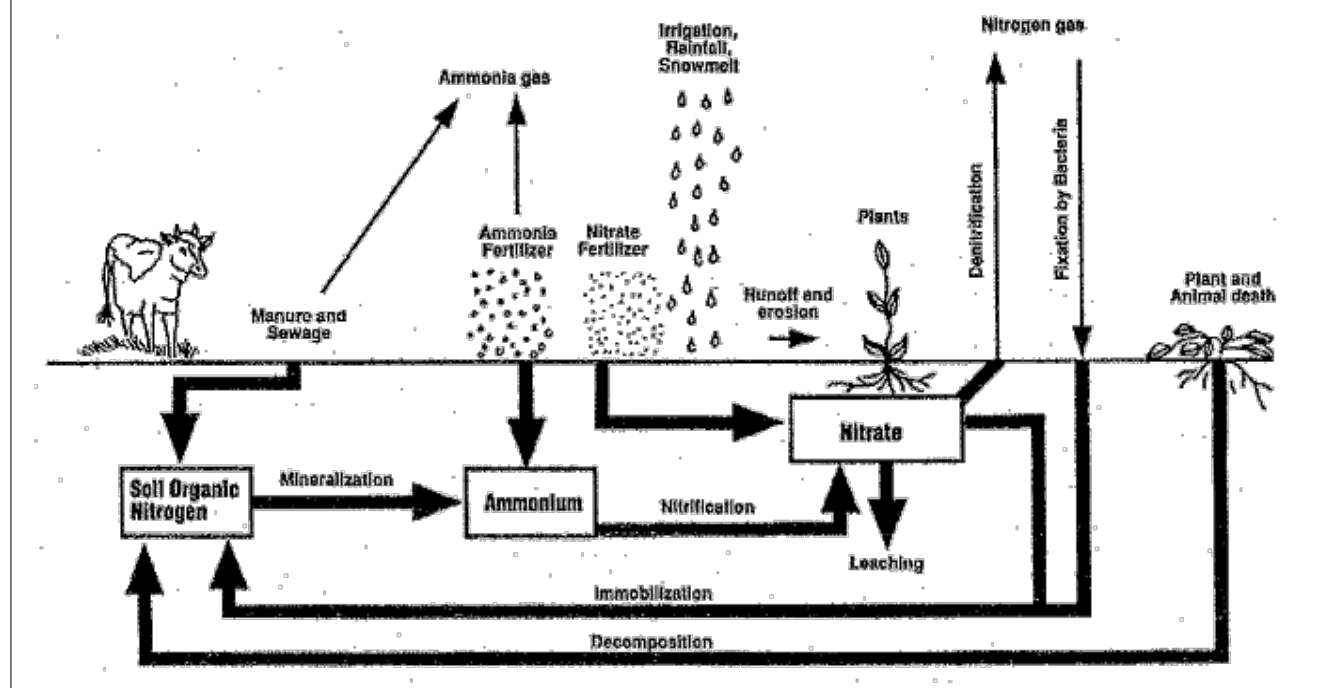
Compound Group	Name(s)	Symbol(s)	Remarks
Inorganic	Ammonium	NH_4^+	Can absorb onto clay and organic matter, preventing large amounts from moving with water. Plant-available.
	Nitrite	NO_2^-	Mobile with water, but not found in large amounts.
	Nitrate	NO_3^-	Typically present in relatively large amounts and very mobile with water. Preferred by most plants.
Organic	Proteins, Amino Acids	R-NH_2	Contained in manure, organic wastes, nucleic acids, and living and dead plants and animals. Immobile. Not plant-available.

Source: Van Es, M., S.D. Klausner, W.S. Reid, 1991.

Nitrogen and the Environment.

Information Bulletin 218, Cornell Cooperative Extension.

Figure 3-D: THE SOIL NITROGEN CYCLE



NITROGEN CYCLE TERMS

Fixation - Although the air we breathe is 78% nitrogen, the gaseous form is useless to plants. However, certain free-living bacteria and bacteria (genus-Rhizobium) living in nodules on the roots of legumes can convert atmospheric nitrogen into plant-available forms.

Immobilization (a.k.a. "robbing the soil of nitrogen") - Occurs when highly carbonaceous materials, such as straw, woodchips and sawdust, are incorporated into the soil. Microbes need nitrogen to digest the organic matter. Soil microbes "eat first at the nutrient table" and convert plant-available inorganic forms of N to organic forms (proteins). This may cause a slight and temporary nitrogen deficiency in your garden plants. Nitrogen remains immobilized in the microbes until they die and decompose. Fresh green wastes, such as grass clippings, are higher in nitrogen than dry materials. Mild immobilization may be caused by manure with large amounts of bedding.

Mineralization - This is the conversion of organic N from plant and animal remains to inorganic ammonium, which is then held by soil colloids, used by plants or transformed into nitrate N.

Nitrification - This is the conversion of ammonium to nitrites and then to nitrates by soil microbes. The process is accelerated when your soil is warm, moist and well aerated.

Denitrification/Volatilization - In poorly drained soils nitrates are converted by bacteria to nitrogen gas which escapes into the atmosphere (denitrification). Ammonia gas can also be lost to the atmosphere when manure is dropped on the garden and not incorporated (volatilization).

Table 3-3: KNOW YOUR PLANT NUTRIENTS

MAJOR NUTRIENTS				
Element & Symbol	Function in Plant	Excess Symptoms	Deficiency Symptoms	Comments Deficiencies are most likely to occur
Nitrogen (N) • absorbed as NO_3^- nitrate and NH_4^+ ammonium • NO_3^- can be leached	Gives dark green colour to plant. Increases growth of leaf crops. Stimulates rapid early growth.	Dark green colours; succulent, spindly growth. Retarded maturity, bud and fruit drop.	Light green to yellow leaves (lower leaves first). Stunted growth. N is mobile in the plant and can be relocated where it is most needed.	Mostly on very light soils which are easily leached.
Phosphorus (P) • absorbed as H_2PO_4^- and HPO_4^{2-}	Stimulates early root growth. Gives plants a rapid and vigorous start. Is important in seed and flower formation. Increases resistance to disease.	Possible tie up of zinc, iron and cobalt.	Red or purple leaves and stems. Stunting; reduced flowering, fruiting and root growth. P is mobile within the plant.	On acid soils; temporary deficiency occurs on cold, wet soil. Not easily leached. Most P in soils is in a form unavailable to plants.
Potassium (K) • absorbed as K^+	Increases plant vigour and disease resistance. Stimulates production of strong, stiff stalks, sugars, starches and oils. Enhances flavour, colour and cold hardness.	Coarse, poor coloured fruit. Reduced absorption of Mg, Ca and even N.	Reduced vigour and yield; susceptibility to diseases. Thin skin and small, misshaped fruit. Leaf margin scorch. Necrotic lesions at leaf tips and between veins. K is mobile within the plant.	Leaches from very light soils and organic soils.
Sulfur (S) • absorbed as SO_4^{2-}	Protein building block.	Sulfur burn from too low pH.	New leaves are light green or yellowish between veins.	Rarely occurs. Sulfur is leachable and immobile in the plant.
Calcium (Ca) • absorbed as Ca^{++}	Needed for growth and cell division.	Reduces the intake of K and Mg and is more evident at high pH levels.	Affects growing point of plants. Causes cell breakdown (blossom-end rot) and leaf-tip die back.	On acid soils or soils with high potassium levels. Very dry soils become deficient. Limited mobility in plant.
Magnesium (Mg) • absorbed as Mg^{++}	Aids photosynthesis. Key element in chlorophyll.	Reduced absorption of Ca and K.	Mottled or interveinal chlorosis. Reduced seed production. Whitish patches on older leaves. Cupped leaves. Mg is mobile within the plant.	On acid soils, light soils easily leached; and high potassium soils.

Table 3-3: KNOW YOUR PLANT NUTRIENTS

MINOR NUTRIENTS				
Element & Symbol	Function in Plant	Excess Symptoms	Deficiency Symptoms	Comments Deficiencies are most likely to occur
Manganese (Mn) • absorbed as Mn^{++}	In enzyme system.	Small dead areas in the leaves with yellow halos. Associated with excessive use of hardwood mulch.	Mottled or interveinal chlorosis or necrosis of leaves. Stunted growth. Mn is not mobile.	On soils with pH above 6.8 and high Ca. Problem with "acid-loving" plants.
Copper (Cu) • absorbed as Cu^{++} and Cu^+	Enzyme activator.	Prevents the uptake of iron, and causes stunting of roots at low pH.	New growth is small, wilted and occurs primarily on organic soils.	On muck or peat soils.
Zinc (Zn) • Zinc Zn^{++}	Aids in cell division; needed for enzyme and auxin formation.	Uncertain, but could appear as an iron or magnesium deficiency.	Small, thin, yellow leaves "Little-Leaf" syndrome. Interveinal chlorosis or necrosis.	On wet, heavy soils in early spring; may be due to excess phosphorus fertilization.
Iron (Fe) • absorbed as Fe^{++} and Fe^{+++}	A catalyst in the enzyme system. Hemoglobin in legumes.	None known.	Interveinal chlorosis. Young tissues appear white. Fe is not mobile in the plant.	Deficiencies occur on soils with pH above 6.8 and soils that are wet or compacted. Poorly drained oxygen-deficient soils are often associated with Fe deficiency. Availability can be a problem with acid-loving plants.
Boron (B) • absorbed as BO_3^- , H_3BO_3	Affects absorption of other elements.. Affects germination of pollen tube.	Leaves turn yellowish red. Interveinal necrosis.	Small leaves. Heart rot and corkiness. Multiple buds. Failure to set seed. Death of apical bud. Chlorosis at leaf bases.	On light, sandy soils and soils with pH above 6.8. .Boron is not mobile within the plant.
Molybdenum (Mo) • absorbed as $MoO_4^{=}$	Aids in the utilization of N.	Poisonous to livestock. Symptoms unknown.	Looks like nitrogen deficiency; symptoms in plants vary greatly. Leaves may become twisted.	On very acid soils.
Chlorine (Cl) • absorbed as Cl^-	A factor, along with Manganese, in photosynthesis stimulation.	Salt burn, desiccation.	Wilting, bronzing, chlorosis/necrosis stunted and thickened roots.	Deficiencies rarely take place because of high solubility and availability.

MICRONUTRIENTS

Micronutrients are essential for good plant growth but are required in very small quantities. For example, a productive, 10m² vegetable garden might require 2 kg of nitrogen each year but only a few teaspoons of a minor element. Because most micronutrients are not mobile, deficiency symptoms are usually found on new growth. Micronutrient availability in the soil is highly dependent on pH and the presence of other nutrient ions. A proper balance between micronutrients, especially the heavy metals, is important because an excess of one element may show up as a deficiency of another.

Incorporating organic matter into your garden soil on a regular basis will provide your plants with an adequate and steady source of micronutrients. For many types of flower and vegetable plants, the micronutrient needs can also be derived entirely from organic matter. It is estimated that 40-44 nutrients are found in green tree leaves. If collected in the fall, these nutrients can be stabilized and released through the composting process.

LEAD IN SOILS

Garden soils contaminated with lead can pose a health risk if vegetables and fruits from the garden are consumed. Soil can be contaminated with lead from chipped or peeling paint around older structures, industrial sites, industrial sludge with heavy metals; and until recently, from auto emissions, old lead plumbing pipes or even old orchard sites in production, when lead arsenate was used as an insecticide. Lead does not leach out of soil; contamination is long term.

We do not require lead in our diet or environment. No detrimental health effects have been noted with the very low levels that naturally occur in soils (15-40 ppm). However, lead contamination can raise the lead level in the body and thus poses a substantial health risk, especially to children under the age of 6, and pregnant women.

Testing the Soil

If you suspect that your soil is contaminated with lead, collect a proper soil sample from the suspected area and have it tested at a reliable laboratory.

In areas with severe lead contamination, soil may need to be removed and replaced.

NUTRIENT UPTAKE BY PLANT ROOTS

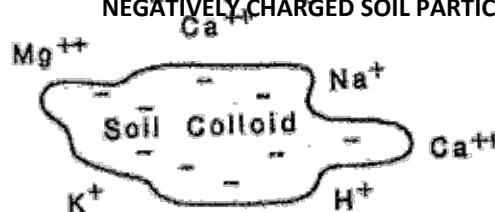
Plant nutrients must be dissolved in a soil and water solution before root hairs can pick them up for transport into plant tissue. The dissolved nutrients are called **ions** which are charged components of individual molecules. Positively charged ions are called **cations** and negatively charged ions are called **anions**. Ions typically enter the soil solution by way of dissolved salts. For example, the salt potassium nitrate, KNO₃, dissolves into K⁺ and NO₃⁻.

CATION EXCHANGE CAPACITY (CEC)

Cations compete for sites on the negatively-charged clay and organic matter particles. Anions with their negative charge are not retained by the colloids, making them especially subject to leaching from the soil solution. Thus, ammoniacal nitrogen, NH₄⁺, is held by the soil colloids against leaching, while nitrate nitrogen, NO₃⁻, is readily leached. This, of course, has important implications for preventing nitrate pollution of groundwater and surficial water bodies.

The "exchange" occurs primarily between H⁺ ions exuded from root hairs and cations held by soil colloids (clay and organic matter). For example, a H⁺ ion will leave a root hair and move through soil water to a nearby colloid; while a K⁺ ion moves from that colloid site to the same root hair where it is taken up as a plant nutrient (see **Figure 3-E**). The ease with which one cation can displace another cation from soil colloids is as follows: H⁺ > Ca⁺⁺ > Mg⁺⁺ > K⁺ > Na⁺. Thus, hydrogen can easily displace all of the cation nutrients needed for plant growth, calcium to a lesser degree, and so on. The total potential charge of the soil particles, which dictates the cation holding capacity of the soil, is termed the cation exchange capacity or CEC. It is easy to see that sandy soils can hold many fewer cations than clay soils. Adding organic matter will increase your soil's nutrient holding capacity. CEC is indicated on many soil test reports as a value between 0 and 40. CEC values range from 5 (poor sandy soils) to 40 (high organic matter soils). A value of 10-15 is considered adequate.

Figure 3-E: CATIONS COMPETE FOR SITES ON A NEGATIVELY-CHARGED SOIL PARTICLE



It is important to maintain a balance between the nutrients needed for good plant growth in the soil solution. When a nutrient is not absorbed by the plant in an adequate amount, it will result in the plant showing a deficiency symptom. A plant deficiency may result from a nutrient being deficient in the soil; the nutrient being out-competed by a more active cation, or overwhelmed by a less active cation; or the nutrient may be present, but tied up, because of an unfavorable pH.

SOIL pH

Soil pH is a measure of the activity of hydrogen ions (H^+) (acid-forming) and hydroxyl ions (OH^-) (alkaline-forming) in the soil or other plant growing media. The scale for measuring this contains 14 divisions known as pH units. These ions neutralize each other by combining to form a molecule of water (H_2O).

- Soil with a pH of 7 is neutral (hydrogen ions equal to hydroxyl ions).
- The greater the excess of hydrogen ions, the more acidic the soil will be, with pH values below 7.
- The greater the excess of hydroxyl ions, the more alkaline the soil will be, with pH values above 7.

pH is a logarithmic scale - each step represents a power of 10. Soil with a pH of 8.5 has 10 times more free hydroxyl ions than a soil with a pH of 7.5, and soil with a pH of 4.5 has ten times more free hydrogen ions than a soil with a pH of 5.5.

Table 3-4: LIMESTONE NEEDED TO RAISE SOIL pH

Change in pH Desired	TEXTURE OF TOPSOIL Limestone (g/m^2)				
	Sand	Sandy Loam	Loam	Silt Loam	Clay Loam
4.0-6.5	293	562	786	932	1,123
4.5-6.5	244	469	649	786	932
5.0-6.5	195	381	513	630	742
5.5-6.5	197	293	381	449	518
6.0-6.5	68	156	200	249	269

Table 3-5: APPROXIMATE QUANTITY OF SOIL SULFUR NEEDED TO INCREASE SOIL ACIDITY TO pH 6.5

Change in pH Desired	TEXTURE OF TOPSOIL Sulfur (g/m^2)		
	Sands	Loams	Clay
8.5-6.5	224	278	336
8.0-6.5	134	168	224
7.5-6.5	56	90	112
7.0-6.5	11	17	34

pH AND NUTRIENTS

A near neutral or slightly acid soil is generally considered ideal for most plants. Extremes in pH have a major impact on the availability of plant nutrients and the soil concentration of the plant-toxic minerals. In highly acid soils, (pH values under 5.0), aluminum and manganese can concentrate at toxic levels while calcium, phosphorus, and magnesium become tied up and unavailable.

- At pH values of 7.0 and above, phosphorus, iron, copper, zinc, boron, and manganese become less available.
- The thickness of the bar in **Figure 3-F** indicates availability of the element at different pH values.

Many ornamental plants require slight to strong acid soil. These species develop iron chlorosis when grown in soils in the alkaline range. Iron chlorosis is often confused with nitrogen deficiency because the symptoms (a definite yellowing of the leaves) are similar. Iron chlorosis can be corrected by reducing soil pH.

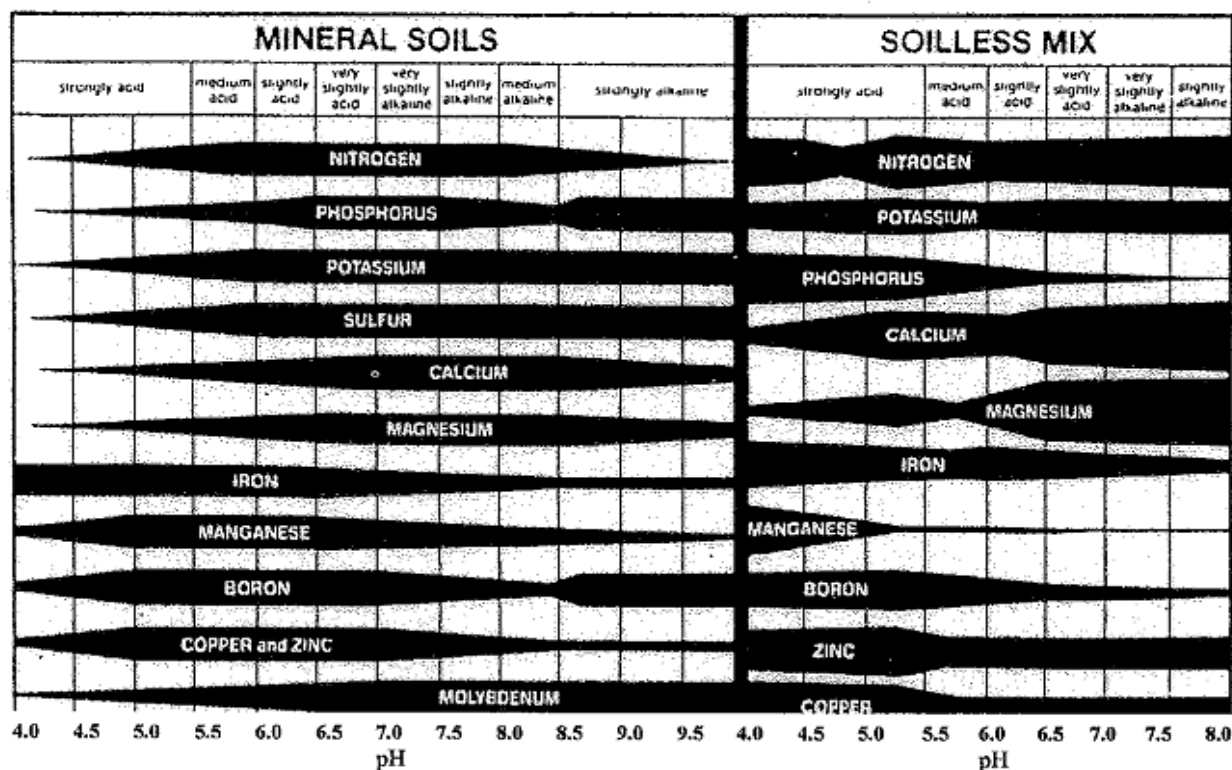
Applying chelated iron formulations to the soil, or spraying foliage with solutions of iron chelate or iron (ferrous) sulfate, is a temporary solution.

Most nutrients do not require the addition of a chelate to aid absorption. Only a few of the metals, such as iron, benefit from added chelates. The types of chelate used will depend on the nutrient needed and the soil pH.

What is a Chelate?

The term chelate (pronounced "key-late") comes from the Greek word for claw. Chelates are chemical claws that help hold metal ions, such as iron, in solution, so that the plant can absorb them. Different chemicals can act as chelates from relatively simple natural chelates like citrate, to more complex manufactured chemicals. When a chelate metal is added to the soil, the nutrient held by the chelate will remain available to the plant.

Figure 3-F: INFLUENCE OF pH ON THE AVAILABILITY OF PLANT NUTRIENTS IN MINERAL SOILS AND SOILLESS MIXES
(Widest portion of dark areas indicates the greatest nutrient availability)



MODIFYING pH

By applying certain materials to the soil, adjustments can be made in pH values, but these changes often take place slowly and are not usually permanent. Decisions should be made based on a reliable soil test report.

RAISING pH

Soil pH can be raised, making it less acid, by the application of limestone (see **Table 3-4**).

- Ground agricultural limestone is the most frequently used.
- Dolomitic limestone adds calcium and magnesium as it increases pH.
- The finer the grind the more rapidly it becomes effective. Different soils and crops will require a different amount of lime to adjust the reaction to the proper range.
- Soils low in organic matter require much less lime than soils high in organic matter to make the same pH change.

The process and reactions by which lime reduces soil acidity are very complex. The reaction works like this:

Calcium ions (Ca^{++}) from the lime flood the soil solution and replace hydrogen ions (H^+) on the soil colloids. These freed hydrogen ions are then neutralized by combining with hydroxyl ions (OH^-) to form water. This decrease in hydrogen ion concentration produces an increase in soil pH.

Remember, the reverse of the above process can also occur. An acid soil can become more acid. As ions such as Ca^{++} , Mg^{++} and K^+ are removed, usually by crop uptake, they can be replaced by H^+ . These ions can also be lost by leaching, again being replaced by H^+ .

Wood ashes can also be used as a soil amendment to raise the soil pH. They contain potash (potassium), phosphate, boron, and other elements.

- It will take twice as much wood ash as limestone to produce the same effect.
- Ashes should not come into contact with germinating seedlings or plant roots as they may cause root damage. Spread on a thin layer during the winter, and incorporate into the soil in the spring. Check pH yearly if you use wood ashes.
- Never use coal ashes or large amounts of wood ash (no more than 100 g/m^2) as toxicity problems may occur.

LOWERING pH

If soil pH is above 6, the pH can be lowered, making it more acid, by the application of iron sulfate (see **Table 3-5**).

For medium-textured soils, add 5.5 to 6.4 kg of iron sulfate per 100 m^2 of area to lower the pH by $\frac{1}{2}$ a unit. These are general guidelines. Actual applications should be based on a reliable soil test report.

If pH is too high, a sulfur source can be added to the soil to reduce alkalinity (see **Table 3-5**). Do not use large amounts of aluminum sulfate to lower the soil pH.

At low soil pH, aluminum is quite soluble, and the addition of aluminum sulfate to such soils will lead to aluminum toxicity.

Adding elemental sulfur to a soil that has a pH above 6.0 will not lower the pH, as the microorganisms that attack elemental sulfur are not very active until the pH has been lowered to 6.0. It is necessary to use iron sulfate to lower the pH to 6.0 and then use elemental sulfur if a pH less than 6.0 is desired.

FERTILIZER

Fertilizer is a substance added to soil to improve its fertility. Since a variety of elements contribute to soil fertility, many individual elements and combinations of elements can be considered fertilizers. Natural and synthetic fertilizers are available in a wide variety of analyses and forms.

ANALYSIS AND GRADE

- "Fertilizer analysis" means how much of an element is in a formulation, based on percentage by weight.
- All fertilizers are labeled with three numbers that indicate the guaranteed analysis, or the fertilizer grade.
- These three numbers give the percentage by weight of nitrogen (N), phosphate (P_2O_5), and potash (K_2O).

Regulations require that actual analysis values must be within certain limits of the labeled grade. Often, to simplify matters, these numbers are said to represent nitrogen, phosphorus, and potassium, or N-P-K. We should remember that it is not N-P-K, but $\text{N-P}_2\text{O}_5\text{-K}_2\text{O}$. For example, if we have a 50 kg bag of fertilizer labeled 20-5-10, there are 10 kg of N, 2.5 kg of P_2O_5 and 5 kg of K_2O . This totals 17.5 kg of nutrients.

The nutrient amounts do not add to 100%, for several reasons. The nutrients are in a compound or material that contains other elements. For example, much of the K used in fertilizers is in the form of potassium chloride. A fertilizer may also contain clay-based fillers or conditioners to ensure good physical properties, and light-weight absorbents to give a slow release of nutrients as well as other nutrient sources besides N, P, and K. In some cases, limestone is added both as filler and as a nutrient to neutralize the acidifying effects of some N sources.

The information contained in fertilizer labeling has been well standardized, and the consumer is protected by laws requiring manufacturers to guarantee the claimed nutrients.

COMPLETE FERTILIZERS

Complete fertilizers contain each of the three major plant nutrients: nitrogen, phosphorus, and potassium. Grades such as 10-10-10, 16-8-8, and 5-10-10 represent complete fertilizers. Grades such as 0-25-25 and 20-0-10 represent incomplete fertilizers.

SPECIAL-PURPOSE FERTILIZERS

When fertilizer shopping, you will find fertilizers packaged for certain uses or types of plants such as "Rhododendron and Azalea Food" or "Rose Food". The rhododendron-azalea fertilizers belong to an old established group, the "acid plant foods". Some of the compounds used in these fertilizers are chosen because they have an acid reaction, so they are especially beneficial for "acid-loving plants" where soil is naturally neutral or alkaline.

Other fertilizers packaged for specific plants, such as those for roses, often do not have a valid research basis. Compare, for example, the fertilizer ratios of three different brands of rose foods, which may be quite different.

Perform a soil test before purchasing any expensive special-purpose fertilizers. It is not possible to make a blanket statement that one fertilizer is best for every area of the province. It is true that different plants use different nutrients at different rates. What is unknown is the reserve of nutrients already in the soil; this changes with every soil type and location.

ORGANIC VERSUS INORGANIC FERTILIZERS

There is much confusion over the terms organic, natural, inorganic and synthetic when applied to fertilizers. It is important to keep in mind that nutrients are available to plants in only one or two forms regardless of the source. Put another way, "a nitrate molecule is a nitrate molecule" whether from manure or ammonium nitrate.

Inorganic

These are manufactured products made from non-living items and are referred to as synthetic or chemical fertilizers. Examples include ammonium sulfate, 21-0-0, commonly used on acid-loving plants like blueberry and azalea; superphosphate, 0-20-0, phosphate rock treated with sulfuric acid; granular fertilizers, such as 10-10-10 and 10-6-4; and liquid fertilizers, such as "Miracle Gro".

- Ammonium nitrate: Half the N is held in NH_4^+ cations and half as NO_3^- anions. Ammoniums can volatilize at the soil surface. Nitrate (NO_3^-) can be leached. This is one of the least expensive forms of N. It can cause physiological drought if applied in excessive amounts. 33-0-0.
- Ammonium sulfate: All N is in NH_4^+ form. The most acidifying of all N fertilizers. A good choice when pH is high. Contains 24% sulfur. Less expensive than ammonium nitrate, UF, IBDU or SCU (see below). 21-0-0.
- Urea: All N is initially available as NH_4^+ . Should be tilled or watered into the soil to reduce potential for volatilization. 46-0-0.
- Urea formaldehyde (UF): A slow release nitrogen source that is made available through microbial degradation and therefore is somewhat temperature dependent. Low risk of foliar burn. 38-0-0.
- Isobutylidene diurea (IBDU): A slow release nitrogen source that is only somewhat water-soluble. Various particle sizes determine the rate of nitrogen release. IBDU is an expensive nitrogen source. 31-0-0.
- Sulfur-coated urea (SCU): A slow release nitrogen source. Individual particles have different thicknesses of sulfur coatings. These coatings are only slowly permeable to water and because of different thicknesses will release nitrogen at different times. 36-0-0.
- Calcium Nitrate: All N is in NO_3^- form; 19% calcium. Useful where soluble N and Ca are required, e.g., some fruits and vegetables. 15-0-0.
- Potassium nitrate: All N is in NO_3^- form. Most commonly used in fruit and vegetable production.

Is 44% K₂O. 13-0-44.

- Superphosphate: Contains 20% Ca and 12% S. Not common. 0-20-0.
- Triple superphosphate: Can be useful when only Phosphorus is required. 0-46-0.
- Monoammonium phosphate: Often occurs in dry blended fertilizers. A good source of phosphorus for seedlings. 11-48-0, 11-52-0.
- Diammonium phosphate: Frequently a component of dry-blended fertilizers. Can cause ammonia burn if placed too close to seed. Acidifying. 18-46-0.
- Muriate of potash: Most common potash carrier. Contains KCl and has a high level of salt activity. 0-0-60.
- Potassium sulfate: Contains 18% S. Uncommon, but could be used on soils with high pH. 0-0-50.

Organic

The term natural organic is applied to fertilizers derived solely from the remains, or a by-product, of a once-living organism. Various wastes and by-products of the plant and animal processing industries can be used as fertilizers (see **Table 3-6**). Cottonseed meal, blood meal, bone meal, hoof and horn meal, and all manures are examples of organic fertilizers.

When packaged as fertilizers these products show the fertilizer grades on the label.

Human-made organic materials used for fertilization are termed synthetic organics. Examples are urea (a water soluble nitrogen source made by a reaction between ammonia and carbon dioxide under controlled conditions); ureaform (made by reacting urea and formaldehyde); and IBDU (made by reacting urea and isobutyraldehyde) (see **Chapter 10, "Turf Management"**).

- Some organic materials, particularly composted manures and sludges, are sold as soil conditioners and do not have a nutrient guarantee although small amounts of nutrients are present.
- Natural fertilizers, like rock phosphate, are not considered organic if they are treated with a chemical to increase nutrient solubility.
- Organic fertilizers may not release enough of their principal nutrient at a time to give the plant what it needs for best growth.
- Because many organic fertilizers depend on soil organisms to break them down to release nutrients, they are only effective when the soil is moist and warm. Microbial activity is also influenced by soil pH and soil aeration.

- Organic fertilizers are beneficial for improving the soil's physical structure, and increasing bacterial and fungal activity (particularly the mycorrhizal fungi that help make other nutrients more available to plants).
- Even though fresh manures have the highest amount of nutrients, most gardeners prefer to use composted forms to reduce weed problems and ensure fewer soluble salts, thereby reducing the chance of burning plants. Fresh manure should not be used where it will contact tender plant roots. Sewage sludge is a recycled product of municipal sewage treatment plants. Although sewage sludge is not commonly utilized by home gardeners, two forms are available, activated and composted. Activated sludge has a higher concentration of nutrients (approximately 6-2-0) than composted sludge (1-2-0). The latter is usually sold in a dry, granular form for use as a soil amendment and, in some cases, is labeled for vegetable crops.

ORGANIC FERTILIZERS FROM THE DEEP BLUE SEA

Fish Emulsion - Strong smelling, thick brown liquid. Good source of slow release nitrogen (about 5%-6%N). It can be used as a liquid fertilizer or foliar spray. It may attract neighbouring cats. Follow dilution instructions.

Liquid Seaweed or Kelp - Fairly expensive; derived from ocean kelp. Rated analysis of 1-0-1.2 with up to 33 trace minerals, growth hormones and vitamins. Brown liquid with a strong smell; can be used as liquid fertilizer or foliar spray. Excellent tonic for plants especially in early spring when cool soils limit nutrient uptake. Imparts a degree of frost tolerance to plants. Follow dilution instructions.

Table 3-6: NATURAL/ORGANIC FERTILIZERS

Fertilizer	%N	%P	%K	Remarks
Alfalfa meal	2.5	1.0	2.0	
Bat guano	10.0	3.0	1.0	
Blood meal	14.0	1.3	0.7	Expensive; N is readily available.
Bone meal – raw	4.0	22.0	1.0	P is very slowly soluble and availability depends on how finely the bone meal is ground.
Bone meal – steamed	0.0	27.0	0.0	P is more soluble than raw bone meal. Calcium raises pH.
Coffee grounds (dried)	2.0	0.4	0.7	
Compost (yard waste)	1.0	0.5	1.0	Nutrient content varies with materials and techniques.
Cottonseed meal	6.0	2.0	2.0	Used for acid loving plants. Most nutrients become available slowly.
Earthworm castings	-	-	-	Microbial rich; nutrient content varies.
Fish scraps	8.0	7.0-13.0	0.0-4.0	Analysis can vary.
Fish emulsion	5.0	2.0	2.0	Can be applied to root zone or foliage.
Grass clippings (fresh)	0.7	0.2	0.7	
Greensand	0.0	1.0	7.0	2% magnesium
Gypsum				23%-57% Ca, 18% SO
Hairy vetch (fresh)	3.0	1.0	2.0	
Kelp meal/Seaweed	1.0	0.0-0.5	1.0-8.0	
Leaf mold	0.6	0.2	0.4	Good soil builder.
Limestone	0	0	0	80% calcium carbonate.
Manure*				
Horse (fresh)	0.6	0.2	0.4	
Horse (composted)	0.7	0.3	0.6	
Cattle (fresh)	2.5	0.2	0.4	
Cattle (dried)	2.0	1.0	1.0	
Poultry (fresh)	1.0	1.0	0.5	
Rabbit (fresh)	2.4	0.6	0.1	
Sheep (fresh)	0.6	0.3	0.2	
Mushroom compost	2.75	1.5	1.5	
Ryegrass (fresh)	1.0	0.5	1.0	
Sewer sludge compost	1.0	2.0	0.0	May contain toxic substances, particularly heavy metals.
Wood ash	0.0	1.5	7.0	A very alkaline source of K ₂ O.
These analyses will vary depending on the source, processing method, age of material, protection against leaching, etc. *Dried manure may have a nutrient content 4 to 5 times greater than fresh manure.				

SOLUBLE SALTS

Fertilizers are salts, much like table salt, except that they contain various plant nutrients. When a fertilizer (salt) is applied to a soil, nearby water begins to move very gradually towards the area where the fertilizer has been applied. Salts in the fertilizer begin to diffuse, or spread out from, the place they have been applied. This dilutes the fertilizer and distributes it through a much larger area.

Soluble salts build up when fertilizer is applied repeatedly without sufficient water to leach (wash) them away. If tender plant roots are close to these salts, water is drawn from these roots, as well as from surrounding soil. This causes plant cells to begin to dehydrate and collapse, and the roots may burn to a point where they cannot recover – this is **physiological drought**. If soil moisture is limited, most of the water drawn towards the salt will come from plant roots, and the damage will be severe.

You should keep two rules in mind when applying a fertilizer during hot, dry weather: (1) do not over apply nitrogen or potassium fertilizers, and (2) make sure adequate moisture is present after applying fertilizers high in salts.

Soluble salt problems commonly occur on plants in containers but are rarely a problem in the garden. The best way to prevent soluble salt injury is to leach the salts out of the pots. When applying water, allow some to drain through and then empty the drip plate. Some water should drain through each time you water the pot.

SLOW-RELEASE FERTILIZERS

Plants take up fertilizers continuously, so it is beneficial to provide them with a balance of nutrients throughout their life. Perhaps the most efficient way to achieve this is to apply a slow-release fertilizer. Slow-release fertilizers contain one or more essential elements, which are released or made available to the plant over an extended period (see **Chapter 10, "Turfgrass Management"**).

Use caution when applying slow-release fertilizers around trees or shrubs, as they may keep the plant growing late in the summer. Late-season growth may not harden off completely, and result in excessive winter damage.

Table 3-7 compares slow-release fertilizers and conventional fertilizers.

Table 3-7: TYPES OF FERTILIZERS

TYPES OF FERTILIZERS	
SLOW-RELEASE FERTILIZER	
<i>Advantages</i>	<i>Disadvantages</i>
Fewer applications	Unit cost is high
Low burn potential	Release rate governed by factors other than plant need
Comparatively slow release rate	
SYNTHETIC FERTILIZER	
<i>Advantages</i>	<i>Disadvantages</i>
Fast acting	Greater burn potential
Low cost	May attract moisture while in the bag and solidify upon drying
	Nitrogen may leach readily
ORGANIC FERTILIZER	
<i>Advantages</i>	<i>Disadvantages</i>
Low burn potential	High soluble salts could be a problem in sewer sludge
Relatively slow release	Bulky
Contains micronutrients	Weed seeds may be a problem
Conditions soil	Heavy metals may be present in sewage sludge

WIN & WSN

The initials WIN and WSN on fertilizer labels stand for "water-insoluble nitrogen" and "water-soluble nitrogen," respectively.

- WSN dissolves readily and is usually in very simple forms such as ammoniacal nitrogen (ammonia) or nitrate nitrogen. Nitrogen that does not dissolve readily may exist in organic forms in the fertilizer and must be broken down into simpler forms before it can be used.
- Water-insoluble nitrogen (WIN) is referred to as a slow-release nitrogen source, delivering nitrogen at different rates according to the amount and composition.
- Slow-release N may also exist as coated soluble N sources, often referred to as controlled-release N (CRN).

The best analysis to use depends on many factors, such as what nutrients are needed and the rate and timing of application.

FERTILIZER RATIO

Fertilizer ratio refers to the relative amounts of N, P₂O₅, and K₂O in a fertilizer. Examples follow:

Grade	Ratio
10-10-10 or 20-20-20	1-1-1
5-10-5 or 10-20-10	1-2-1
12-24-12 or 6-12-6	1-2-1
12-4-8 or 24-8-16	3-1-2
0-25-25 or 0-5-5	0-1-1

Remember however, that the actual number is what is most important. One measure of a 20-20-20 fertilizer would give you twice the amount of nutrients as the same measure of a 10-10-10 fertilizer. It is important to follow instructions.

APPLICATION METHODS

Methods of applying fertilizer depend on the formulation and the crop's needs.

Broadcasting

A recommended rate of fertilizer is spread over the growing area and left to filter into the soil or is incorporated into the soil with a rototiller or spade. Broadcasting is used over large garden areas or when time or labour is a limitation.

Banding

In the vegetable garden, narrow bands of fertilizer may be applied in furrows several cm to the side and below the seeds or plants to be planted. Putting the fertilizer band too close to seeds will burn seedling roots. The best technique is to stretch a string where the seed row is to be planted. With a corner of a hoe, dig a furrow 8 cm deep, 8 cm to one side of, and parallel with the string. Spread the fertilizer in the furrow and cover with soil. Repeat the banding operation on the other side of the string, then, sow seeds underneath the string.

For widely spaced plants, such as tomatoes, place fertilizer in bands 15 cm long for each plant or in a circle around the plant. Place the bands 10 cm from the plant base. If fertilizer is used in the hole itself, place the fertilizer at the bottom of the hole, work it into the soil, and place a layer of soil about 5 cm deep over the fertilized soil before putting the plant in the hole.

FEEDING YOUNG PLANTS

Banding is one way to satisfy the phosphorus need of many plants (especially tomatoes) as the first roots develop. When fertilizers are broadcast and worked into soil, much of the phosphorus is locked up by the soil and is not immediately available to the plant. By concentrating the phosphorus in the band, the plant is given what it needs even though much of the phosphorus stays locked up.

Another way to satisfy the need for phosphorus when setting out transplants of tomatoes, eggplant, peppers, or cabbage is to use a liquid fertilizer high in phosphorus as a starter solution. Follow label directions.

Side Dressing

Dry fertilizer is applied as a side dressing after plants are up and growing. Scatter fertilizer on both sides of the row 15 to 20 cm from plants. Work it into the soil and water thoroughly.

Foliar Feeding

Foliar feeding is used if (1) insufficient fertilizer was applied before planting; (2) a quick growth response is wanted; (3) micronutrients (such as iron or zinc) are locked up in the soil; or (4) the soil is too cold for plants to extract or use nutrients from the soil.

Foliar-applied nutrients are absorbed and used by plants quite rapidly. Absorption begins within minutes after application and, for most nutrients, is completed within 1 to 2 days. Foliar nutrition supplements soil nutrition at a critical time for the plant, but it is not a substitute.

At transplanting time, a foliar application of a balanced fertilizer will help establish young plants in cold soils. Be sure to use label-recommended dilutions.

APPLYING FERTILIZERS

Calculate the amount of fertilizer needed before distributing it. This amount will be dependent upon the analysis of the fertilizer, the area to be covered, and the plants to be fertilized.

Granular Fertilizers

Suppose the recommended application rate for lawns is 0.5kg of nitrogen for every 100 m².

Example 1:

Given: Your lawn is 175 m².
Ammonium sulfate has an analysis of 21-0-0. What weight of this fertilizer would you need?

Solve:

Step 1: Calculate the weight of the 21-0-0 fertilizer needed to provide .5Kg of nitrogen:

$$0.5 \div 0.21 = 2.38 \text{ Kg}$$

Step 2: Divide your area by unit area to get the area factor:

$$175 \div 100 = 1.75$$

Step 3: Multiply weight by area factor:

$$2.38 \text{ kg} \times 1.75 = 4.165 \text{ kg}$$

So you will need 4.17Kg of Ammonium sulfate.

Liquid Fertilizers

The amount of liquid fertilizers to use requires an extra step because the amount of fertilizer in a container is expressed on a volume basis, while the analysis is expressed as a percentage by weight.

As well as the N-P-K analysis, you will need to know the weight of a given volume of the fertilizer. This information will usually be on the label.

Given an 80 m² lawn:

Example 2:

How much 4-7-6 liquid fertilizer would you apply to obtain a fertilization rate of 0.5 kg of nitrogen/100 m²? The label indicates that 500 ml of the fertilizer weighs .65 kg.

Solve:

Step 1: Calculate the weight of a 4-7-6 liquid fertilizer needed to get .5 kg of nitrogen:

$$0.5 \div 0.04 = 12.5 \text{ kg}$$

Step 2: Calculate area factor:

$$80 \div 100 = 0.8$$

Step 3: Multiply weight needed by area factor:

$$12.5 \text{ kg} \times 0.8 = 10 \text{ Kg}$$

Step 4: Calculate the volume of fertilizer needed to get 10Kg of nitrogen given that 500 ml weighs 0.65 kg:

$$10 \text{ kg} \div 0.65 \text{ kg} \times 500 \text{ ml} = 7692 \text{ ml or } 7.7 \text{ liters}$$

If you are unable to purchase the fertilizer you wish, you may have to settle for one with a different analysis. When you do this, you will have to adjust the amount of fertilizer applied per unit area to compensate for difference in analysis. As an illustration, to obtain 0.5 kg of nitrogen/100 m², you would have to use the following amounts of the indicated fertilizers.

<u>Formula</u>	<u>kg/100m²</u>
5-10-10	$0.5 \div 0.05 = 10.00$
6-18-6	$0.5 \div 0.06 = 8.33$
8-12-4	$0.5 \div 0.08 = 6.25$
12-6-6	$0.5 \div 0.12 = 4.16$
16-16-16	$0.5 \div 0.16 = 3.12$

SOIL TESTING

The purpose of a soil test is to supply the homeowner with enough information to make informed decisions about applying fertilizers and soil amendments. Soil tests done at any reliable Ontario laboratory can provide information on soil texture, pH, salt content, and nutrient levels (calcium, magnesium, phosphorus and potassium). Soil tests should be performed if such tests have never been done before. A soil test need not be performed more often than every 3 to 4 years. Submit the sample the fall before planting or tilling so you can apply needed lime to change the pH over the winter. Fertilizers should be incorporated the next spring, except for turfgrass and trees (see **Chapter 10** and **Chapter 12**, respectively).

The accuracy of the soil test reflects the sample taken. Be sure the sample is representative of the area to be treated. Sample the soil from 10 random areas of the garden to a depth of 15 to 20 cm. On established lawns, where fertilizer will be broadcast on the surface and not incorporated, sample to a depth of 5 to 8 cm at a minimum of 10 random sites on the lawn. Avoid sampling unusual areas such as those near gravel roads, manure or compost spots, brush piles, or under eaves. Place the samples in a clean pail or container, mix the soil thoroughly and allow it to air dry. Then transfer the required amount to a sample bag. Be sure to fill out the information sheets before mailing.

Remember, your soil is alive and constantly changing. By keeping it fertile and rich, you can lessen many gardening problems. Soil is the basis for plant growth, and much attention should be paid to getting and keeping it in the best condition.

[Accredited soil testing labs in Ontario](#)

Table 3-8: 13 WAYS TO CONSERVE NUTRIENTS, PREVENT POLLUTION AND PRESERVE SOIL

1. Use calcium magnesium acetate (CMA), potassium chloride (KCl), sodium chloride (NaCl) or calcium chloride (CaCl₂) to melt winter ice. Don't use urea, potassium nitrate or other chemical fertilizers contain-ing nitrogen or phosphorous.
2. Keep bare soil covered with mulch or plant a cover crop or ground cover.
3. Fertilize according to soil test recommendations. Don't over apply fertilizers and do not exceed label directions.
4. Don't apply fertilizers to hard surfaces or allow them to wash onto streets and driveways.
5. Don't fertilize turf in the spring, unless it is a new stand or you did not fertilize in the fall.
6. Choose direct application methods (e.g., in planting hole or furrow) rather than broadcasting over a large area.
7. Leave grass clippings on your lawn ("Grasscycling") - they are a source of nitrogen for your lawn.
8. Keep stored manures and compost covered to prevent leaching of nutrients.
9. Incorporate or compost plant residues.
10. Grow ground covers in place of turf in deep shade.
11. When appropriate, substitute slow-release fertilizers for those that are highly soluble and substitute locally available organic fertilizers like farmyard manure, backyard compost and municipal yard waste compost or sewer sludge for manufactured chemical fertilizers.
12. Keep soil in raised beds framed with solid sides; avoid soil compaction.
13. Avoid cultivating soils on steep slopes; construct terraces where appropriate.

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**Revised by the Master Gardeners of Ontario Inc. from
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CHAPTER 4: BACKYARD COMPOSTING

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BACKYARD COMPOSTING

WHAT IS COMPOST?

Compost is a dark, crumbly, earthy-smelling form of well-decomposed leaves, grass clippings, other plant materials, and possibly kitchen waste. It is much like the natural organic matter existing in all soil and can be made by just about every gardener or homeowner.

The nutrients in compost are held in a desirable organic form and stay in the soil over a long time. The humus particles break down slowly and release nutrients to plants gradually. Losses of nutrients through leaching are generally much lower from compost than losses from equivalent quantities of inorganic fertilizers. Composting simply allows you to expedite a natural process to produce a regular supply of "black gold" for your landscape.

WHY SHOULD A GARDENER MAKE COMPOST?

There are some very compelling reasons to compost:

It's fun, educational and a great family activity.

- It's a valuable soil amendment that can be substituted for expensive purchased materials like peat moss.
- Compost improves soil tilth, aeration and water holding capacity and contains a wide range of plant nutrients. All garden soils benefit from regular additions of compost.
- It reduces the amount of material entering our waste stream by 35% or even 60% at some times of the year. This includes food and yard wastes. Disposing of yard waste in landfills is expensive and environmentally unsound. Burning organic materials uses up fossil fuels and releases pollutants.
- It is free!

HOW IS COMPOST MADE?

Composting is the controlled, biological and chemical decomposition of organic matter. Decay takes place naturally, but composting speeds up the process. Composting can be done in open piles or within an enclosure. The term "compost pile" is generally used to include all composting systems. Each gardener supports their own method of composting because it works for them. No matter which method you use, sooner or later you are bound to get compost.

There are six important and related factors involved in effective composting:

- The microbes that digest organic matter
- The air, water and food they require
- The size of the food particles (ingredients)
- The volume of the pile

A very simplified composting equation can be stated as:

Organic yard and food waste + oxygen + water + soil organisms = carbon dioxide + water + heat + compost

The goal is to manage the materials and environmental conditions to ensure the rapid and complete breakdown of organic matter.

THE DIGESTERS

Bacteria, fungi, and other microbes are the key players in composting. These organisms "feed" on organic matter and use the carbon and nitrogen it contains to grow and reproduce. The heat generated by your compost pile is a result of microbial activity. Microbes are active in small numbers at temperatures just above freezing and are most efficient at 55°- 60°C. The aerobic microbes – those which require air - do most of the composting work and can be divided into three classes.

- High heat bacteria digest available organic materials rapidly and, with sufficient oxygen, can cause temperatures within the compost pile to reach 66 - 71°C within a few days. These bacteria prefer soft, easily rotted organic materials that are high in nitrogen.
- Fungi appear in 7 to 10 days and live in the cooler, outer shell of the pile.
- Actinomycetes show up last. They are a race of bacteria that live in the moderate warmth near the pile's edges. The fungi and the Actinomycetes together have a greyish cobwebby look. Both are extremely important in the decomposition of woody materials which bacteria cannot digest.

These microbes are followed by larger organisms; small mites, springtails, beetles, centipedes, sow bugs, flies, slugs, earwigs and worms. These organisms all prefer the compost pile when it is cooler - don't add them to a hot, steamy pile. They are all beneficial to your compost pile and should be left to do their work.

These same organisms are responsible for the decay of forest floor litter and the corn stubble left in a farmer's field. When working with your pile or diagnosing problems, put yourself in the "shoes" of a microbe. If you provide well for their basic needs you will enjoy success as a composter.

There are approximately 5 billion microbes in one gram of soil!

INGREDIENTS: CARBON NITROGEN

Composting microbes use carbon for energy and nitrogen for growth (protein synthesis). When you mix various forms of organic material in your compost bin, it is important to achieve a proper balance of carbon to nitrogen (C/N ratio). Optimum composting occurs when the mixture of materials contains 30 parts of carbon to 1 part of nitrogen. The proportion can vary; the microbes will function well at ratios from 25:1 to 40:1. Most organic materials do not fit the 30:1 ratio exactly, so different materials are mixed together. With the proper mix, microbes begin to decompose organic material quickly. For example, a mix containing equal quantities of vegetable waste (C/N ratio of 15:1) and mature leaves (C/N ratio of 65:1) would have a carbon to nitrogen ratio of 40:1.

Organic matter for composting comes in two broad forms:

- **Green Materials** - fresh grass clippings and weeds, kitchen waste, and manure; low in carbon and high in nitrogen and moisture. These materials are also high in readily-digested sugars and starches.
- **Brown Materials** - mature, woody materials like fallen leaves, straw, wood chips, and sawdust; high in carbon, low in moisture and slow to break down. They contain large amounts of cellulose and lignin.



A blending of equal parts (by volume or weight) of green and brown materials gives microbes an ideal diet. The following illustrates the C/N ratios for some readily available materials that can be composted.

Table 4-1

Materials with high nitrogen levels: Green	
vegetable waste	12-20:1
grass clippings	12-25:1
cow manure	12-25:1
horse manure	25:1
horse manure with litter	30-50:1
poultry manure	10:1
poultry manure with litter	13-18:1
coffee grounds	20: 1
Materials with high carbon levels: Brown	
dead (mature) leaves	30-80:1
corn stalks	60:1
straw	40-100:1
tree bark	100-130:1
paper	150-200:1
wood chips and sawdust	100-500:1

WATER AND OXYGEN

All life on earth needs a certain amount of oxygen and water to sustain itself. The microorganisms that produce compost are no different. You can control the content and movement of air and water in the composting system to enhance the activity of the fungi and bacteria.

Composting occurs with oxygen (**aerobic**) or without oxygen (**anaerobic**). Microbes exist under both these conditions, but aerobic composting with oxygen is much preferred because it is faster and more effective. Anaerobic microbes compost by fermentation, which results in the formation of foul odours, acids, and alcohols that can harm plants in the garden. Aerobic composting, when done properly, is essentially odourless.

As composting occurs, microbes consume oxygen in the pile, resulting in the need for additional air. Air flow may be limited by too much finely chopped material and compaction that results from an overly large pile. Although some aeration occurs naturally, stirring the compost pile will replace the inner oxygen-poor air with fresh air. Adding coarse materials like dead leaves, straw, or fine twigs, along with periodic turning or mixing, will also improve aeration.

Microbes function best when composting materials are about as damp as a wrung-out sponge and have numerous air passages.

Very wet or dry conditions will adversely affect the moisture and air balance in the compost pile. Moisture is important because microbes can only break down moist materials. If the organic materials are too dry, the process will slow and the organisms will go dormant. The same result occurs if the materials become too wet. Air is pushed out of the pile, nutrients are lost, and unpleasant odours develop.

An easy way to determine moisture content is to squeeze a handful of composting material. If nothing comes out, the material is too dry. If the material oozes between your fingers, it is too wet. You can dry down wet compost by mixing the pile or incorporating coarse materials like leaves, straw, or sawdust. To adequately wet a dry pile, turn the material and add water gradually. Use the squeeze test at several points to determine the degree of wetness.

When building the pile, 'green' materials usually don't require additional water, but dry 'brown' materials often do and should be wet down as they are added. It is a good idea to monitor the heat and moisture in a pile. This can be done by inserting a pole into the pile in various places. An actively working pile may become dry in the center as steam escapes and it may be necessary to add moisture for microbial activity to continue. During hot, dry periods, the pile may also need additional water. In areas with heavy rainfall, the pile should be protected or covered to prevent materials from becoming water-logged. Compost piles built with rounded tops tend to shed excess water better than those that have a flat surface.

PARTICLE SIZE

The organisms responsible for decomposition work on the surface of the organic matter. You can increase the surface area by shredding or chopping the material to be composted into smaller pieces. Although this is not essential, it does speed up the process. When space is limited you may want to compost material quickly to make room for the next season's supply.

A wide range of shredders and chippers are available. Consider the amount and type of material you plan to handle when deciding whether or not to purchase such equipment. Also ask yourself how often you will use the equipment in any one season. Pruning shears, string trimmers, lawnmowers, machetes and hatchets are adequate to cut most yard waste.

An easy way to shred fallen leaves is to mow them before raking. Collect the shredded leaves directly with a mower bag attachment.

If a mower bag is not available, rake the leaves to the compost area and run your lawn mower through them with the discharge shoot directed towards the pile, where the finer pieces will settle.

Leaves can also be chopped using a gas-powered string trimmer and a large container such as a metal garbage can or large bin.

Pile Volume

A compost pile should be at least 1 metre wide by 1 metre long by 1 metre high (1cubic metre).

- A smaller pile may not have sufficient critical mass to heat up and stay hot.
- A pile higher or wider than 1.5 m high is difficult to manage and may not allow sufficient aeration in the centre.

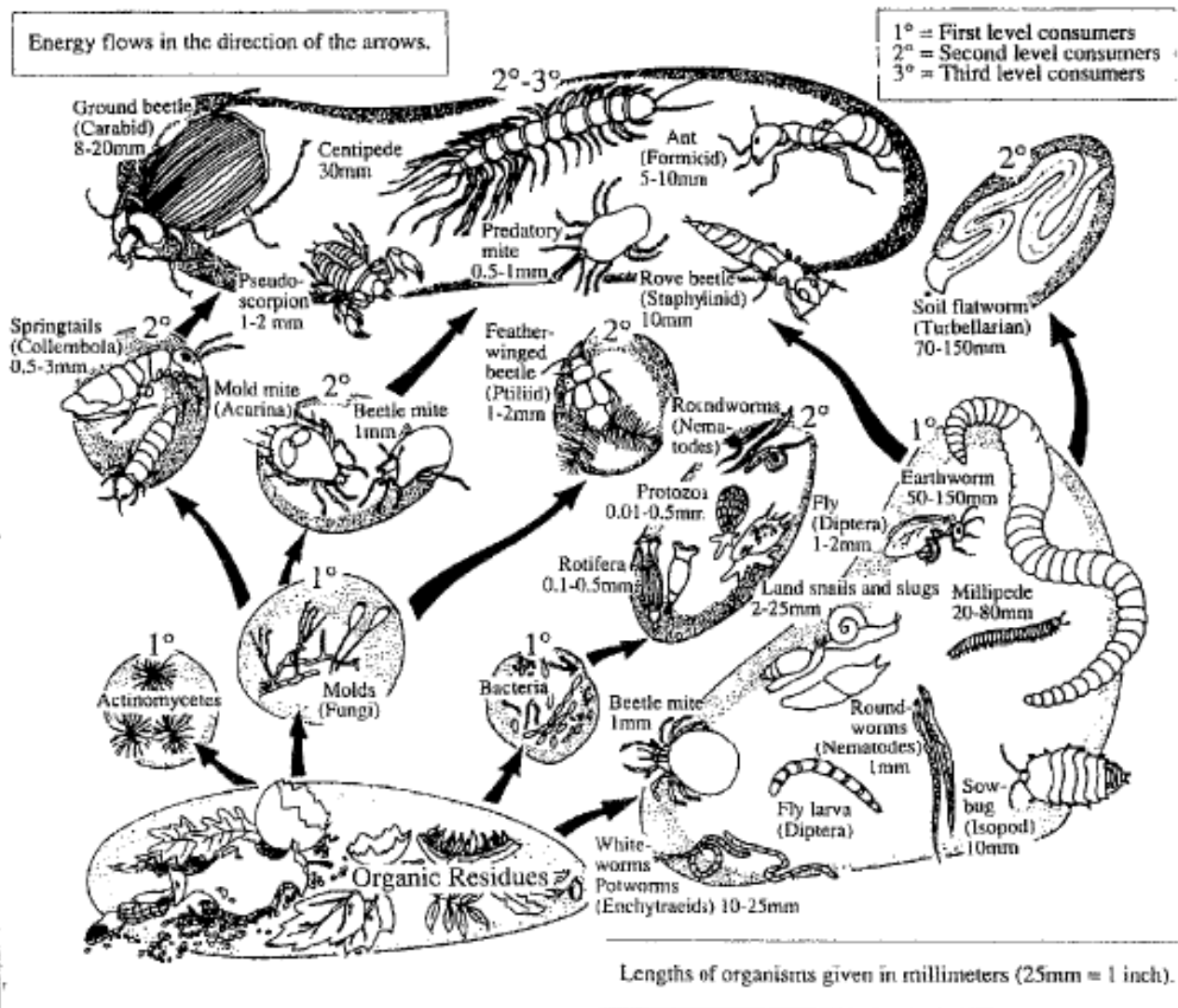
Turn, Turn, Turn

Compost piles may heat up to 70°- 80°C, 3-4 days after being fully charged (loaded to capacity). The temperature quickly drops as microbes use up nitrogen, oxygen and water to digest the sugars and starches.

Oxygen is often the principal limiting factor to the complete break-down of ingredients. Reviving the microbes with fresh air causes the pile to re-heat. This is typically done by turning or inverting the pile with a garden or pitch fork. Turn by slicing down through the pile and inverting each slice. The goal is to shift materials from the outer parts of the pile closer to the center for better decomposition and to incorporate oxygen.

Novice composters are often turned off by the prospect of physically turning ½ to 1 tonne of raw organic matter. Alternatives to turning include stirring with a slender metal pipe or "compost turner", or laying perforated plastic pipes through the pile (vertically or horizontally) to increase air flow.

Figure 4-A: THE ORGANISMS IN THE FOOD WEB OF THE COMPOST PILE



WHAT CAN BE COMPOSTED?

Anything organic can be composted, but some materials are more appropriate for backyard composting than others. Materials that would otherwise go out in household garbage, like vegetable waste and garden leaves, can go in the compost. A wide variety of different materials in the compost increases the chances of achieving a proper balance of carbon and nitrogen and also broadens the range of elements that will be returned to the soil.

DO COMPOST!

- Ideally, begin your composting system with a large supply of organic matter. One of the best starting materials is tree leaves, because you generally have a large quantity in a relatively short time. Then, add organic matter from other sources during the remainder of the year.
- Practically any plant material can be composted - sod, grass clippings, hay, straw, weeds, chopped corn stalks or cobs, sawdust, shredded newspaper and cardboard, wood ashes or hedge clippings.
- Grass clippings should be left on the lawn whenever possible as they return nutrients directly to the turf. If added to the compost pile, they are an excellent source of nitrogen and need to be thoroughly mixed with brown materials such as leaves to prevent matting and odours.
- Most kitchen waste may be used in the composting system excepting those materials containing grease, fat or meat. Kitchen scraps should be mixed into the middle of the pile. Items such as fruit rinds, vegetable peelings, egg shells, tea and coffee grounds are all appropriate items.
- Most non-glossy paper, such as newsprint, tablet paper, cardboard and items like paper egg cartons will decompose and are safe to include. Coated or treated paper products may contain chemicals that inhibit microbial activity and are not suitable.
- A wise guide for composting is "Variety and moderation mixed well". Many items such as rhubarb leaves or leaves from various species of the genus *Juglans* (Black Walnut or Butternut) can be detrimental if used in large quantities. If used in relatively small amounts, these materials are unlikely to disrupt microbial populations in the compost, or cause impaired plant growth when used in the garden.

DON'T COMPOST!

- Try to avoid woody materials because they decompose too slowly; however, it is possible to screen pieces of wood out of compost and turn them back into the system for further decomposition. Small twigs can also aerate.
- It is best not to include plants from the flower and vegetable garden that were infected with diseases. The same holds true for weeds that have produced seed heads or that spread easily by stolons or rhizomes. As microorganisms decompose the organic matter, temperatures within the system approach 60°C at the center, killing many weed seeds and disease organisms. In the cooler outer layers of the pile, however, such sterilization may be incomplete.
- Do not add cat and dog manure or cat litter to the compost pile. This may spread certain diseases and attract neighborhood cats and dogs to the pile.
- Barbecue ashes/coal - These contain sulfur oxides which, in large quantities, are harmful in the garden. There is also concern with the chemicals applied to charcoal to assist ignition.
- Dairy products such as butter, cheese, salad dressings, milk, yogurt or sour cream are not suitable for the compost as they will produce unpleasant odours and attract pests.
- Dishwater may contain soap, perfumes, grease or sodium. These contaminants can disrupt the microbial population in the compost pile or attract unwanted pests.
- Fats, grease and oils if present in any significant quantity will putrefy, producing foul odours as they break down.
- Meat, bones, fish scraps will attract animal pests to the compost and cause unpleasant odours as they break down. Meat and fish scraps also contain significant amounts of oil.

Pesticides and Composting

Should organic material treated with pesticides, especially weed killers (herbicides) be composted? As noted earlier, composting is a rapid version of the natural decay process found in nature, and many compounds break down more quickly in a compost pile than they would in soil.

If the grass clippings have been composting for at least a year, pesticides should not be a problem. If you intend to collect and compost the grass clippings from herbicide treated turf, mow your lawn twice, leaving the clippings each time. An additional precaution would be to avoid using compost that contains materials treated with a pesticide on vegetable gardens and apply it to only ornamental plantings.

GETTING STARTED

LOCATING YOUR COMPOSTING SYSTEM

- On a level spot in the garden. This reduces the chances of water runoff from your property or into other areas of the garden.
- Near the garden or where the raw material is generated and the end product will be used.
- A nearby source of water is very helpful.
- Where it can be screened from your property and the neighbour's property.
- Away from wooden buildings to avoid attracting termites.
- Away from trees and shrubs which will send their roots into the compost or cast heavy shade.
- Be sure you have sufficient room to stockpile ingredients, turn the pile(s) and store finished compost.
- A full-sun site is not necessary because the process is driven by microbes, not the sun. However, locating the compost pile in deep shade will mean that it will warm up more slowly in spring and cool more quickly in autumn.

TOOLS

Some helpful tools and supplies include: pitch fork, turning tool or metal rod (for stirring ingredients), temperature probe and goggles (to use when chipping or shredding). Chopping and shredding tools include machetes, string trimmers, chipper/shredders and mulching mowers.

COMPOSTING METHODS

The composting method most suited to your needs is determined by several factors:

1. Aesthetic requirements.
2. The amount and kinds of organic matter you have for composting.
3. Available space.
4. Your need for finished compost.
5. The time and money you are willing to spend.

If you have limited quantities of leaves or garden waste, or if you don't need to produce compost in the shortest possible time, consider starting with a "holding" pile that you construct as the materials become available. You may even be able to simply incorporate directly into garden beds small amounts of kitchen scraps, spent plants and fallen leaves.

A sequence of several "turning" piles in a row allows you to move composting material from one bin to the next on a regular basis. Such turning piles are most appropriate if you have a large volume of material and the desire to make high-quality compost in a short time. A row of three bins or piles can be quite effective, with the first unit holding compost that is actively working. Use the middle unit to hold compost that is close to completion and the third unit to finish and store compost before it is put in the garden (see **Figure 4-C**).

BINS AND BARRELS

Carefully consider your needs along with the design merits of any bin or barrel you buy or build:

- Can it handle my volume of yard waste? Is it best suited to fast or slow composting?
- Is it attractive and unobtrusive? Will it create neighbour problems?
- Is it rodent-proof? Can I use it for food scraps?
- Is it durable? What's the useful life?
- Is it big enough to generate and hold heat? Is there sufficient ventilation?
- Can I easily turn the ingredients and remove the finished compost?

Bins

Woven wire fencing (hog, chicken or turkey wire, hardware cloth and chain link), wood slat fencing (snow fence), cement blocks, bricks, or scrap lumber all can be used to enclose a compost system. The number of enclosures will determine the activity of your system. Fencing materials need corner supports, although small cylinders made of slatted fence need little or no support.

Bricks or cement blocks may be piled without mortar, but space should be left between them to allow air movement through the sides. Scrap lumber and used wooden pallets are loose enough for good air movement but have to be replaced as they decay along with the contents. One side of the enclosure should be open, or easily opened, for turning and removing the finished compost. A large number of manufactured, free-standing bins (often from recycled plastic) are available in the marketplace.

Barrels

Tumbler units work best where space is limited, appearance is important and kitchen scraps are primary ingredients. These units can be constructed at home (typically using 200 litre plastic food-grade containers) or purchased ready-made. These drums are usually supported on a shaft running through the diameter or length of the container. Every few days the drum is rotated, allowing the material inside to be aerated. To use tumblers effectively, it is important to:

1. Initially load the barrel to capacity (fully charged).
2. Maintain a C/N ratio of 25-40:1.
3. Avoid excess moisture.
4. Keep the ingredients aerated.

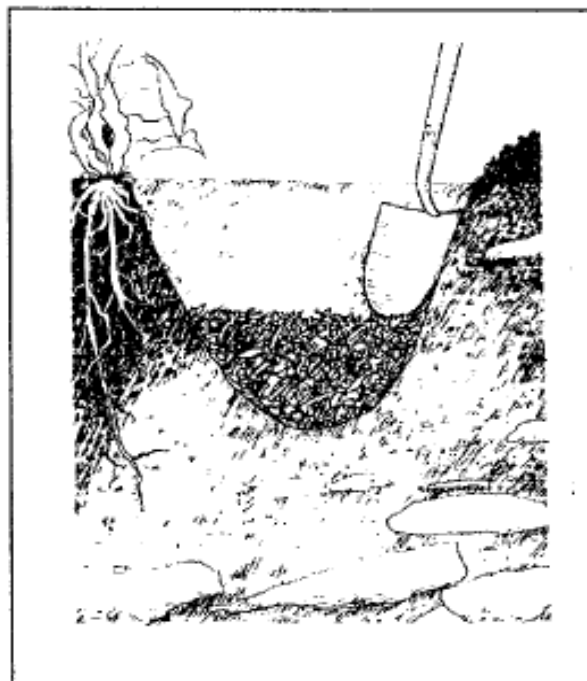


Figure 4-B:

The technique of soil incorporation accomplished by digging a hole, mixing waste with soil, and covering the waste with at least 20cm of additional soil.

Figure 4-C: A Three Bin Composting System

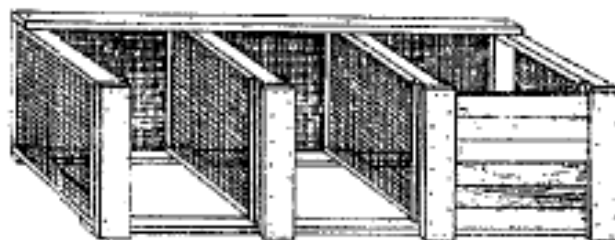


Table 4-2: WHICH COMPOSTING SYSTEM IS FOR ME?

System Used	Cost	Time for Finished Compost (Rate of Composting)	Comments
YARD WASTE			
Compost mound/pile	None	Slow if not turned; 6 months - 2 yrs.	Very low maintenance; ok where aesthetics not a concern.
Holding unit	Low	Slow - medium; 4 - 6 months if not turned	Can be used as turning unit by inverting pile and re-enclosing materials.
Turning unit	High; lower if scrap and recycled materials are used for construction.	Fast minimum 3 weeks	Materials are turned from bin to bin. Good for large yards.
Mulch	Low	Can use immediately, but material should be shredded and mixed	Materials can be incorporated at end of season
Direct incorporation into soil	Low	Slow-medium	Okay to chop and mix small quantities of grass clippings or spent plants into garden soil. High carbon materials (leaves) can produce a nitrogen deficiency.
Commercial bin	High	Fast, minimum 3 weeks	Finished compost can usually be drawn out from bottom of bin. Helps to stir or turn materials.
KITCHEN WASTE*			
Trench composting; aka "compost pockets"	None	Fast, minimum 2 weeks	Wastes are buried 20 - 30 cm deep in garden beds.
Garbage can composter	Low	Slow; faster if turned or mixed	Drill holes in sides and bottom. Raise can up on blocks. Position a length of perforated rigid pipe vertically through lid. This "chimney" will help hasten the process.
Worm composting bin	Medium	Fast, minimum 4 weeks	Can be done inside or outside. Excellent project for children.
Barrel or drum turning unit	High	Fast, minimum 4 weeks	Can be purchased or constructed at home.

* Note that kitchen scraps can also be safely and effectively composted in "yard waste" systems. It's best to insert these scraps into the middle of the pile.

This chart is adapted from **'Composting: Wastes to Resources'**, by Jean F. Bonhotal and Marianne E. Krasny, (a 4-H guide), Cornell University.

KITCHEN SCRAPS

Some jurisdictions prohibit the composting of kitchen scraps. Regardless of the legality, your neighbors may become upset by your choice of composting materials. Try these methods for safe and effective composting:

Trenching - Dig a hole or trench 20 to 30 cm deep and bury your scraps (see **Figure 4-B**).

Above Ground Piles - Insert scraps into pile middle.

Barrels - Don't overwater. Keep them well-aerated.

Solar Cones - Simple plastic composter consisting of buried composting chamber and above ground cones. Locate on loose, rich garden soil; does not provide useable compost.

5 WAYS TO HANDLE LEAVES*

- Spread them on bare ground and around trees, shrubs and perennial beds.
- Incorporate directly into garden soil; add a nitrogen source to reduce nitrogen tie-up.
- Leaves can be easily composted by adding a shovelful of aged manure or finished compost to each large bag of leaves. This mixture can be piled or left in bags to compost over winter. If allowing the leaves to remain in the bags, then they should be moistened and have ventilation holes punched in the bags.
- Shred them several times with a mulching mower and leave them on the lawn (if no more than 1 cm deep).

* **Shredding leaves will reduce the volume, hasten decomposition and make them more useful and manageable.**

"FAST COMPOST"

Rapid composting is recommended for gardeners with large and regular supplies of a variety of organic materials. It is labour intensive because of the time needed to gather, store and prepare adequate quantities of materials, and manage the composting operation. Having several turning bins simplifies management; you can simply transfer materials to an adjacent bin at each turning.

- Chop or shred the organic matter before adding it to the pile. Mechanical chippers or shredders are most effective for reducing particle size. However, a lawnmower, a pair of pruners, or a hatchet can all be used to chop organic material. Paper should be shredded before it is incorporated into a compost pile.
- Charge (completely fill) your bin at one time; this will contribute to rapid heating.
- Thoroughly mix equal amounts of "greens" and "browns"; add extra nitrogen if you are short on "green" material.
- Turn the pile after three days. Considerable amounts of steam should arise in the summer. If the pile is not heating, check the section "Troubleshooting" for a possible cause and cure. Also check for proper moisture content and adjust if necessary.
- The "fast" method generates very high temperatures of about 70° C. This is high enough to kill most weed seeds and disease organisms, but temperatures above 70° C kill composting microbes as well.
- After two weeks of regular turning, the temperature will have dropped as the composting process slows the compost will be brown and crumbly and have an earthy smell. Some larger pieces of organic matter may still be recognizable and can be screened from the final product. Age the compost for an additional two weeks before using it around plants.

COMPOSTING TIPS

The composting process is a mixture of science, art, and mystery. No two compost piles are exactly the same and there is no single "correct" set of composting techniques that all gardeners should follow. Select your particular methods based on your own unique circumstances. However, these basic tips may help you compost more effectively:

- Mix materials thoroughly; it's usually not helpful to layer materials thickly.
- To speed up the process add an extra nitrogen source at each turning.
- Keep your compost pile moist (but not soggy) for efficient decomposition. Excess moisture causes anaerobic decomposition and offensive odours.
- During dry weather it may be necessary to add water at weekly intervals.
- Do not add branches and other woody materials unless they are chipped into small pieces.

- You may need to cover the pile to prevent excess moisture loss and to aid decomposition in dry periods.
- A plastic covering also protects the pile from becoming too wet during heavy rainfall and prevents nutrient leaching.
- The pile should be periodically turned or mixed. If fall-gathered leaves make up the bulk of the pile, turn the pile in mid-November before freezing can occur. Do not turn the pile in winter because this allows too much heat to escape and slows decomposition.
- Whenever kitchen scraps are collected or composted it is helpful to mix in a dry, high-carbon material, like sawdust or shredded paper.
- **OK to add:**
 - **Oak leaves, waxy leaves, pine needles** - they take longer to break down but will not cause the finished compost to be acidic.
 - **Citrus rinds** - do contain limonene which has insecticidal properties. Pose no problem to pile inhabitants.
 - **Walnut plant parts** - juglone, the chemical exuded by walnut roots, is broken down and rendered harmless by the composting process.
- **Best to avoid:**
 - **Lime** - drives off nitrogen as ammonia gas; inhibits microbes. Although raw materials, like leaves, may be acidic, the finished compost will have a pH of 7.0-7.2.
 - **Soil** - is very dense and may "smother" a pile.
 - **Bioactivator** - a commercially available mixture of dormant microbes and nitrogen source. Proven to be completely unnecessary for backyard composting. **FINISHED COMPOST IS THE BEST "STARTER"**. Yard waste and kitchen scraps contain enough microbes to start the composting process.

HOW TO USE YOUR COMPOST

FINISHED COMPOST

When is it ready to use? This is a common question asked by beginning composters. Compost is ready to use when its temperature has decreased to slightly above air temperature. Finished compost is dark and fairly homogeneous, although you will see pieces of the original ingredients such as nut shells, egg shells, or woody plant material.

Composted material taken directly from the pile will contain particles of many sizes. Even under optimum conditions the process is not complete in a single season.

You may wish to screen out coarser particles by passing the material through a 2 to 3 cm screen and return them to the pile for further decomposition. Rough-textured compost may also be used directly in the garden as surface mulch or incorporated into the soil.

Once composting is complete, the organic residues are relatively stable. The pile will be reduced in volume by 20 - 60%, the moisture content will be less than 40% and the weight reduced by up to 50%. The pH of finished compost is near neutral. Undesirable odours of the starting material are generally replaced by an earthy smell.

A fully-charged 1 m³ bin of organic materials will yield ½ that volume of finished compost.

Keep finished compost covered to prevent nutrient leaching and anaerobic digestion. Compost that becomes water-logged or is stacked over 1 m high may become anaerobic, producing alcohol and methanol.

TIPS ON COMPOST USE

Soil Incorporation

- Compost can be incorporated into garden soil at a rate of 1 to 2 m³ per 100 m² of area - a 1 to 2 cm layer of compost uniformly spread over the entire surface. The organic matter should be mixed into the top 15 to 20 cm of soil. You can apply compost every year.

As a mulch

- Coarse-textured compost, particularly coarse leaf compost, can also be used as organic mulch on the soil surface. Organic mulches are valuable because they:
 - reduce rainfall runoff
 - decrease water evaporation from the soil surface
 - keep soils cooler in summer
 - keep soils frozen in winter and reduce plant heaving
 - prevent soil erosion
 - make soil easier to cultivate
 - prevent soil splashing; keep fruit and flowers clean
 - help control weeds
 - present an attractive surface covering
- Don't use fine-textured, screened, or very old compost from any source as soil mulch. The small particle size of such material encourages surface crusting of the compost as it dries, inhibiting the

penetration of rainfall or irrigation water. The finer material may also blow from the bed area.

- Organic mulch should not be applied more thickly than 5 to 8 cm around trees and shrubs. A slightly deeper layer is effective on shallow-rooted, acid-tolerant plants, like blueberry and azalea. Mulch should never be allowed to contact tree or shrub trunks. The moisture-holding quality of the mulch may cause the bark to rot, killing the plant. Before new mulch layers are added in following years, stir, loosen and incorporate the old layer to improve aeration.

For Potting

- Use compost for potting house plants and for starting a variety of seeds. However, no more than 25%-30% of the potting mix should consist of compost. Leaf compost in particular may continue to decompose, resulting in a significant volume reduction of the potting soil after a year. Some sources suggest 'cooking' the compost in a slow (85°C/180°F) conventional oven to sterilize the compost and kill any weed seeds. Other sources suggest that this step is not necessary. Your choice may depend on whether you feel the compost pile was hot enough to kill any seeds.

- Compost can also be used as a growing medium for outdoor potted plants. No more than ½ of the mix should be compost. Pots filled entirely with compost tend to dry out quickly during the summer months. To minimize this problem, fill the bottom and sides of your containers with compost and reserve the middle of the pot for a heavy garden soil that can hold water more tightly.

Top Dressing for Your Lawn

- A thin layer of screened compost can be used as a top dressing for your lawn.

Compost Tea

- When your plants need a boost, water them with nutrient-rich compost tea. This can be made by soaking a cloth bag of compost in a watering can or barrel for a few days. Dilute this solution to a 'weak tea' colour. Reuse the bag of compost 1 or 2 times, and then put the remaining solids on your garden.

Determining Application Rates

How many cubic metres of compost do I need to cover my 18 m² flower bed with 5 cm of compost?

$$18 \text{ m}^2 \times 0.05 \text{ m} = 0.9 \text{ m}^3$$

Table 4-3: COMPOST TROUBLESHOOTING GUIDE

PROBLEM	POSSIBLE CAUSES	SOLUTION
ROTTEN ODOUR	- excess moisture (anaerobic conditions) - compaction (anaerobic conditions)	- turn pile, or add dry, porous material, such as twigs, wood chips, or straw - turn pile, or make pile smaller
AMMONIA ODOUR	too much nitrogen (lack of carbon)	add high carbon material, such as sawdust, wood chips, or straw
LOW PILE TEMPERATURE	- pile too small - insufficient moisture - poor aeration - lack of nitrogen - cold weather	- make pile bigger or insulate sides - add water while turning pile - turn pile - mix in nitrogen sources such as grass clippings or manure - increase pile size, or insulate pile with an extra layer of material such as straw
HIGH PILE TEMPERATURE (>60°C)	- pile too large - insufficient ventilation	- reduce pile size - turn pile
PESTS rats raccoons insects	presence of meat scraps or fatty food waste	- do not add meat and fatty foods to pile and cover with a layer of soil or sawdust - build an animal-proof compost bin, or - turn pile to increase temperature

GRASSCYCLING

("Mow 'em High and Let 'em Lie")

Grasscycling is the practice of leaving mowed grass clippings to decompose naturally on your lawn. Both you and your lawn will benefit from this recommended practice.

- Grasscycling eliminates the need for "bagging and dragging" grass clippings, which reduces mowing time by one-third.
- A 0.2 hectare lawn produces over 2 tonnes of grass clippings in a year. This creates an unnecessary stress on local landfills.
- Grass clippings have a 4-2-1 (N-P-K) analysis. A 90 m² (1,000 sq ft) lawn produces 5 kg (11-12 pounds) of nitrogen per year, reducing the need for supplemental fertilizers.
- Grass clippings help reduce weed pressure, conserve soil moisture and keep soil cooler in the summer.

Myths about Grasscycling

Myth #1: *Some homeowners believe that grass cycling contributes to the thatch layer in turf.* This is not true. Thatch is the tightly interwoven layer of partially decomposed stems and roots located between the soil and green vegetation. Grass clippings are high in moisture and decompose rapidly. Finely chopped grass clippings decompose more rapidly. To hasten decomposition, keep your mower blade sharp and use a mulching attachment.

Myth #2: Grasscycling is messy. This need not be true. Try mowing late in the day so the clippings have time to dry and settle overnight. Grass clippings decay quickly and disappear within a day or two.

Myth #3: Grass clippings damage lawns. Allowing your grass to grow too long between cutting results in thick patches of clippings that can suffocate your lawn. But mowing regularly at the correct height actually improves your lawn. A good rule of thumb is to never remove more than one third of the leaf surface at any one time.

Myth #4: Grasscycling spreads diseases. The spores that cause grass diseases are present whether clippings are collected or not. Watering properly, maintaining soil fertility levels, and keeping your mower blade sharp will help your lawn resist disease.

VERMICULTURE

What is it?

Vermiculture is a method of recycling food waste by 'composting' with worms. The great advantage is that this can be done indoors and outdoors. It's a great solution for apartment dwellers. Worms eat and expel the equivalent of their own weight every day. Even a small bin of red worms will produce many kilograms of finished compost.

How to Get Started

- First you need a plastic or wooden bin with a lid (see table below for bin size).
- Make eight to ten holes in the bottom of the bin to allow for adequate drainage. Place the bin on blocks with a tray underneath - a plastic boot tray works well.
- Worms are available from stores selling fishing bait, garden centers and worm breeders or from other vermicomposters. The type of worms best suited to vermicomposting are the redworms: *Eisenia foetida* (red wiggler) and *Lumbricus rubellus*. Dew worms are not suitable for vermiculture.
- Suitable bedding materials are straw, grass clippings, dried leaves, chopped plants, dampened peat moss, aged animal manures, ground cardboard or shredded paper. Try to vary the bedding as much as possible to provide more nutrients for the worms and to create richer compost. Add a couple of handfuls of sand or soil to provide necessary grit for the worm's digestion of food. **The bedding must be kept as moist as a well wrung sponge.**
- Fill the bin about three-quarters full of moistened bedding (don't compact- the worms need air spaces) and then put in the worms.
- Feed your worms kitchen scraps such as vegetable and fruit wastes, coffee grinds, tea bags and finely crushed egg shells. Always dig the waste into the bedding, burying successive loads in different locations in the bin.
- **Don't** put starches, meats or fats into your composter.

What Bin Size if Right for You?		
Number of People	Quantity of Worms	Bin Size (h x l x w)
1-2	0.5 kg	45 x 60 x 30 cm
2-3	1.0 kg	60 x 60 x 30 cm
4-6	1.5 – 2.0 kg	60 x 105 x 30 cm

Where to Locate Your Bin

The bins can be used indoors all year round and outdoors during the milder months. Worms prefer temperatures between 4-27°C.

How to Maintain Your Bin

Continue to add kitchen scraps to the bin. After three months the bedding will have decreased in volume and the original bedding will no longer be recognizable. At this point the compost is finished. To separate the worms, move the finished compost over to one side and add new bedding and kitchen scraps to the vacant side. The worms will gradually move from the finished compost to the new bedding in search of new food. The finished compost can then be skimmed off as needed. Watch out for tiny, lemon-shaped worm cocoons which contain between two and twenty baby worms! Too many worms- you can supply a friend with worms to set up their own vermiculture system.

Common Problems and Solutions

Unpleasant, strong odours

- overloading with food waste; food sits around too long and the bin contents become too wet

Solution

- stop adding food; allow worms and micro-organisms to catch up
- check the drainage holes; worms can drown if their surroundings are too wet

Worms are crawling out of the bedding

- bin conditions are too wet (see above)
- bedding is too acidic (caused by adding too many citrus peels or other acidic foods)

Solution

- adjust pH by adding a little garden lime
- cut down on the acidic wastes

Fruit Flies

Solution

- Discourage them by always burying the food waste and not overloading

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CHAPTER 5: INTRODUCTION TO INSECTS

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INTRODUCTION TO ENTOMOLOGY

INTRODUCTION

The purpose of this section is to provide an understanding of the morphology and life cycles of insects, as well as a review of some major insect groups. This knowledge can play an important role in identifying the insect and controlling potential damage and spread.

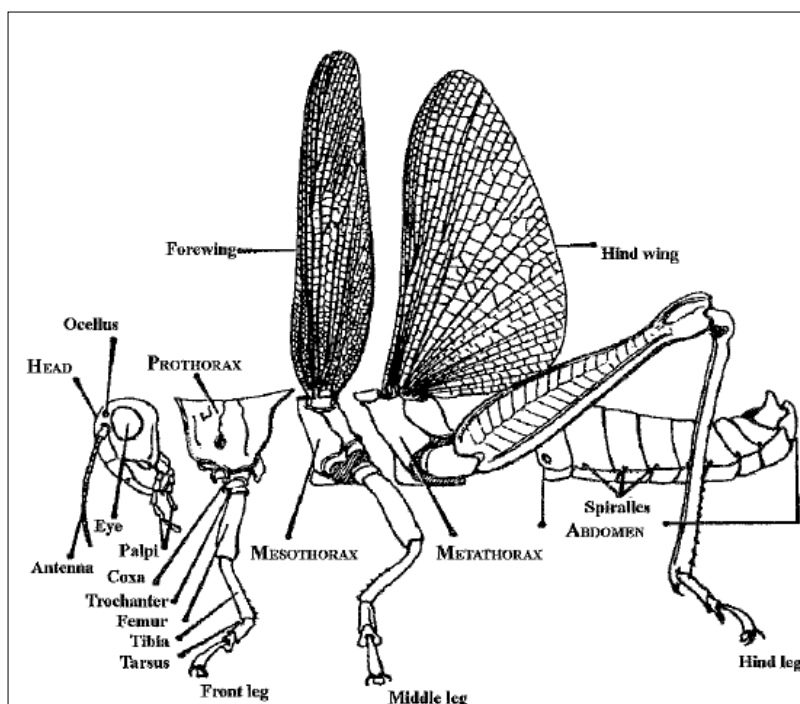
Insects are the most successful group of animals in the world. They are extremely adaptable and inhabit a wide range of habitats from deserts to the arctic. There are more than 100,000 species in North America alone. The vast majority of insects are beneficial or harmless. They pollinate crops, provide food for animals such as birds and fish, produce products such as honey, wax, and silk; others prey on or parasitize pest insects. Less than 10% of insects are considered pests. Some pest insects may cause damage to crops, ornamental trees and plants, stored products, fabrics, and other items. Others attack humans and animals and some transmit diseases.

CLASSIFICATION

Insects are part of the animal kingdom, which is divided into phyla. Insects are in the phylum Arthropoda which is subdivided into classes. In the following chart are a few examples of classes of Arthropods.

Class	Examples	Pairs of Legs
Crustacea	Crayfish, sowbugs	5
Arachnida	Spiders, mites, ticks	4
Diplopoda	Millipedes	2 pairs/segment
Chilopoda	Centipedes	1 pair/segment
Insecta	All Insects	3

Figure 5-A: GENERAL INSECT STRUCTURE



Classes are further divided into orders. Orders are divided into Families, then genus and species. There are 26 orders of insects. Common insect orders will be covered in some detail. All orders can be found in the table at the end of the chapter in **Table 5-1**.

INSECT STRUCTURE - MORPHOLOGY

All adult insects possess the following characteristics: 3 body regions (head, thorax and abdomen), 3 pairs of legs, one pair of antennae, and 0-4 wings. Insects are also cold-blooded. Their body temperature depends on the ambient temperature of the environment. This is why many insects are most active during warmer parts of the day and the warmer months of the year.

HEAD, THORAX AND ABDOMEN

The three distinct body regions of an insect are the head, thorax and abdomen. Many insects can be distinguished by a hard exoskeleton made up of a tough impervious material called chitin. The exoskeleton supports and contains the insect's internal organs. The outer layer of the exoskeleton is the cuticle; it contains a layer of wax that prevents desiccation or drying.

The cuticle on each segment of the insect is formed into several hardened plates called sclerites that are separated by infolds or sutures. Many immature insects have only a soft, elastic exoskeleton covering their bodies and are thus much more susceptible to such environmental pressures as desiccation or chemical sprays.

In order to escape their enemies, many insects have colourings which allow them to blend in with their environment, strange shapes or many hairs or spines that make them undesirable by predators. Colouration is acquired, either through pigments in the chitin, coloured hairs growing on the exoskeleton or the chitin may be transparent and the colours shown are those of the internal organs or blood.

Figure 2: TYPES OF ANTENNAE

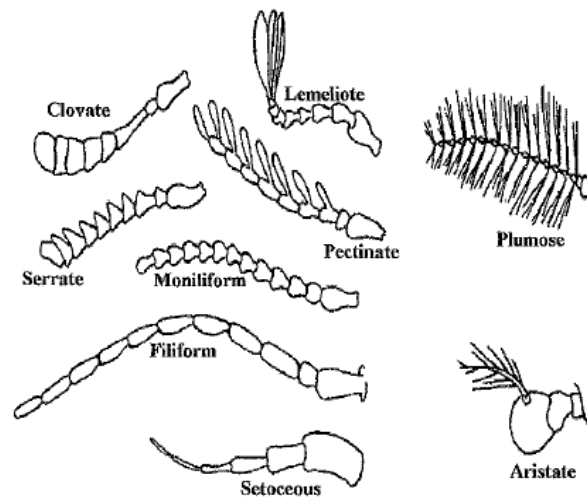
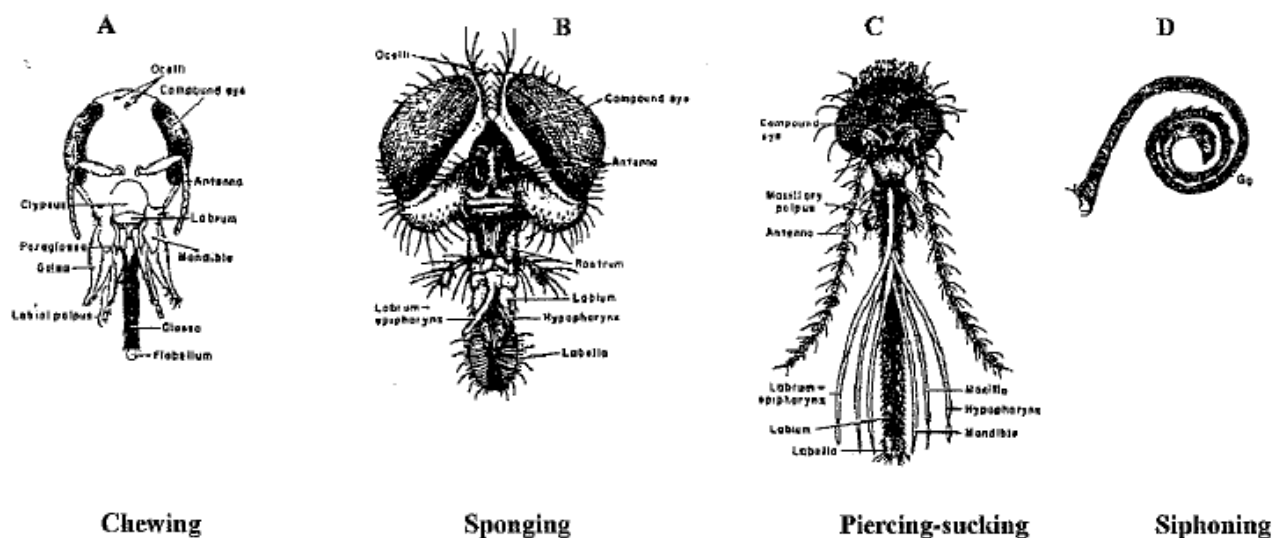


Figure 5-C: TYPES OF MOUTHPARTS



HEAD

The head of an insect contains many of the sensory organs and allows it to receive input from the environment and direct its movements and activities.

Eyesight

Most insects have very good eyesight for the activities essential to their existence. Many mature insects have two **compound eyes** which are made up of hundreds of separate lenses. Insects can perceive motion by sensing visual stimuli as they pass across the many facets of their compound eyes. Insects also have from 1 to 3 simple eyes called **ocelli**. These are used mainly for light detection.

Antennae

Most insects have one pair of antennae located on the front of the head. They are extremely variable in shape and number of segments. They are used in identification of many insects. Antennae are primarily used to sense odours. However, depending on the insect, they may be used to taste, smell, or to detect pheromones, sound, food, water, and sites for egg-laying.

Mouthparts

The mouthparts of insects vary in form and function and are located on either the anterior or ventral part of the head. There are basically two types: **chewing and piercing-sucking**. Insects with chewing mouthparts, which are the most common, have mandibles that move laterally to chew off portions of food for ingestion. Insects with piercing-sucking mouthparts remove liquid food. There are several intermediate types: rasping-sucking, where the plant tissue is rasped and the escaping sap sucked; and siphoning or simple mouthparts where the insect feeds on nectar or sap.

THORAX

The portion of the insect that provides movement, including the wings and large leg muscles, is the thorax. The thorax is made up of three segments: prothorax, mesothorax and metathorax.

Legs

Most adult and many immature insects have three pairs of jointed legs which are attached to each segment on the thorax. The legs are usually used for walking, jumping or running, but may be modified for other activities such as grasping, digging and swimming. Insect feet are called tarsi and are segmented. They may have claws or pads to aid in holding onto a surface or food. Some insects have sensory organs in their tarsi. The legs and tarsi vary in size and form depending on the insect and are an aid in their classification.

Wings

Most insects have 2 pairs of wings, but others only have 1 pair or none. Wings are attached to the mesothorax and/or the metathorax. The wings of insects are extremely variable. Most are membranous, some are leathery and many are covered with hairs or scales. All wings have veins. The pattern or arrangement is called venation and is different for each species of insect. Venation is an important descriptive characteristic in classification and identification.

Many insect order names end in "ptera", which comes from the Greek word meaning "with wings". Hemiptera means half-winged; Hymenoptera means membrane-winged; Diptera means two-winged; and Isoptera means equal wings.

ABDOMEN

Reproductive and digestive organs within the abdomen enable the insect to obtain nutrients from its food, excrete waste products and reproduce. The abdomen may have up to 11 or 12 segments (many have less) which are often difficult to distinguish. Some insects may have a pair of appendages at the tip of the abdomen. They may be short as in grasshoppers, long and delicate as in mayflies, or curved and pincer-like as in earwigs. Immature insects such as caterpillars may also have short abdominal legs called prolegs. Prolegs aid in moving the body around. Spiracles are paired openings on the lateral sides of the segments. These openings are breathing organs connected to tubes which conduct free air to the cells of the body. The ovipositor of female insects is located at the end of the abdomen and is used for laying eggs.

Figure 5-D: Various Legs and Wings of Insects

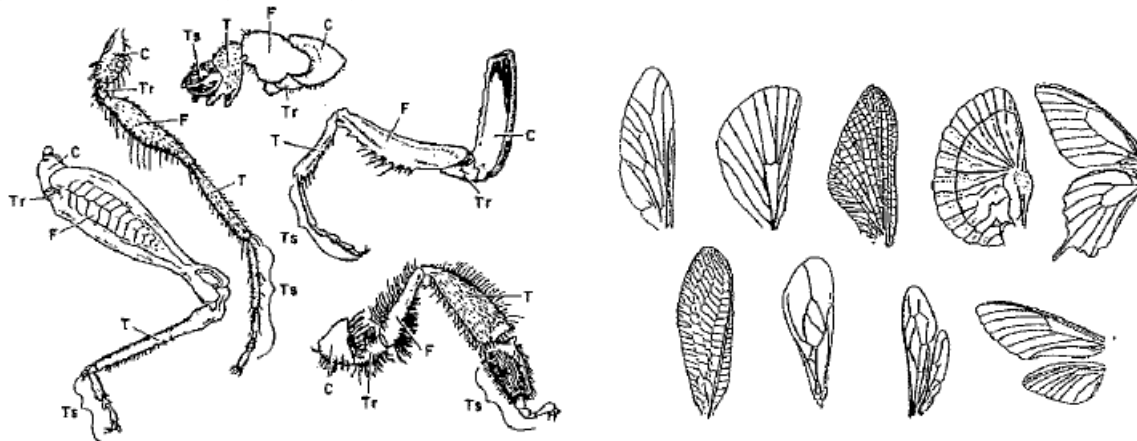
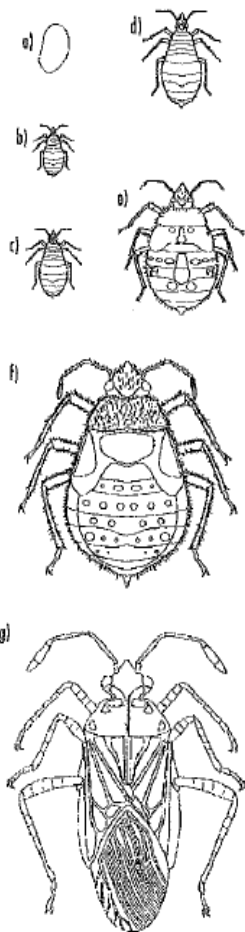
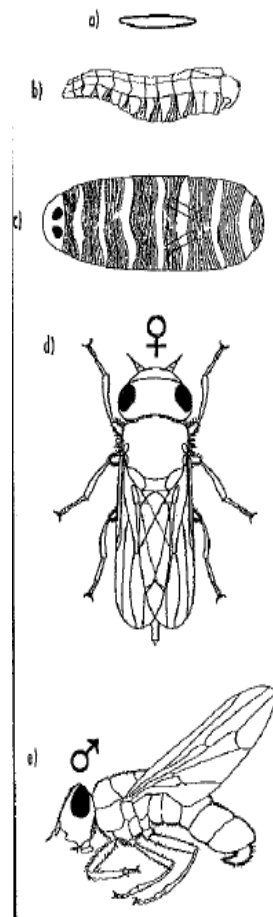


Figure 5-E: METAMORPHOSIS

Incomplete Metamorphosis**Complete Metamorphosis**

Incomplete Metamorphosis of a plant bug showing:

- a) egg
- b) first nymphal instar
- c) second nymphal instar
- d) third nymphal instar
- e) fourth nymphal instar
- f) fifth nymphal instar
- g) adult

Complete Metamorphosis of a root maggot fly

- a) egg
- b) larva
- c) pupa
- d) adult female
- e) adult male

INSECT GROWTH - METAMORPHOSIS

Life cycles of insects are often similar from one species to another. The life history of an insect is a tabulation of the growth phases through which a species passes the length of time in each phase and the number of life cycles. The details of their life history are important for understanding the nature of the damage insects can create and the best way to control or prevent damage from occurring.

All insects begin life as an egg from which they hatch into an immature feeding and growing stage. Insect eggs are usually quite small and quite varied in form. They are usually laid near or on the food that is used by the hatching young. The newly hatched forms of many species are quite unlike the adults into which they develop. The process of insect development from egg to adult is known as metamorphosis. There are two types of metamorphosis: incomplete (or gradual) and complete.

Incomplete Metamorphosis	Complete Metamorphosis
egg ↓ nymph ↓ adult	egg ↓ larva ↓ pupa ↓ adult

When the young of insects with incomplete metamorphosis hatch, they are somewhat similar to adults of the species, but lack wings. These young are known as nymphs and have similar feeding habits to the adults. The growth of a nymph is restricted by its exoskeleton which must be shed in order to grow larger. A new exoskeleton develops beneath the old one and a split develops in the cuticle of the old exoskeleton, allowing the larger nymph to emerge. Nymphs will generally undergo several moults and the periods between moults are called instars. Insects with incomplete metamorphosis are more easily controlled with insecticides when they are young nymphs.

The young of insects with complete metamorphosis look quite different from the adult, e.g., white grubs and June beetles, or caterpillars and butterflies. The larvae of insects with complete metamorphosis also undergo a number of moults as they increase in size.

The appearance of many larvae is worm-like, although size varies greatly. It is the larval feeding stage that is responsible for much plant damage. The resting stage or pupa occurs after the final larval moult. Pupae are usually immobile and do not feed. During this stage of growth, the internal structures of the larvae degenerate and new adult organs and structures are formed. This growth phase is resistant and generally hidden from exposure and insecticides.

Once an insect reaches the adult phase, there is no further increase in size. Adults feed, but only to reproduce. Some adult insects do not feed and live only long enough to mate and lay eggs.

The usual life history is divided into an active and dormant period. The active period is subdivided into a primary life cycle starting in the spring, and subsequent secondary cycles. Some insect populations - such as those in the tropics or in greenhouses - have individuals at each stage of metamorphosis occurring at one time. Such populations do not experience a dormant period. The stage of growth in which an insect spends the winter differs with each species. Most insects overwinter in protected places such as in plant tissue, in the soil, under tree bark or on objects on the ground.

There are 26 separate Orders within the Class Insecta and a complete summary is given in **Table 5-1: Classification of the Class Insecta**.

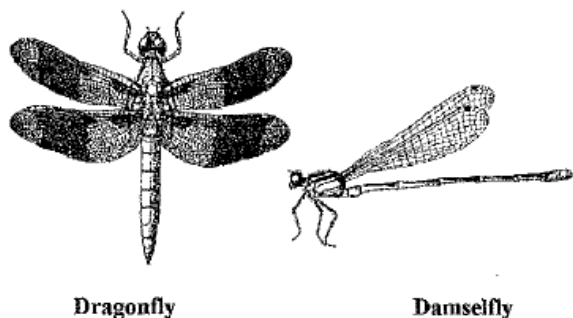
INSECTS WITH INCOMPLETE METAMORPHOSIS

Figure 5-F: ORDER THYSANURA - SILVERFISH AND FIREBRATS



Adults: 13 mm long, elongate, 3 tail-like appendages, chewing mouthparts and wingless. Silverfish: gray; Firebrats: tan. **Change little except for size** during metamorphosis; are very active and run rapidly. Household pests—Silverfish: cool, damp areas; Firebrats: warm situations. Feed on starchy substances including glue, linens, silks, paper, vegetables and starchy food.

Figure 5-G: ORDER ODONATA - DRAGONFLIES AND DAMSELFLIES



Adults: up to 75 mm, damselflies more delicate, chewing mouthparts, 2 pairs of wings: elongate; many veins and may or may not be patterned. Dragonflies hold wings horizontally at rest; damselflies fold them over the back. Eyes large, thorax robust, abdomen long and slender, antennae small and bristle-like. Colours: green, blue, red, orange, brown and black. Found around bodies of water; nymphs aquatic. Adults feed on insects.

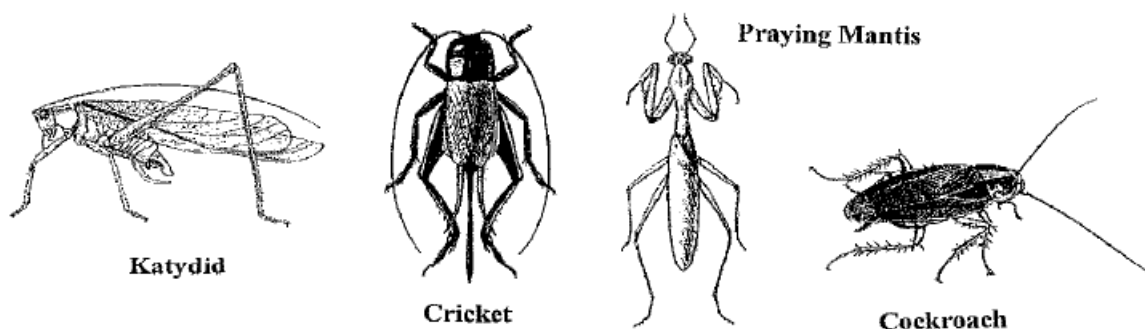
Nymphs: aquatic, feed on insects and other aquatic organisms.

Figure 5-I: ORDER DERMAPTERA - EARWIGS



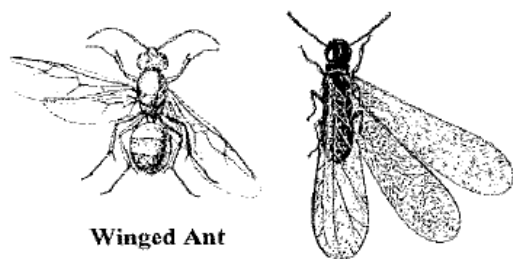
Adults: 10-20 mm long, elongate, flattened, brown in colour, chewing mouthparts, thread-like antennae, 2 pairs of wings, front pair short and leathery, hind pair, when present, membranous and folded under front wings. Pair of forceps-like cerci (pincers) at rear. Nocturnal, hide during day in leaf litter, mulch, under bark, etc. Feed on plant material, are scavengers, sometimes predators. Believed to be good nocturnal predators of aphids, etc. Nymphs: resemble adults, smaller, wings reduced or lacking, chewing mouthparts, found with adults.

Figure 5-H: ORDER ORTHOPTERA - GRASSHOPPERS, KATYDIDS, CRICKET MANTIDS, WALKINGSTICKS, AND COCKROACHES



Adults: 10-150 mm, chewing mouthparts, body elongate, may be narrow or flattened, colour variable. Legs: walking, jumping, running and grasping. Wings: 2 pairs, front pair generally long, narrow and leathery; hind pair broad, many-veined, and usually folded under front wings when at rest; some wings reduced. Habitat: variable, depending on species, trees, shrubs, herbaceous vegetation, indoor pests. Food variable depending on species, plant feeders, predators, omnivores and scavengers. **Nymphs:** resemble adults, no or reduced wings, chewing mouthparts.

Figure 5 -J: ORDER ISOPTERA – TERMITES



Winged Ant

Swarmer Termite

Adults: 6 mm long. Workers: whitish, wingless, or wing buds, short thread- or bead-like antennae, broad waist. Swimmers: dark brown, 2 pairs of nearly identical wings that are longer than the body. Chewing mouthparts. **Nymphs:** resemble workers, but smaller and wingless. Feed on wood, structural pests. Highly developed social structure with many castes. Colony occurs in the soil. When infesting a structure termites construct mud tubes to maintain soil contact for moisture and moving food to the colony. Eastern subterranean termite most common in this area. Dry wood termites occur in the southern United States and do not live in the soil.

Distinguished from ants: termites have straight antennae and thick waists, winged forms have 2 pair of equal length wings; ants have elbowed antennae and narrow waists, winged forms have front pair of wings largest.

Figure 5-L: ORDER HEMIPTERA - TRUE BUGS



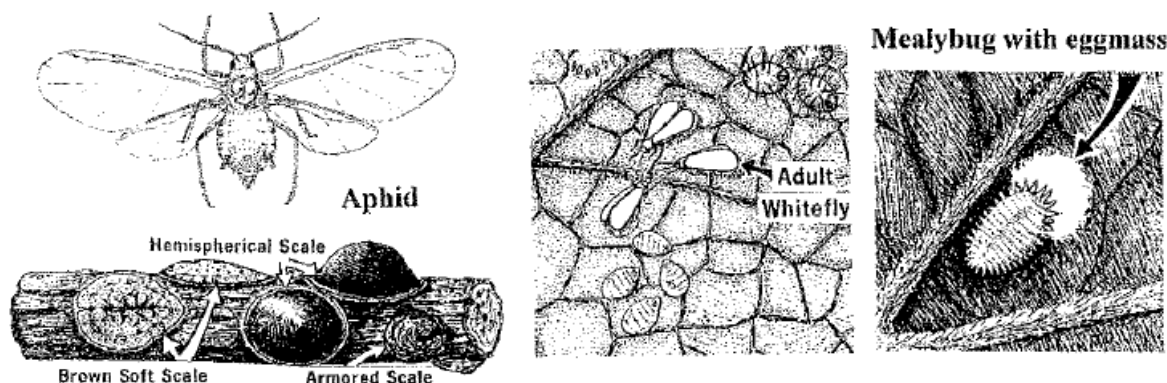
Adults: size variable: 3mm to over 50 mm, body variable: oval to long and narrow, colour variable, piercing-sucking, beak-like mouthparts. Wings: 2 pairs if present, basal portion of front pair thick and leathery, apical portion membranous. Hind wings membranous and shorter than front wings. Antennae long and eyes well developed. Large, widely distributed group including water bugs, lace bugs, bed bugs, assassin bugs, plant bugs, etc. Habits and habitats variable: aquatic, terrestrial, predators, plant feeders, blood feeders. **Nymphs:** resemble adults, but smaller with no or reduced wings.

Figure 5-K: ORDER THYSANOPTERA - THRIPS



Adults: minute, 5 mm or less, slender-bodied, colour varies from yellow to black, rasping- sucking mouthparts, winged or wingless. If winged, 2 pairs, long, narrow, and fringed with hairs, short antennae. Food and habits include plant feeders, gall formers, plant disease vectors, predators and fungal feeders.

Figure 5-M: ORDER HOMOPTERA - CICADAS, LEAF AND PLANT HOPPERS, PSYLLIDS, WHITEFLIES, APHIDS AND SCALES

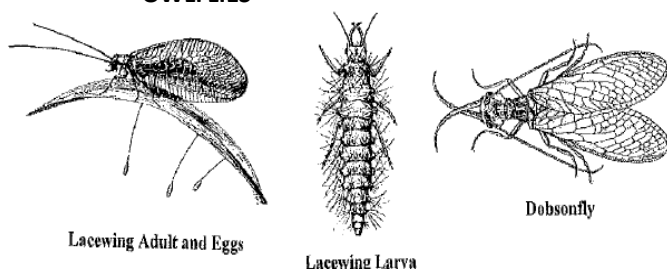


Diverse in size and appearance. Size varies from 5 mm to over 50 mm. Some have complex life cycles that may involve parthenogenesis (asexual reproduction), winged and wingless individuals, and sometimes regular alternation of food plants. All are plant feeders, some are pests, some transmit plant diseases, all have sucking mouthparts, most are soft-bodied.

Cicadas: up to 50 mm, produce sound, hard-bodied. Damage plants by egg-laying. **Leaf and Plant Hoppers:** very common, less than 10 mm, shape variable (some resemble plant parts, colour variable (pale green to very colourful), some transmit plant diseases, all produce honeydew. **Psyllids:** "plant lice", resemble miniature cicadas, some pit and gall formers, some cup leaves. **Whiteflies:** Adults: 5 mm long, resemble tiny white moths. **Nymphs:** wingless, active first instars, subsequently sessile (attached and not capable of moving), oval in shape and resemble scales. Feed on undersides of leaves. **Aphids:** small, soft-bodied, pear-like shape, pair of cornicles (pair of tubular structures at rear of the abdomen). Generally feed on young shoots or leaves of plants. Some produce waxy covering. **Adelgids:** related to aphids, most produce galls, some covered with wax and do not produce galls. **Scale Insects:** very diverse, generally minute, and specialized. Females wingless, usually sessile; males 1 pair of wings. Armored scales: protected by 3 mm circular or elongate, variously coloured cover. **Soft scales:** up to 5 mm, raised, may be waxy or cottony. **Mealy bugs:** smaller, oval, segmented, covered with dusty white wax.

INSECTS WITH COMPLETE METAMORPHOSIS

Figure 5-N: ORDER NEUROPTERA - ALDERFLIES, DOBSONFLIES, FISHFLIES, SNAKEFLIES, LACEWINGS, ANTLIONS, AND OWLFLIES



Adults: soft-bodied, 10 mm to over 50 mm, chewing mouthparts, 2 pairs of membranous wings with many veins and held roof-like over body, antennae long, colour varies green to brown, and most predaceous. Larvae: chewing mouthparts, most predaceous with sickle-like mouthparts, some aquatic. Forty percent of all insect species are beetles.

Adults: size varies from less than 1 mm to over 175 mm, body hard, round to elongate, colour highly variable. 2 pairs of wings: front pair hardened or leathery called elytra, hind wings membranous and folded under front wings. Front wings may be greatly reduced, e.g. Rove Beetles. Mouthparts: chewing. Antennae: clubbed, serrated, feathery, bead-like or thread-like. **Larvae:** soft-bodied, have head capsule, 3 pairs of legs on thorax, no legs on abdomen (Weevil larvae lack legs on thorax). Some larvae "c-shaped" grubs, others elongate and very active, borers are legless. Food and habits extremely variable: plant feeders, predators, scavengers, and parasites. Occupy almost every habitat in which an insect is found.

Figure 5-O: ORDER COLEOPTERA - BEETLES AND WEEVILS

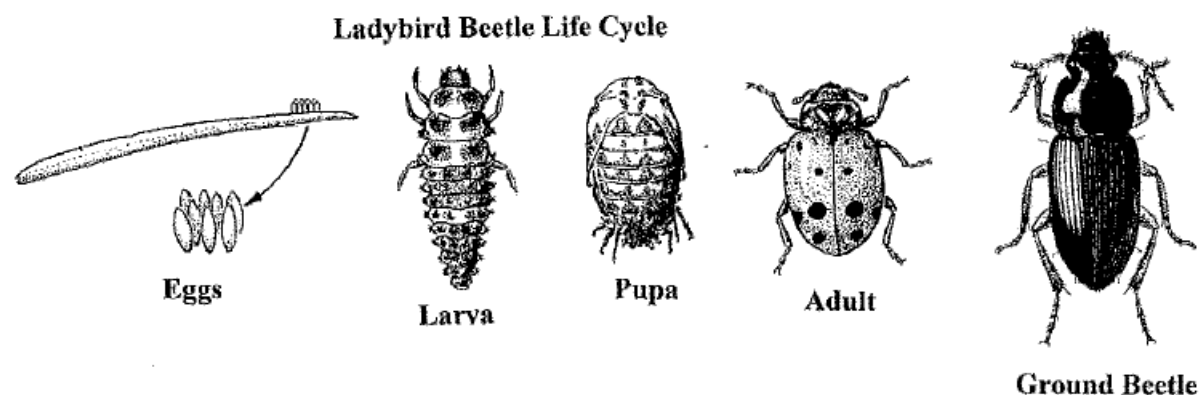
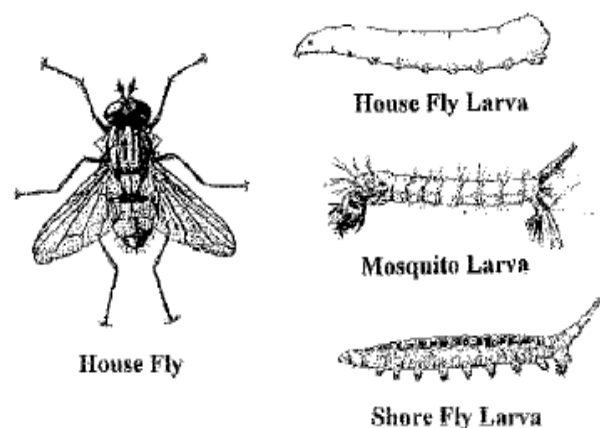
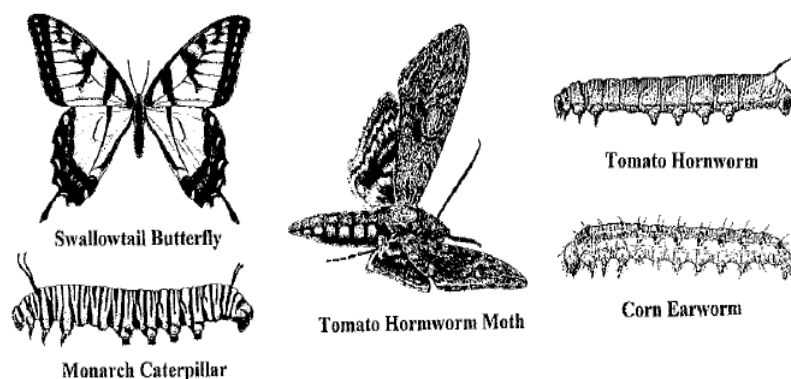


Figure 5-P: ORDER DIPTERA - FLIES



Adults: size variable from less than 3 mm to over 25 mm, colour variable from black to iridescent blue, most small and soft-bodied. One pair of membranous wings. Hind wings reduced to small knobs called halteres. Mouthparts: sucking or modified to piercing or sponging. **Larvae:** legless and wormlike (maggots), head capsules may be well developed in primitive flies and non-existent in more advanced flies with mouthparts only visible as mouth hooks. Food and habits: adults feed on nectar sap, some blood feeders, many predaceous. Larvae occur in wide variety of habitats, many in some sort of aquatic habitat. Plant feeders generally feed within plant tissue as leaf miners, borers or gall formers. Predaceous larvae live in water, soil, under bark or stones or on vegetation. Many species feed during the larval stage in decaying plant or animal matter.

Figure 5-Q: ORDER LEPIDOPTERA - BUTTERFLIES AND MOTHS



Adults: 6 mm to over 50 mm, soft-bodied, elongate shape, colour highly variable. Antennae: long and slender, sometimes plumose, always knobbed apically in butterflies. Mouthparts: sucking, proboscis usually in form of a coiled tube. 4 membranous wings, mostly or entirely covered with scales.

Larvae: size variable, chewing mouthparts, 3 pairs of thoracic legs, 5 or fewer pairs of abdominal prolegs. Prolegs: short and fleshy with tiny apical hooks (crochets). Lack compound eyes, but have a group of small ocelli on each side of head. Many have hairs or spines, colour variable. Many larvae pupate in silk cocoons, some do not. Butterfly pupae are called chrysalides, which may be sculptured and brightly coloured. Moth pupae are smooth and brown. Food and habits: adults feed on nectar and other liquid food; some do not feed. Some butterflies migrate long distances. Most larvae feed externally on plant material, others are leaf miners, borers, and gall makers. A few are predators.

Figure 5-R: ORDER SIPHONAPTERA – FLEAS



Adults: less than 3 mm, brown to black, laterally flattened, jump. Mouthparts: piercing-sucking.

Larvae: tiny, whitish, legless, resemble maggots.

Chewing mouthparts. Food and habits: adults feed on blood, most eggs laid in nest of host. Very active, many non-host specific, spend large part of time off host, and long-lived. Larvae feed primarily on dried blood in feces of adult fleas.

Figure 5-S: ORDER HYMENOPTERA - SAWFLIES, ANTS, WASPS AND BEES



Pine Sawfly



Ant



Thread-waisted Wasp



Honey Bee



Pine Sawfly Larva



Yellowjacket



Leafcutter Bee Larva

Most advanced order, and most beneficial to humans. **Adults:** size variable from less than 3 mm to several millimetres, colour variable, 2 pairs of membranous wings (hind wings smaller than front wings), mouthparts chewing (modified in bees into tongue-like structure). Ovipositor well developed, some modified into stinger for offense and defense, only females can sting. **Larvae:** grub-like or maggot-like.

Sawflies: Adults: wasp-like, do not have narrow waist, some brightly coloured, usually less than 25 mm. Larvae: caterpillar-like, more than 5 pairs of prolegs, plant feeders, most externally on foliage. Ants: widely distributed, size variable, carnivores, scavengers and plant feeders. Reproductive forms have wings; workers do not. Complex social structure. Wasps and Hornets: includes parasitic Hymenoptera, some may have very long ovipositors, nest builders, both aerial and ground nesting hornets and yellow jackets, and solitary nesting wasps. Most are predatory. Bees: generally robust, many hairy, most species solitary, some social, important pollinators.

Figure 5-T: OTHER COMMON ARTHROPODS



Mites: Tiny, soft-bodied, one obvious body region, 6 legs as larvae, 8 legs as nymphs and adults, no antennae. Plant and blood feeders, some live in soil and feed on fungi and organic matter.



Ticks: Parasitic blood feeders only, 6 legs as larvae, 8 legs as nymphs and adults, no antennae. Many carry diseases. Hard ticks: hard dorsal plate called a scutum, mouthparts visible from above. Soft ticks: lack a scutum, soft-bodied, mouthparts not visible from above.



Spiders: 2 distinct body regions, size and colour variable, all are predators.



Millipedes: elongate, rounded in cross section, 2 pairs of short legs per body segment, short antennae, slow-moving. Feed on fungi and decaying organic matter.



Centipedes: elongate, longer antenna, flattened in cross section, 1 pair of longer legs per body segment, move rapidly, most predators.



Sowbugs and Pillbugs: oval, hard, segmented, outer shell, associated with moist habitats. Generally feed on decaying organic matter.

TWELVE COMMON INSECT PESTS IN THE GARDEN

Ants	- many different species: 3 mm to 6 mm; red, brown or black - form colonies and burrow in gardens, more common in sandy soil - usually no severe plant damage - can transmit disease spores or eggs of other insects, i.e. aphids	Sod Webworm	adult moth: 0.5-1.2 cm; long, thin, tan coloured; caterpillar: to 2 cm; white to tan with darker spots and a dark head
Aphids	- small: 0.5 - 2 mm; green, black, yellow - often found in great numbers on stems and leaves - can transmit disease from plant to plant - suck sap from plants and excrete honeydew which attracts ants - a favourite food of ladybird beetles	Tent Caterpillars	- several species (Eastern, Forest) - adult moth: to 4 cm; yellow-brown - caterpillar: to 50 mm with various brightly coloured stripes or spots - Eastern Tent caterpillar forms large colonies in forks of tree branches - egg masses are shiny and encircle branches over winter
Chinch Bug	3-5 mm; black and white with red-brown legs - sucks juices from grass stems and crowns causing dead patches, usually in August - adults overwinter in flower beds, shrub borders and near foundations - nymphs can be easily controlled with insecticide applied at key stages of development	Thrips	- small: 0.5-2 mm; light coloured with feathery wings - extracts sap from plants, especially flowers - may spread viral or fungal diseases
Earwigs	- to 20 mm; black or brown with pincers at tip of abdomen - nocturnal, feeding on plants and scavenging - large colonies can be found in debris and other protected situations in daytime	Whitefly	- to 2 mm; white with powdery wings - usually found feeding on underside of leaf but will fly if disturbed - may leave a deposit on foliage which attracts ants
Mealy Bugs	- small: to 2 mm; oval white, cottony, slow-moving - can form large colonies - suck sap from leaves and stems - serious pests of some fruit trees, shrubs and greenhouse plants	White Grubs	- adult June beetle to 3 cm, black, shiny larvae: to 4 cm; white with brown head and 3 pairs of legs - larvae feed on grass roots over several years before maturing; adults feed on foliage and flowers - more mature larvae can cause serious damage to lawns
Scale	- small: 0.5 - 2 mm; brown, black, mottled hard shell, slow-moving or sessile - suck sap from leaves and stems - serious pest of many ornamental plants		

CLASSIFICATION OF THE CLASS INSECTA

Table 5-1: CLASSIFICATION OF THE CLASS INSECTA

Order	Common Name	Metamorphosis	Mouthparts	Wings	Usual Size	Habitat
Anoplura	Sucking lice	incomplete	sucking	none	minute	on mammals
Coleoptera	Beetles	complete	chewing	0-4	minute to large	all habitats
Collembola	Springtails	incomplete	chewing	none	minute	in debris
Dermaptera	Earwigs	incomplete	chewing	0-4	medium to small	in debris, plants
Diptera	Flies	complete	sucking	0-2	minute to large	on vegetation, other habitats
Embioptera	Webspinners	incomplete	chewing	0-4	small	in debris
Ephemeroptera	Mayflies	incomplete, nymphs aquatic	vestigial	4	medium	near water
Hemiptera	Bugs	incomplete	sucking	0-4	medium	on debris, on vegetation in water
Homoptera	Cicadas, hoppers, whiteflies, aphids, scale insects	incomplete	sucking	0-4	minute to large	on vegetation
Hymenoptera	Sawflies, ants, wasps and bees	complete	chewing, chewing-sucking	0-4	minute to large	on ground or vegetation
Isoptera	Termites	incomplete	chewing	4	small	in ground or wood
Lepidoptera	Butterflies, moths	complete	sucking, chewing	0-4	minute to large	on vegetation
Mallophaga	Chewing lice	incomplete	chewing	none	minute	on birds or mammals
Mecoptera	Scorpionflies	complete	chewing; beaklike	0-4	medium	on vegetation
Neuroptera	Dobsonflies, fishflies, alderflies, lacewings, antlions	complete	chewing	4	medium to large	on vegetation, often near water
Odonata	Dragonflies, damselflies	incomplete, nymphs aquatic	chewing	4	large	near water
Orthoptera	Grasshoppers, crickets, cockroaches, mantids, walkingsticks	incomplete	chewing	0-4	large	on ground or vegetation
Plecoptera	Stoneflies	incomplete, nymphs aquatic	chewing	4	medium	near water
Protura	Proturans	incomplete	sucking	none	minute	in debris

Order	Common Name	Metamorphosis	Mouthparts	Wings	Usual Size	Habitat
Psocoptera	Booklice, barklice	incomplete	chewing	0-4	small to minute	in debris, buildings
Siphonaptera	Fleas	complete	sucking	none	minute	on birds or mammals
Strepsiptera	Twisted-winged parasites	complete	vestigial	0-2, male	minute	in other insects
Thysanoptera	Thrips	incomplete	rasping-sucking	0-4	minute	on debris or on vegetation
Thysanura	Bristletails (silverfish and firebrats)	incomplete	chewing	none	medium	in debris, buildings
Trichoptera	Caddisflies	complete	chewing; reduced	4	small to medium	near water
Zoraptera	Zorapterans	incomplete	chewing	0-4	minute	in debris

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CHAPTER 6: PLANT DISEASES

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PLANT DISEASES

INTRODUCTION

Plant pathologists study plant diseases caused by fungi, bacteria, viruses, parasitic plants and nematodes. Pathologists also examine ways diseases spread, the disease cycle, and the best control options. The study of plant pathology also includes plant disorders caused by nutrient imbalances, air pollution, and unfavorable growing conditions.

A BRIEF HISTORY

Plant diseases have had profound effects on mankind through the centuries, as evidenced by Biblical references to blasting and mildew of plants. The Greek philosopher Theophrastus (370-286 B.C.) was the first to describe maladies of trees, cereals and legumes that we today classify as leaf scorch, rots, scab, and cereal rust. The Romans were also aware of rust diseases of their grain crops. They celebrated the holiday of Robigalia that involved sacrifices of reddish coloured dogs and cattle in an attempt to appease the rust God Robigo.

With the invention of the microscope in the seventeenth century, fungi and bacteria associated with plants were investigated. In 1665, Robert Hooke published the first illustration of rust on a rose leaf. Advances in the study of disease life cycles were hampered by the widely held belief in "spontaneous generation". This theory, held by most people in the mid 18th century, considered pathogenic microorganisms as products of disease rather than causal agents of disease.

The devastating epidemics of Late Blight of Potato in Ireland in 1845 and 1846 dramatized the effect of plant diseases on mankind. Tragically, these epidemics caused famine and death for over a million people and resulted in a loss of nearly a third of Ireland's population between 1845 and 1860. In 1861, a German botanist Anton De Bary, proved that a fungus, *Phytophthora infestans*, was the causal agent of late blight of potato. This was a milestone in the study of plant disease since it showed that a fungal pathogen was indeed the cause of late blight of potato rather than an organism simply associated with the disease. Two years later in 1863, Louis Pasteur proposed his germ theory of disease that finally disproved the theory of spontaneous generation. This milestone essentially changed the way modern science investigated the diseases of all living creatures.

SIGNIFICANCE OF PLANT DISEASES IN NORTH AMERICA

A few examples of plant disease epidemics that have resulted in devastating plant losses in North America include:

- Chestnut Blight, introduced in 1904, has virtually eliminated American chestnut trees from North America.
- Citrus Canker, introduced in 1910 and a closely related bacterial disease called Citrus Bacterial Spot discovered in 1984 have resulted in the destruction of millions of citrus trees.
- White Pine Blister Rust, introduced in 1912, has caused large economic losses in the timber industry.
- Dutch Elm Disease, introduced in 1930, continues to destroy large numbers of elm trees across the continent.

The Canadian Food Inspection Agency was created in April 1997 by an Act of Parliament to consolidate all federally mandated food inspection and animal and plant health services. The Agency reports to the Parliament through the Minister of Agriculture and Agri-Food Canada.

The Plant Protection Act and Seeds Act are administered by Plant Protection Division which implements programs that protect plant life and agricultural and forestry sectors across Canada.

The Plant Protection Act deals with the:

- Prevention of entry and spread of pests injurious to plants in Canada and foreign countries.
- Provisions for the control or eradication of such pests whenever necessary.
- Issuance of movement certificates of regulated domestic plants, plant products and related items for transportation within Canada.
- Forestry, field crops (cereals, oilseeds and forages) and nursery and horticultural crops (fruits, vegetables and ornamentals) are supported by the program.

The Seeds Act requires that all seed be graded in Canada. A certificate is available for every lot of seed that has been graded. It includes the Latin and common names as well as percentage of pure seed, other crops and weed seeds. Results of germination tests are also indicated.

BASIC PLANT DISEASE CONCEPTS

THE CONCEPT OF DISEASE

There are many ways to describe or define a plant disease. A simple definition:

- Plant diseases involve profound physiological and morphological changes that cause a disruption of normal plant function over time.

A working definition of a healthy plant is:

- A plant that can carry out its physiological functions to the best of its genetic ability.

Symptoms are the visible reactions of a plant to a disease and may suggest a causal agent (see **Table 6- 1**). A sampling of disease symptoms might include:

- wilting
- necrosis
- abnormal colouration
- defoliation
- fruit drop
- abnormal cellular growth
- cankers
- galls
- damping off
- stunting

However, it is important to remember and frustrating at times to realize that different disease agents can cause similar symptoms on the same host. An equally important point to remember is that plant damage caused by insect or mite feeding or environmental conditions can also cause "disease-like" symptoms on plants.

Signs are the visible parts of the pathogen or its products seen on the host that can be used to identify the pathogen. Examples of common disease signs would include:

- The white coating of powdery mildew on leaves
- Mushroom growth on a tree limb
- Droplets of bacterial ooze on a fruit tree twig
- Nematode cysts on plant roots
- Dark fungal fruiting bodies visible in leaf lesions

CAUSAL AGENTS OF DISEASE

A **pathogen** is any organism that can incite a disease. Pathogens cause infectious diseases that can spread from an infected plant to a healthy plant. Proof that an organism is a pathogen has to be verified through a set of procedures called Koch's Postulates. Robert Koch was a German microbiologist who set up a series of postulates in 1876 to prove that anthrax disease of cattle was caused by a bacterium. Examples of pathogens that cause infectious diseases are:

- bacteria
- fungi
- viruses
- nematodes
- parasitic plants

Plant diseases can also be caused by non-infectious or nonliving factors. Causes of disease by nonliving factors include:

- unfavorable growing conditions
- mineral deficiencies
- air pollution

Some pathogens are restricted to a single plant species while others can infect a single plant genus. There are still others that can attack a large number of hosts that span many plant genera.

There are also several levels of parasitism that pathogens can have with their hosts.

- When a pathogen is capable of infecting a plant, the plant is considered **susceptible** to that pathogen.
- If a pathogen cannot infect a plant then the plant is considered **resistant** to that pathogen.
- Plants can vary in their resistance to pathogens from **complete resistance**, or no disease development to **partial resistance**, or a little disease development.
- Pathogens can vary in their degree of virulence (aggressiveness) on a susceptible plant ranging from highly virulent, causing severe disease symptoms to weakly virulent, causing less disease.

INOCULUM AND PATHOGEN DISSEMINATION

Inoculum is any part of the pathogen that can cause infection. Examples of inoculum include:

- fungal spores
- fungal mycelium
- bacterial cells
- virus particles
- nematode eggs

Inoculum that survives the winter and causes the original or primary infection in the spring is called primary inoculum. Secondary inoculum causes additional infections throughout the growing season.

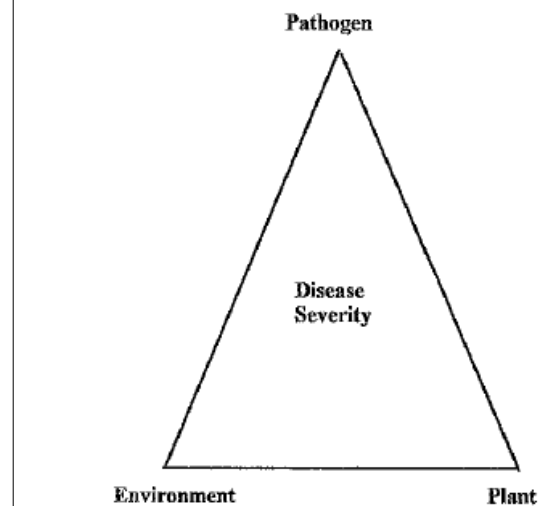
Inoculum is sometimes **present at the site** where a plant is grown or it can be **introduced from an outside source**. Examples of inoculum already present at a planting site include soil pathogens or pathogens that overwinter on perennial weeds. Examples of introduced inoculum include infected plant material such as infected seeds or inoculum brought in by insect vectors.

Inoculum can be **disseminated passively** by wind, rain, insect vectors, and man. Examples of **actively disseminated** inoculum are nematodes or fungal zoospores swimming through water in the soil toward plant roots. Only a small fraction of any pathogen's inoculum will ever land on a susceptible host. The vast majority of inoculum typically lands on material that cannot be infected. Most pathogens produce a tremendous surplus of inoculum.

PATHOGEN SURVIVAL

Pathogens in temperate climates must have a way of overwintering when their host plants are dormant or absent. In perennial plants, pathogens can survive in infected plant parts such as roots, bulbs, stems, and bud scales. Annual plants, however, die at the end of the growing season and pathogens must form resistant resting structures or survive in seeds or insect vectors, an agent that carries disease organisms from one host to another.

Figure 6-A: PLANT DISEASE TRIANGLE



HOST PATHOGEN INTERACTIONS

The interactions of the three components of disease may be diagrammed as a **disease triangle (Figure 6-A)**. Plant disease occurs when a susceptible plant is infected by a pathogen under environmental conditions that favor disease. Each of these three components can affect the amount of disease that occurs. For example:

- A plant can have variable levels of resistance to the pathogen or may be at a non-susceptible growth stage for infection.
- The pathogen may vary in its virulence to the host, or may not be present.
- The environment can influence disease levels through fluctuations above or below the optimum temperature and humidity level needed for infection.
- The weather can also affect pathogen dispersal by wind or rain, and can alter the migration of insect vectors.

DESCRIPTION OF PLANT DISEASES AND THEIR PATHOGENS

PLANT DISEASES CAUSED BY FUNGI

The study of fungi is called **mycology** after the Greek word *mykes*, which refers to fungi. Fungi are filamentous organisms that are for the most part microscopic, but some produce large structures such as toadstools or mushrooms.

Since fungi lack chlorophyll they cannot manufacture their own food and therefore need to draw their sustenance from other living things. Fungi grow as microscopic threads or filaments which branch in all directions. These filaments are called **hyphae** which originate from a Greek word for web. Many hyphae are collectively called **mycelium**. Taxonomically, primitive fungi produce an essentially undivided tube of cytoplasm in contrast to higher fungi that divide their hyphae into sections with cross walls called **septa**. A mycelium that is not divided by cross walls is said to be non-septate. Specialized aggregates of mycelium with a hard rind, known as **sclerotia**, function to enable some fungi to survive unfavorable climatic conditions and thus overwinter.

Approximately 100,000 fungal species have been described and most of them are beneficial or benign. There are only about 8,000 fungal species that cause plant diseases.

REPRODUCTION

The main reproductive unit is the **spore**. Spores are frequently fanned in specialized structures on the mycelium. Fungi can be differentiated and identified by their spore morphology and spore bearing structures. Fungi can also reproduce by both sexual and asexual spores as well as regenerating from pieces of mycelium:

- **Asexual spores** involve no genetic changes and are simply a means of dispersal or survival.

Asexual spores can be of several types. Water molds such as *Pythium*, *Phytophthora* and the downy mildews produce two kinds of asexual spores called **sporangia** and **zoospores**. Sporangia may germinate directly or, depending on moisture and temperature, they may produce motile zoospores that swim in water to find a suitable plant host.

More advanced fungal groups produce asexual spores called **conidia**. Conidia are usually carried by wind, although in some cases insects can serve as vectors. Sexual spores are very different in morphology from the asexual spores produced by the same fungus, and often are produced only at one point in the life cycle.

- **Sexual spores** are the result of a recombination of genetic material and give rise to genetic variation in a fungal species. This variation enables a fungus to adapt to a variety of conditions.

Sexual spores are named according to their taxonomic classification, e.g., Oomycetes produce oospores, Zygomycetes produce zygospores, Ascomycetes produce ascospores and Basidiomycetes produce basidiospores. Recombination of genetic material can sometimes result in new fungal strains that can overcome plant disease resistance or give rise to fungal resistance to chemical disease controls.

PLANT PATHOGENIC FUNGI

Fungi constitute 85%- 90% of the soil biomass. Together with bacteria, fungi are the major decomposers of organic material in the soil and recyclers of nutrients. Fungi also form symbiotic mycorrhizal associations with plant roots. The fungi either enter the roots or cover the root surface with a mycelial sheath. In this association the fungus obtains sugars and other nutrients from the plant and in return extends its filaments throughout the soil increasing the surface area of the plant's roots and thus the plant's ability to obtain water and nutrients.

Oomycetes - The Water Molds, Downy Mildews and White Rust

The Oomycetes include the water molds, so called because of their dependence on wet conditions for reproduction and growth. This class also includes the downy mildew and white rust fungi. The Oomycetes reproduce asexually by means of zoospores contained within a sack-like structure called a **zoosporangium**. They form thick walled sexual spores called **oospores**. The oospores can survive adverse conditions. These fungi do not produce mycelium with septa; they are non-septate.

The genera *Pythium* and *Phytophthora* are two important members of the water mold group. The genus *Pythium* typically causes damping off diseases of many plants as well as seed decay, root rots, and also blights on turf grass.

Phytophthora is the pathogen of the infamous late blight of potato as well as being the causal agent for root diseases on a wide variety of landscape plants. Dispersal is by transport of infected plants or soil or water contaminated with zoospores.

Another group of organisms in this class are the downy mildew fungi. These fungi are obligate parasites (i.e., they cannot be cultured apart from their host) and disperse their zoosporangia by wind. Examples of diseases in this group are downy mildew of grape, caused by *Plasmopora*, downy mildew of lettuce caused by *Bremia*, and downy mildew of onions caused by *Peronospora*.

The genus *Albugo* is called the white rust fungus because of the white pustules formed on diseased plants. An example of a disease caused by *Albugo* is white rust of crucifers. Spore dispersal is accomplished by windblown zoosporangia.

Zygomycetes - The Bread Molds

The Zygomycetes, are known as the bread molds since one of the principle organisms in the class, *Rhizopus*, is frequently seen on moldy bread. These fungi don't produce motile zoospores, but still encase their spores in a sporangium. The sexual spore is called a **zygospore**. These fungi also produce mycelium without septa.

Many of the Zygomycetes are soil dwellers and saprobic, that is, they decompose and feed on dead and dying organic matter. Others form mycorrhizal relationships with various plants including agricultural crops. Fungi of the order Entomophthorales parasitize flies and other insects.

Ascomycetes - The Sac Fungi

The Ascomycetes are referred to as the sac fungi because the sexual spores (**ascospores**) are enclosed in a sac called the **ascus**. The ascus can be exposed or naked or formed within a fruiting body called an **ascocarp**.

Ascocarps that are flask shaped are called **perithecia**.

Ascocarps that are open and saucer shaped are called **apothecia**. This is a large assemblage of fungi with many widely differing morphologies and characteristics. These fungi produce well developed septate mycelium and can be distinguished by their characteristic spore morphologies.

Diseases caused by Ascomycetes include: powdery mildews on many host plants, black rot of grape, Dutch Elm Disease (*Ophiostoma ulmi*) and Oak wilt.

Basidiomycetes - The Club Fungi

The Basidiomycetes are called the club fungi because they produce their sexual spores, called **basidiospores**, within a microscopic club shaped structure called a **basidium**. This group of fungi produces some of the largest fruiting structures in the fungal kingdom in the form of mushrooms, puffballs and conks. The Basidiomycetes can be associated in beneficial relationships with tree roots as mycorrhizal fungi, or cause root rots and wood decay diseases in trees. Both the rust and the smut fungi are Basidiomycetes and obligate parasites that cause some of the most destructive crop diseases known. Many of these fungi have complex life cycles. For example many of the rust fungi must infect two unrelated plant genera to complete their reproductive cycle.

Deuteromycetes - The Imperfect Fungi

The Deuteromycetes reproduce asexually by forming coridia, although some genera are associated with a sexual life stage. These fungi possess well developed mycelia separated by septa. Diseases caused by Deuteromycetes includes Verticillium wilt, Fusarium wilt, Anthracnose, Diplodia stalk rot of sweet corn, Septoria blights and Alternaria blights, e.g., Early potato blight.

Some examples of common, pathogenic fungi include:

- Wood rot fungi (*Schizophyllum commune*)
- Stump rot of conifers (*Fomes annosus*)
- Silverleaf of fruit trees (*Stereum purpureum*)
- Leaf, flower or stem gall of Rhododendron or Azalea (*Exobasidium* spp.)
- Snapdragon rust (*Puccinia antirrhini*)
- Cereal rust (*Puccinia graminis*) Barberry is aecial host, wheat and other cereals are telial hosts.
- Cedar - apple rust (*Gymnosporangium juniperi-Virginianae*) Red cedar is aecial host, apple is telial host
- Bean rust (*Uromyces appenaculatus*)
- Bunt or Stinking smut of wheat (*Tilleta* spp.)

PLANT DISEASES CAUSED BY BACTERIA

Bacteria are simple single celled organisms that are microscopic. Approximately 1,600 bacterial species have been described and about 80 species are plant pathogens. Most bacteria can be grown in culture. Almost all plant pathogenic bacteria are rod shaped with the exception of *Streptomyces* which is filamentous. Most of these bacteria are enveloped in a protective layer of **viscous gummy material** and most also have **flagella** that are distributed in various patterns over the cell wall.

Most bacteria found in the soil are beneficial. They decompose dead organic matter, recycle nutrients and make them available to plants.

Bacteria multiply and divide asexually by binary fission-reproduction by splitting into two equal halves. Bacteria can go through this process very rapidly and under favorable conditions may divide every 20 minutes. At this doubling rate of reproduction one bacterium could produce one million bacteria in the time span of about ten hours.

Bacteria invade plants through **wounds or natural openings** such as lenticels or stomata. Wounds can occur from cultivation practices, environmental damage and from nematode or insect feeding. Bacteria can be spread from plant to plant by way of soil, water, infected seeds or plant parts, tools and insects. Most plant pathogenic bacteria develop in their host, but have the ability to also remain active for a period of time on plant debris. In some cases they can survive in the soil for extended periods.

There are seven major plant pathogenic bacteria genera and within each genus there are numerous species and subspecies or **pathovars**. Bacterial pathogens are often characterized by differential growth media, flagellar arrangement, and chemical composition of their cell walls, nutrition requirements and serological techniques. Bacterial diseases include wilts, rots, blights, galls and cankers.

PLANT DISEASES CAUSED BY MYCOPLASMA-LIKE ORGANISMS

Mycoplasmas associated with plant diseases were first described in 1967. Although to date Koch's Postulates have not been completed for all of these organisms, most pathologists consider them to be valid plant pathogens. Prior to their description many of the diseases they are associated with were lumped together with plant virus diseases. Since 1967, Mycoplasmas have been associated with more than 200 plant diseases affecting several hundred plant genera.

Mycoplasmas are very small organisms found in the phloem of diseased plants. These pathogens differ from bacteria in that they have neither a cell wall nor flagella and have a pleomorphic or variable shape. They reproduce by binary fission and by budding, but don't produce spores. Mycoplasmas are spread by leafhopper, plant hopper and psyllid insect vectors as well as by grafting and the plant parasite dodder. A sub-group of the mycoplasmas are called the spiroplasmas which are helical shaped.

Aster yellow is an example of a disease caused by a Mycoplasma-like organism. The disease is spread by the six-spotted leafhopper. It affects many flowering annuals as well as several vegetables, such as lettuce, carrots and celery, field crops and weeds.

PLANT DISEASES CAUSED BY NEMATODES

Plant parasitic nematodes are tiny (0.2-4 mm) worms. There are also many other free living or non-plant feeding nematode species found in every kind of habitat. All plant parasitic nematodes have a needle-like structure called a **stylet**. The stylet is located in the nematode head and is used to puncture plant cells so that the nematode can consume the cellular contents.

Nematodes can be classified either as **endoparasites** that burrow into tissues and feed internally within a plant, or as **ectoparasites** that feed from the surface of plant tissues. Both of these kinds of nematodes may also be further classified as either **migratory** or **sedentary**. Migratory forms are mobile throughout all stages in their life cycle except the egg stage. Sedentary forms enlarge and become immobile once they start to feed.

Soil nematodes cause damage to root tissues and interfere with the uptake of water and nutrients from the root to the shoot. In addition to the direct injury nematodes cause to plants, they sometimes also inject toxic substances into the cells they feed on, further disrupting cellular function. Certain plant parasitic nematodes can serve as virus vectors. Others cause severe enough feeding wounds to allow other soil pathogens such as fungi and bacteria to gain entry into damaged plants.

Some nematodes have broad host ranges while others attack very specific plants. Many nematode species can also survive and complete their life cycles on weeds. Most nematodes have large food reserves that allow them to survive for long periods of time without a host. Some nematodes can live as long as a year without a host and many can even survive through the winter in frozen soil. A few plant parasitic nematodes can lie in a dormant state within a cyst for many years.

The soil-lesion nematode is wide-spread in Ontario. It feeds on many hosts, including most vegetables and also strawberries. There are no chemical nematicides available to home gardeners in Ontario.

PARASITIC PLANTS

Several seed plants are capable of parasitizing other plants. Examples of these include dodder, mistletoe, witchweed and broomrape. Dodder and mistletoe attach to aerial portions of a plant, while witchweed and broomrape attach to plant roots. Dodder produces twining yellow to orange stems that resemble spaghetti. Dodder produces small structures called **haustoria** that actually penetrate into the host plant's vascular system. The dodder plant derives all of its nourishment directly from the host plant.

Cuscuta campestris, Field dodder, native to Ontario, parasitizes horticultural crops such as carrots, tomatoes, petunias, etc.

PLANT DISEASES CAUSED BY PLANT VIRUSES

Plant viruses differ from all other plant pathogens. They are not made up of cells and they can only be seen with the aid of an electron microscope. Since viruses are not cellular, they do not have Latin names and are given common names of the host in which they were first studied. Individual viruses are referred to as virus particles or **virions**.

Viruses are composed of a small piece of either DNA or RNA encapsulated inside a protein coat or **capsid**. Many viruses consist of one type of virions that contains all the genetic information needed for the virus to function; however, some viruses split their genome, or gene pool among several particles.

Viruses are unique in that they have none of the attributes of cellular pathogens, but they can reproduce inside living cells, spread within infected plant tissues and they can be spread to other plants by vectors. Viruses do not divide or produce any kind of reproductive structures such as spores. Instead, viruses multiply by taking control of the plant cell and forcing it to manufacture more virus particles.

Viruses cannot be cultured on artificial media since they need living cells on which to multiply. Serological tests (e.g., ELISA) and molecular biological techniques (e.g., PCR) are currently the most common methods used to detect viruses. Most plant viruses cause systemic infections and there is no cure for infected plants. Viruses do not kill cells by consuming them, but instead they disrupt normal cellular processes and eventually cause abnormal cellular function.

Viruses in nature rely on vectors to spread from plant to plant. Viruses can be spread by vegetative propagation, sap, seeds, pollen, insects, mites, nematodes, fungi, and parasitic plants. Viruses can be spread relatively long distances in insect vectors such as aphids carried on the prevailing winds.

In addition to typical viruses there are disease agents called **viroids**, discovered in 1971 by T. O. Diener at USDA Beltsville. They are small, naked, circular pieces of single stranded RNAs capable of infecting plants. Viroids seem to be the smallest nucleic acid molecules known to infect plants. Viroids disease symptoms generally resemble those caused by virus infections.

The symptoms of virus diseases are variable and can be confusing. They include mottling, yellowing, leaf-drop, rosetting, ring spots, wilting and stunting of the whole plant. Prevention of infection is the best way of dealing with virus diseases. Control insects and other vectors that spread the disease. Select virus-free plants, grow cultivars that are resistant and practice good cultural techniques and sanitation. Remove and destroy affected plants.

ENVIRONMENTAL DISEASES

Diseases and disorders caused by environmental factors are not contagious diseases, but they can cause substantial plant damage. In general most environmental problems are caused by deficiencies or excesses of normal factors that support life.

TEMPERATURE EFFECTS

Plants may be damaged by very high or very low temperatures. Rapid temperature changes are most likely to cause injury. Late frosts often damage the fruit buds of peaches, cherry, apricots and strawberries. Low temperatures in winter can cause bark splitting or **frost cracks** on the sunny side of many tree species in the landscape. Tropical indoor plants are prone to low temperature injury both in the home and while in transport. Cold injury symptoms usually show up as a blackening of the tissues and typically don't appear until a week after the injury has occurred.

High temperature injury includes **sunscauld** on indoor plants that are moved outside too quickly in the spring before the plant has had time to acclimatize itself to sunlight. Fleshy vegetables such as tomatoes, peppers and potatoes will also show sunscauld injury in the home vegetable garden.

MOISTURE EFFECTS

Excessive moisture and drought both damage plants. Poor drainage results in root decay because of reduced oxygen levels in the root zone. Root damage due to lack of oxygen then results in wilting and death of the leaves and shoots. Proper drainage is important to outdoor plants as well as indoor plants. More house plants suffer from overwatering practices than for any other reason. Drought injury causes wilting, scorch of the foliage, and stunting as well as abortion of flowers and fruit.

Another injury which sometimes occurs under excessive moisture conditions is swelling or oedema, and appears as numerous swollen bumps on the lower side of leaves. These swellings later turn brown and become corky in texture. This damage is common on certain herbaceous plants such as geraniums.

NUTRITIONAL EFFECTS

Plants require both macro and trace elements to maintain healthy growth. Lower than optimum levels of nutrients usually result in growth reduction.

Chronic nutrient deficiency can result in severe decline or death in extreme situations. Some minerals and salts are toxic if present in high concentrations and can interfere with normal metabolism. A common problem in home gardens is blossom end rot of tomato and peppers caused by a localized calcium deficiency in the fruits. This condition can be brought on by water stress and excessive amounts of nitrogen fertilizer that reduce the uptake of calcium from the soil.

AIR POLLUTION

The most serious damage to plants from air pollutants are caused by gases in the atmosphere such as ozone, sulfur dioxide, hydrogen fluoride, nitrogen dioxide and peroxyacetyl nitrate (PAN). Some of these pollutants, such as sulfur dioxide and hydrogen fluoride, are produced directly from industrial sources, while others such as ozone and PAN are produced as by products of photo-chemical reactions.

Incomplete combustion of hydrocarbons in internal combustion engines, e.g., cars, releases large amounts of both ozone and PAN in populated areas. These gases enter plants through stomata and cause characteristic bronzing of leaves.

PRINCIPLES OF PLANT DISEASE CONTROL

People who encounter plant diseases (apart from plant pathologists who think plant diseases are intellectually stimulating) usually want to know the best control measures. Unfortunately, by the time the disease symptoms appear it is often too late to reverse the damage caused by the disease agent. In some cases there are no acceptable control measures available that will halt the disease short of plant removal. Diagnosis of the disease can allow planning for a control method to prevent the disease next season. The various controls for diseases can be classified as:

- exclusion strategies
- inoculum reduction methods
- chemical controls
- biological controls
- integrated pest management (IPM) strategies, which may utilize any or all of these methods

EXCLUSION

Exclusion strategies are used to prevent or exclude a pathogen from an area. On a national scale this involves quarantine laws and plant inspectors stationed at points of entry into the country. On a homeowner scale, this involves purchasing disease free seeds, bulbs and plants and inspecting plants carefully before planting. Whenever a plant is divided or propagated asexually the parent plant should be certified disease free. Purchased strawberry and bramble plants should be virus-indexed and certified virus free. Nursery plants should have health inspection certificates.

When available, select cultivated varieties with purported disease resistance, especially to those diseases that are known to be a problem in your area.

INOCULUM REDUCTION

Inoculum reduction involves the elimination or reduction of plant pathogens.

This can be accomplished by:

- Breaking a link in the disease triangle by eliminating one of the conditions for infestation, for example, by controlling the insect carrying the pathogen.
- Practicing good cultural techniques
- Giving the plants a good start by planting them in good, well-drained soil, at the right time in the proper location.
- Lowering the chances for diseases to develop by allowing for air circulation, watering wisely, adjusting soil pH, balancing soil fertility
- Practicing good methods of sanitation, including removal and disposal of infected plant material, disinfecting containers, seedling flats and tools, avoiding walking on wet soil and working with wet plants.
- Using a soil amendment, e.g., compost that favours microflora antagonistic to the plant pathogens.

CHEMICAL CONTROLS

The original version of this document, written in the 1990s, contained detailed description of possible chemical controls for problem diseases. Since that time Ontario has implemented a Pesticide Ban so this section has been removed.

BIOLOGICAL AND INTEGRATED PEST MANAGEMENT CONTROLS

BIOLOGICAL CONTROL OF PLANT PATHOGENS

Biological control of plant pathogens involves the use of antagonistic microorganisms to prevent the incidence of a disease or to suppress its symptoms. This method is considered to be safe and environmentally friendly. *Agrobacterium radiobacter* (Dygal) was registered by Agriculture Canada (Decision Document Nov. 6, 1989) as a root dip and seed treatment for ornamentals and non-bearing fruit trees. In 1994 Dygal was still the only biological pesticide listed in Canada to control bacterial disease. It is used to control crown gall of nursery stock.

The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) have included microbial pest research in its Food systems Pest Management Research Program 1988 - 2002. It has already reported encouraging test results. For example, the naturally occurring microorganism, *Glyocadium coseum* suppressed lead scorch and gray mold of strawberries as effectively as chemical fungicides. Experiments with *Tricoderma* spp., a naturally occurring fungus, were shown to be promising for controlling Botrytis on strawberries and Phytophthora root rot of raspberries. Registration of microbiological pesticides by the Federal Government may take years. A disease-controlling fungus or bacterium has to undergo the same process as chemical pesticides for Federal registration.

INTEGRATED PEST MANAGEMENT

Integrated pest management is a strategy for pest control that recognizes a number of control measures and employs one or several when needed. The selection is based on results of infestation or infection monitoring, which determines whether a treatment is necessary and what measures should be taken to prevent unacceptable damage.

This approach requires good knowledge of the ecosystem:

- Climate, weather, soil
- Natural and cultivated plant habitats
- Life cycles, feeding and reproductive habits of plants, animals and microorganisms
- The relationships among the various inhabitants of the ecosystem -predators and their prey, pathogens and their hosts
- Application of the disease triangle

Integrated Pest Management also requires a good knowledge of:

- The damage caused by the pests, pathogen, and weeds
- Tolerable levels of the damage with respect to safety, economics and esthetics

To develop control strategies the treatments must:

- Reduce pest population
- Leave small untreated areas which ensure food for natural enemies
- Be specific to a targeted organism
- Upset natural controls the least
- Be acceptable safe
- Be cost-effective

The I.P.M. process includes:

- Selecting clean seeds and transplants
- Providing optimum soil, moisture and nutrient conditions
- Monitoring the pests or diseases
- Determining whether control methods are necessary
- Selecting one or several methods
 - Breaking the disease cycle by crop rotation
 - Cultural methods
 - Good sanitation
 - Biological methods

GENERAL CATEGORIES OF PLANT DISEASES, SYMPTOMS AND EXAMPLES OF SUSCEPTIBLE PLANTS

Table 6-1

Disease and Pathogen(s)	Description
Anthrachnose Fungus All types of woody and herbaceous plants	Distinct spots with definite margins often with pinkish spore masses, on leaves, stems and fruit; spots may spread to affect the whole plant
Aster yellows Moloplasma-like organisms Many flowering annuals, carrots, lettuce	Yellowing leaves, distorted greenish yellow flowers, regardless of real colour, stunted plants
Black Knot Fungus Cherries and plums	Black, knotty enlargement of woody tissue
Blackleg Fungus Cruciferous vegetables; herbaceous ornamentals	Darkening and decay of the base of the plant
Blackspot Fungus Roses	Circular black spots, often surrounded by a yellow ring
Blights Bacteria or fungi Vascular and woody plants	Rapid dieback of shoots, branches or complete plants
Cankers Bacteria, fungus or physiological conditions Woody plants	Localized, frequently oozing lesions on stems and trunks of dead tissue; may be accompanied by dying back from the top
Club Root Fungus Plants of the Cabbage family	Distorted, swollen roots; causing stunting, yellowing or wilting
Damping Off Fungus Seedlings in general	Rotting of seeds in soil or sudden wilting of seedlings
Dodder Parasitic plant <i>Cuscuta</i> spp. All types of plants	Sucker-type roots formed on slender stems penetrate the tissues of host plants and extract nutrients
Downy mildews Fungus Many woody and herbaceous plants	Fruiting structures protrude from a mycelium inside the host to form white, gray or violet patches on lower leaf surfaces; upper leaf surfaces may have yellow spots which later darken
Fairy Rings Fungus Turf	Mushrooms growing in circles
Galls leaves, stems and roots Bacteria, fungus and insects Trees, shrubs and vines	Noticeable enlargements of abnormal tissue on leaves, stems and roots
Leaf Scorch Physiological conditions, drought and heat Many wood and herbaceous plants	Browning of leaves along the margins and sometimes between the veins; may affect growth and eventually kill the plant
Leaf Spots Bacteria, fungi, chemical sprays Herbaceous and woody plants	Delimited dead areas in leaves, with or without margins that are randomly distributed

Table 6-1 (cont'd)

Disease and Pathogen(s)	Description
Needle casts Fungus Many types of plants with needle-shaped leaves	Conspicuous shedding of needles
Nematodes All types of woody and herbaceous plants	Small lesions on roots, knots or galls; upper parts of the plant appear stressed
Powdery Mildews Fungus Many types of woody and herbaceous plants	Superficial white powdery growth on leaves and flowers
Rots Bacteria, fungi and environmental conditions All types of woody and herbaceous plants	Soft and hard decay of disintegrated plant tissues; decay products of soft bacterial rot have a foul odour
Rusts Fungus Trees, herbaceous ornamentals, some vegetables	Superficial mycelium and orange red spore masses on the underside of leaves and on stems
Scab Bacteria-like organisms or fungus Apple, crab apple pear, potato	Raised or rust like lesions on leaves or fruit
Slime Molds Fungus Turf	Gray to light yellow patches found in lawns and mulched areas
Smuts Fungus Turf, corn, wheat	Galls on all above-ground parts of sweet corn eventually breaking open to release black spores
Snow mold Fungus Turf	Light patches in turf, especially early spring
Sooty mold Fungus Many ornamentals	Superficial black mycelium growing on "honey dew" excreted by insects
Virus Diseases Viruses Ornamentals, fruit and vegetables	Mottling, yellowing, leaf deformation, leaf spots, resetting, wilting and stunting
White mold Fungus All vegetables except sweet corn, annual ornamentals	Rotted lower stems and leaves, white cottony tufts with black fungal bodies
Wilts Bacteria, fungi or environmental conditions All types of plants	Yellowing and wilting of leaves, death of branches of woody plants, collapse of vascular plants caused by damage to the vascular system or drought
Wood decay Fungus Woody plants	Decay (rotting) caused by fungi which enters the tree through wounds

This table provides only a generalized reference for various plant diseases. Different species of plants may exhibit very different symptoms of the same disease.

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INTERNET WEBSITES CONTAINING RELEVANT INFORMATION

Canadian Food Inspection Agency
www.inspection.gc.ca

Pest Management Regulatory Agency; Health Canada
www.hc-sc.gc.ca/ahc-asc/branch-dirgen/pmra-arla/index-eng.php

Ontario Ministry of Agriculture, Food and Rural Affairs
<http://www.omafra.gov.on.ca/english>

Ontario Ministry of the Environment
<http://www.ene.gov.on.ca/environment/en/index.htm>

Revised by the Master Gardeners of Ontario Inc. from the Maryland Master Gardener Handbook.

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CHAPTER 7: PLANT PROPAGATION

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PLANT PROPAGATION

INTRODUCTION

Plant propagation is the process of multiplying the numbers of a species, perpetuating a species, or maintaining the youthfulness of a plant. Propagation may be sexual or asexual. Sexual reproduction is the union of pollen and egg, drawing from the genes of two parents to create a third new individual. Sexual propagation involves the floral parts of a plant. Asexual propagation occurs by taking a vegetative part of one parent plant (stems, roots, or leaves) and causing it to regenerate itself into a new plant. Genetically, the new plant is identical to its one parent.

There are several advantages to sexual propagation: it may be cheaper and quicker than other methods; it may be the only way to obtain new varieties and hybrid vigor; in certain species it is the only viable method of propagation and it may avoid transmitting certain diseases. Asexual propagation also has advantages. It may also be easier and faster in some species; it may be the only way to perpetuate some cultivars; and it bypasses the juvenile characteristics of certain species.

SEXUAL PROPAGATION

Sexual propagation is the union of pollen from the male with the egg of the female to produce a seed. The seed is made up of three parts: the outer seed coat, which protects the seed; the endosperm, a food reserve; and the embryo, the young plant itself. When a seed is mature and put into a favorable environment it will germinate, and begin to grow.

SEED

To obtain high quality plants, start with high quality seed from a reliable dealer. Select varieties to provide the size, color, and habit of growth desired. Choose varieties adapted to your area so that they will reach maturity before an early frost, when planted outdoors.

Although some seeds will keep for several years if stored properly, it is advisable to purchase only enough seed for the current year's use. The seed packet usually provides essential information about the variety, the year for which the seeds were packaged, the rate of germination, and notes about any chemical treatment of the seeds. If seeds are obtained well in advance of the actual sowing date or are surplus seeds that have been stored, keep

them in a cool, dry place. Laminated foil packets help ensure dry storage. Paper packets are best kept in tightly closed jars or containers, and maintained around 5°C with a low humidity (see **Chapter 13, "The Vegetable Garden"** for a discussion of seed saving and storing techniques).

When planning your seed order keep in mind that often only about 60%-80% of the seeds that germinate will produce sturdy, vigorous transplants. Gauge your needs accordingly.

GERMINATION

Seeds of all species have one or more mechanisms to delay germination until the seed is dispersed and the seed is likely to be surrounded by a favourable environment. Many species require a complex series of conditioning treatments before germination is evident e.g., fluctuating temperatures or light conditions. This period before germination has long been termed dormancy and the treatments used to promote germination, breaking dormancy. Research has shown that the seed is not truly dormant and at many stages throughout the conditioning treatments high levels of metabolic activity can be detected.

With most species, the germination delay mechanism is chemical in nature. This chemical blocking system can be destroyed by light, drying, or various temperature cycles. The treatment required is specific to each species. It is also common for a species to have more than one chemical blocking mechanism.

Some plant species rely on a physical or mechanical means for delaying germination. This usually involves an impervious seed coat.

Seed Scarification

Seed scarification is breaking, scratching, or softening the seed coat so that water can enter and initiate germination. There are several methods of scarifying seeds. In acid scarification, seeds are put in a glass container and covered with diluted acid (vinegar or buttermilk could be used for less difficult types of seed). The seeds are gently stirred and allowed to soak from 10 minutes to several hours, depending on the hardness of the seed coat. When the coat has become thin, the seeds can be removed, washed, and planted. There is some risk of causing damage to the seed, particularly if a strongly acidic solution is used and the optimal length of scarification is unknown.

Mechanical methods of scarification include filing seeds with a metal file, rubbing them with sandpaper, or cracking them with a hammer to weaken the seed coat. Hot water scarification involves putting seeds in hot water (75°-100°C) and allowing them to soak for 12-24 hours before planting.

Seed Stratification

Seeds of many species of temperate zones will not germinate unless chilled underground as they overwinter; they require cold to remove a chemical inhibitor to germination. This may also be accomplished artificially.

The following procedure is usually successful:

1. Fill a sterile container with moistened, soilless mix.
2. Place seeds on top of the growing medium and do not cover.
3. Gently spray to moisten the surface and seeds.
4. Seal the container and seeds in a plastic bag.
5. Place the sealed container in the refrigerator. Check periodically, additional water will probably not be necessary.
6. After 10-12 weeks, remove the container from the refrigerator, place in a warm location and monitor the pot periodically.
7. If there is no evidence of growth after 12 weeks, the cycle should be repeated.

There are several alternative methods that require less space in the refrigerator.

1. Seeds can be enclosed in moistened layers of paper towels and then sealed in a plastic bag.
2. Seeds - particularly very large ones - can be mixed with a moistened soilless mix or sand directly in a plastic bag.

With both of these methods, care should be taken to avoid breaking small roots or shoots when moving or opening packages.

Handle seeds carefully. Small roots and shoots begin to emerge at the end of the stratification period. Care must be taken not to break these off. Seeds of most fruit and nut trees can be successfully germinated by these procedures. Seeds of peaches should be removed from the hard pit. Care must be taken when cracking the pits. Any injury to the seed itself can be an entry path for disease organisms.

STARTING SEEDS

Germination is affected by four external environmental factors (water, oxygen, light, and heat) and begins when certain internal requirements have been met. A seed must: (1) have a mature embryo, (2) contain a large enough food supply, either in the endosperm or cotyledons, to sustain the embryo during germination, and (3) contain enough plant growth regulators, or auxins, to initiate the process.

Watering

Seed germination begins with the absorption of water, referred to as imbibitions. The amount of available water in the germination medium affects the uptake of water. An adequate and continuous supply is essential. Once the process has begun, a dry period will cause the death of the embryo. Always mix warm water into your growing medium to moisten it prior to seeding.

Ideally, seed flats should remain sufficiently moist during the germination period so that watering is not necessary. To achieve this you can slip the whole flat or pot into a clear plastic bag after an initial watering with a fine mist spray. The plastic should not rest directly on the growing medium. Keep the container out of direct sunlight to prevent heat build-up. Be sure to remove the plastic bag as soon as the first seedlings appear. Surface watering can then be practiced if care is taken not to overwater or flood out young seedlings.

Lack of uniformity, overwatering, and drying out are problems associated with hand watering. Sub-irrigation or watering from below works well to keep the flats moist. Sub-irrigate the flats when the surface of the medium begins to dry out. Then remove the flats from the water.

Temperature

A favorable temperature is also necessary for germination. This affects not only the number of seeds that germinate, but also the rate of germination. Some seeds will germinate over a wide range of temperatures, whereas others require a narrow range. Many seeds have minimum, maximum, and optimum temperatures for germination. For example, tomato seed has a minimum germination temperature of 10°C and a maximum temperature of 33°C, but an optimum germination temperature of about 27°C. Where germination temperatures are listed, they are usually the optimum temperatures.

Generally, 18°-25°C is best for germinating seeds of most plants. This should be the temperature of the growing medium, not the air. Therefore, germination flats and containers may have to be placed in special chambers or on radiators, heating cables or heating mats or on top of a refrigerator to maintain optimum temperatures.

After germination and seedling establishment, move the flats to a light, airy, cooler location, with a 13°-16°C night temperature and an 18°-21°C day reading. This will prevent soft, leggy growth and minimize disease troubles. Some crops, of course, may germinate or grow best at a different constant temperature and must be handled separately from the bulk of your plants.

Light

Light is known to influence the germination of many plant's seed. Some crops that need light for seed germination are ageratum, begonia, browallia, impatiens, lettuce, and petunia. Conversely, calendula, centaurea, annual phlox, verbena, and vinca are plants whose seed germinate best in the dark. Other plants are not specific at all. Seed catalogs and seed packets often list germination or cultural tips for individual varieties.

When sowing light-requiring seed, do as nature does and leave them on the soil surface. Or cover them very lightly with fine peat moss or fine vermiculite. These two materials will permit some light to reach the seed and will not inhibit germination.

Seedlings must receive bright light after germination. Where possible, place them in a large, south-facing window. Otherwise, place the seedlings under a fluorescent light (shop light). Use 40-watt fluorescent tubes held 5 cm above your plants. Keep the lights on about 14-16 hours each day. As the seedlings grow, the lights should be raised to maintain the 5 cm separation. In rooms that are excessively dry and cool, drape clear plastic sheeting over your light stand to increase temperature and humidity.

Media

The good qualities of good germination medium include the following:

- Rather fine and uniform, yet well aerated and loose, (seeds will not germinate well in oxygen-poor media)
- Free of insects, disease organisms, and weed seeds
- Low in fertility or total soluble salts and capable of holding and moving moisture by capillary action.

Sterilizing soil or compost in an oven or microwave produces very unpleasant odours and is not recommended. An artificial, soilless mix will provide all of the desired qualities of a good germination medium. The basic ingredients of such a mix include sphagnum peat moss, shredded bark, perlite and vermiculite. These are generally free of diseases, weed seeds, and insects. The ingredients are readily available, easy to handle, lightweight, and produce uniform plant growth.

The importance of using sterile growing medium and container cannot be overemphasized. The "damping-off" fungi, Pythium and Rhizoctonia, can quickly kill a stand of seedlings. Wood or plastic growing containers and implements should be washed to remove any debris dipped for 1-2 minutes in a solution of 1 part chlorine bleach to 10 parts water and then rinsed with clean water. Avoid recontamination of the medium and tools.

Containers

You can buy plastic flats and trays, or make your own from scrap lumber. Flower pots of either clay or plastic can be used along with recyclable containers (cottage cheese containers, the bottoms of milk cartons or bleach containers, and pie pans), as long as good drainage is provided.

Numerous types of pots and strips made of compressed peat are on the market for starting seeds. Plastic cell packs are also available; each cell or mini-pot holds a single plant, reducing the risk of root injury when transplanting. Peat pellets, peat- or fibre-based blocks, and expanded plastic foam cubes can also be used for seeding. The growing medium itself forms the container unit.

Seeding

The proper time to sow seeds for transplants depends on when plants may safely be moved out-of-doors in your area. This period may range from 4 to 20 weeks before transplanting, depending on the speed of germination, rate of growth, and cultural conditions provided. A common mistake is to sow seeds too early and then attempt to hold the seedlings back under poor light or improper temperature ranges. This usually results in tall, weak, spindly plants that do not perform well in the garden. After selecting a container, fill it to within 1.5 cm of the top with the moistened medium you have chosen. For very small seeds, at least the top 0.5 cm should be of a fine, screened mix or a layer of vermiculite.

Firm the medium very lightly at the corners and edges with your fingers or a block of wood to provide a uniform, flat surface.

For medium-to-large seeds, make rows about 2 to 5 cm apart and 0.3 to 0.6 cm deep across the surface of the container, using a narrow board or pot label. Good light and air movement results from sowing in rows. If the damping-off fungus does appear, there is less chance it will spread. Seedlings grown in rows are easier to label and handle at transplanting time. Sow the seeds thinly and uniformly in the rows by gently tapping the packet of seed as it is moved along the row. Lightly cover the seeds with dry vermiculite or sifted medium if they require darkness for germination. A suitable planting depth is usually about twice the diameter of the seed.

Do not plant seeds too deeply. Extremely fine seed such as petunia, begonia, and snapdragon are not covered but are lightly pressed into the medium or watered in with a fine mist spray. If these seeds are broadcast, sow them evenly to ensure a uniform stand.

Sow large seeds directly into small containers or cell packs, eliminating the need for transplanting. Sow two or three seeds per unit and later thin to allow the strongest seedling to grow. (Cut the weaker seedlings at the soil line with scissors; don't pull them)

Seed Tape

Most garden stores and seed catalogs offer indoor and outdoor seed tapes. Seed tape has precisely spaced seeds enclosed in an organic, water-soluble material. When planted, the tape dissolves and the seeds germinate normally. Seed tapes are especially convenient for tiny, hard-to-handle seeds, like carrots. However, tapes are much more expensive per seed. Seed tapes allow uniform emergence of seedlings, eliminate overcrowding of seedlings, and permit sowing in perfectly straight rows. The tapes can be cut at any point for multiple row plantings, and thinning is rarely necessary.

Pre-germination

Another method of starting seeds is to sprout the seeds before they are planted in pots or in the garden. By closely controlling temperature and moisture you can achieve a higher and quicker rate of germination. Lay seeds between the folds of a moistened paper towel and place inside a clear plastic bag. Keep seeds moist and in a warm place. When roots begin to show, plant the seeds into containers or directly into your garden.

When transplanting seedlings, be careful not to break off tender roots. Keep the transplants from drying out until they become established.

When planting seeds in a container to set out in the garden later, place one seed in a 5 to 8 cm container. Plant the seeds to the recommended depth. Gently press a little moistened media over the sprouted seed. Keep the pots in a warm place and care for them just as for any other newly transplanted seedling.

TRANSPLANTING AND HANDLING

If plants have not been seeded in individual containers, they must be transplanted ("potted-up") to give them proper growing space. One of the most common mistakes gardeners make is leaving seedlings in the seed flat too long. The ideal time to transplant young seedlings is when they are small and there is little danger from setback. This is usually about the time the first true leaves appear above or between the cotyledon leaves (the cotyledons or seed leaves are the first leaves the seedling produces, see **Chapter 2, "Botany"**). Don't let your plants get hard and stunted or tall and leggy.

Seedling Growing Media

Seedling growing mixes contain more plant nutrients than a germination mix. However, nutrients are easily leached out of the media and should be replenished every two weeks with a soluble plant food. Dilute and apply the plant food according to label directions. Wash off any liquid fertilizer that contacts foliage. Remember that young seedlings are easily damaged by too much fertilizer, especially if they are under any moisture stress. A fertilizer such as 10-52-10 will encourage strong roots.

Reduce your costs by mixing finely screened yard waste compost (use 13 mm mesh) with your soilless media. The final mix should be no more than one third compost. The compost will provide nutrients, reducing the need for additional fertilizers.

Containers for Transplanting

Select containers that are economical and durable, and that make good use of space. Containers made out of pressed peat can be purchased in varying sizes. Individual peat pots or strips of connected peat pots fit closely together, and can be planted directly into the garden. Although square containers require more potting mix than round containers, they are often available in webbed sheets which are easier to fill and water.

Plastic cell packs are durable strips of connected individual pots. Many homeowners find a variety of materials from around the house useful for containers. These homemade containers should be deep enough to encourage vigorous root growth and have plenty of drainage holes in the bottom.

When setting out plants grown in peat pots, be careful to cover the pot completely with garden soil. If the top edge of the peat pot extends above the soil level, it may act as a wick and draw water away from the soil in the pot. To avoid this, tear off the top lip and bottom of the pot and then plant flush with the soil level.

To Transplant

- Carefully dig up the small plants from the seed flat using a knife or wooden plant label.
- Gently ease them apart in small groups to make it easier to separate individual plants. Avoid tearing roots in the process. Handle small seedlings by their leaves, not their delicate stems.
- Punch a hole in the medium into which the seedling will be planted. Make it deep enough so the seedling can be put at the same depth it was growing in the seed flat.
- Firm the media around each plant and water gently.
- Keep newly transplanted seedlings in the shade for a few days or place them under fluorescent lights. Keep them away from direct heat sources. Continue watering as you did for the seed flats.

Most plants transplant well and can be started indoors, but a few are difficult to transplant. Examples are zinnias and cucurbits, such as cucumbers, squash and a few herbs. These are generally directly seeded outdoors or sown directly into individual containers such as peat pots indoors.

Hardening Plants

Hardening is the process of altering the quality of plant growth. This process enables your plants to withstand the change in environmental conditions they will face when transferred from the greenhouse or home to the garden. Your plants could suffer a severe setback in growth if planted outdoors without a transition period. Hardening is more critical with early crops when adverse climatic conditions can be expected than it is for crops planted later in the season. To harden your plants, gradually lower temperatures and relative humidity and reduce water.

This procedure results in an accumulation of carbohydrates and a thickening of cell walls causing a change from a soft, succulent type of growth to a firmer, harder growth.

Start the process at least 2 weeks before planting in the garden. If possible, move plants to a shady spot outdoors where the temperature is above 10°C. When placed outdoors, plants should be shaded and then gradually moved into sunlight. Each day, gradually increase the length of exposure. Don't put tender seedlings outdoors on windy days or when temperatures are below 10°C.

If freezing temperatures threaten, plants can be brought inside. When night time temperatures are expected to be above freezing, plants can be moved next to a sheltered wall and covered with a blanket.

A cold frame is excellent for this process. In the north, supplementary warmth from heating cables or a light bulb may be necessary. Old blankets can be used to provide extra protection at night if temperatures dip too low. During the day, sashes can be left open for increasingly longer periods once the danger of cold temperatures has passed. If an unheated greenhouse is used, the ventilation system should be left open for longer periods each day. Reduce the frequency of watering to slow plant growth, but don't allow plants to wilt. Even cold-hardy plants will be hurt if exposed to freezing temperatures before they are hardened. After proper hardening, tomato plants can usually tolerate light and unexpected frosts with minimum damage.

The hardening process is intended to slow plant growth. If carried to the extreme of actually stopping plant growth, significant damage can be done to certain crops. For example, cauliflower will produce thumb-sized heads and fail to develop further. Cucumbers and melons will stop growing if hardened too severely.

ASEXUAL PROPAGATION

Asexual propagation, as mentioned earlier, is the best way to maintain some species, particularly an individual that best represents that species. Clones are groups of plants that are identical to their one parent and that can only be propagated asexually. The Bartlett pear (1770) and the Delicious apple (1870) are examples of clones that have been asexually propagated for many years.

The major methods of asexual propagation are cuttings, layering, budding, and grafting.

Cuttings

Many types of woody and herbaceous plants are propagated by cuttings. A cutting is a vegetative plant part that is severed from the parent plant in order to regenerate itself, thereby forming a whole new plant.

Take cuttings with a sharp knife or razor blade to reduce injury to the parent plant. Dip the cutting tool in rubbing alcohol or a mixture of one part bleach to nine parts water to prevent transmitting diseases from infected plant parts to healthy ones. Remove flowers and flower buds from the cutting. This will allow it to use its energy and stored carbohydrates for root and shoot formation rather than fruit and seed production. Use a rooting powder to hasten rooting, increase the number of roots, or obtain uniform rooting (except on soft fleshy stems). Prevent possible contamination of the entire supply of rooting hormone by putting some in a separate container for dipping cuttings.

Insert cuttings into a rooting medium such as coarse sand, vermiculite, soil, water, or a mixture of peat and perlite. In general, the rooting medium should be sterile, low in fertility, well-drained and able to retain enough moisture to prevent water stress. Moisten the medium before inserting cuttings, and keep it evenly moist while cuttings are rooting and forming new shoots. Contrary to popular thought, water is often the best rooting medium for many types of cuttings.

Place stem and leaf cuttings in bright but indirect light. Root cuttings can be kept dark until new shoots appear. Covering the potted cutting with plastic will encourage root growth and maintain even moisture.

Stem Cuttings

Numerous plant species are propagated by stem cuttings. Some can be taken at any time of the year, but stem cuttings of many woody plants must be taken in the fall or in the dormant season.

Tip Cuttings: Detach a 5 to 15 cm piece of stem, including the terminal bud. Make the cut just below a node. Remove lower leaves that would touch or be below the surface of the medium. Dip the stem in rooting compound if desired. Gently tap the end of the cutting to remove excess powder. Insert the cutting deeply enough into the medium to support itself. At least one node must be below the surface.

Medial Cuttings: Make the first cut just above a node, and the second cut just above a node 5 to 15 cm down the stem. Prepare and insert the cutting as you would a tip cutting. Be sure to position right side up. Axial buds are always above leaves.

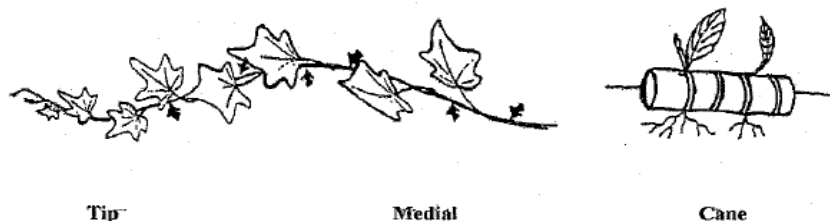
Cane Cuttings: Cut cane like stems into sections containing one or two nodes. Allow to dry several hours. Lay horizontally with about half of the cutting below the medium surface, node facing upward. Cane cuttings are usually potted when roots and new shoots appear, but new shoots from dracaena and croton are often cut off and re-rooted in sand.

Single Eye: This method is used for plants with alternate leaves when space or stock material is limited. The "eye" refers to the node. Cut the stem about 1.5 cm above and 1.5 cm below a node. Place cutting horizontally or vertically in the medium.

Double Eye: This method is used for plants with opposite leaves when space or stock material is limited. Cut the stem about 1.5 cm above and 1.5 cm below the same node. Insert the cutting vertically in the medium with the node just touching the surface.

Heel Cuttings: This method makes efficient use of stock material with woody stems. Make a shield-shaped cut about halfway through the wood around a leaf and axial bud. Insert the shield into the medium such that the stem is upright.

Figure 7-A: STEM CUTTINGS



Leaf Cuttings

Leaf cuttings are used almost exclusively for a few indoor plants. Leaves of most plants will either produce a few roots but no plant, or just decay.

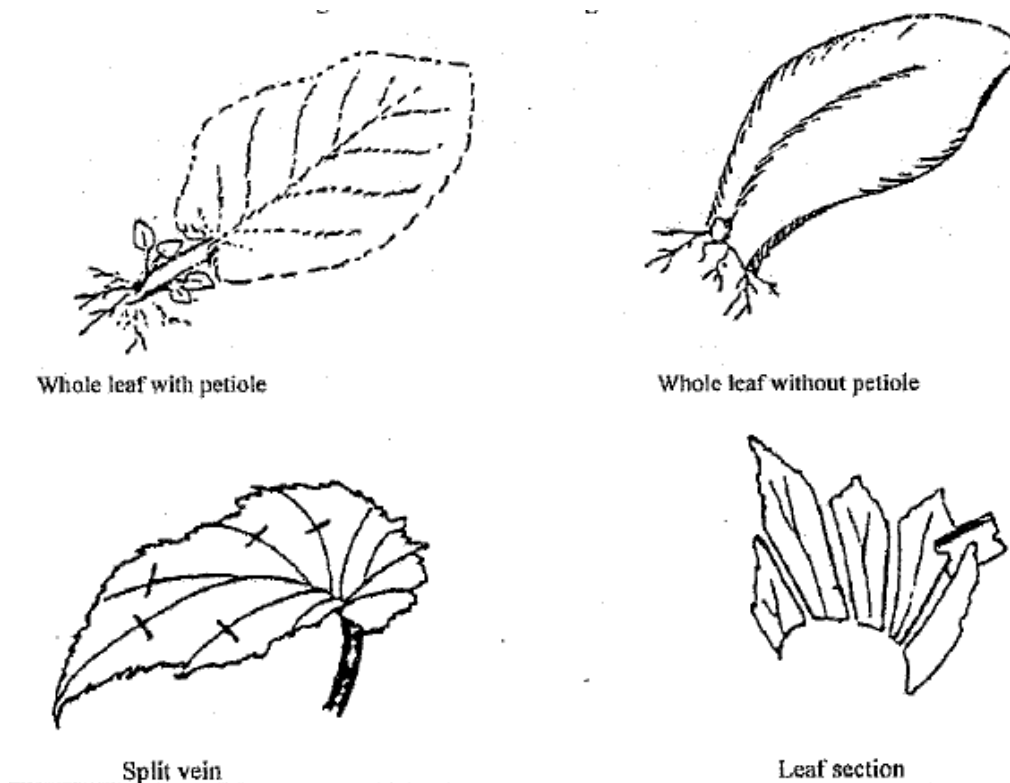
Whole Leaf with Petiole: Detach a healthy, full-grown leaf with approximately 2.5 cm of petiole. Insert the petiole, upright, into the growing medium such that the leaf does not touch the rooting medium. Several plantlets should form at the base of the petiole. These young plants can be gently teased apart and planted separately. The leaf and petiole may be reused. This is a method of propagating African violets.

Whole Leaf without Petiole: This method is used for plants with sessile or petiole less leaves. Insert the cutting vertically into the medium. A new plant will form from the auxiliary bud. The leaf may be removed when the new plant has its own roots. This method can be used to propagate *Crassula*, *Echeveria* or *Sanseveria*.

Split Vein: Detach a leaf from the stock plant. Make perpendicular slits in the veins on the lower leaf surface. Lay the cutting, lower side down, on the medium. New plants will form at each cut. If the leaf tends to curl up, hold it in place by covering the margins with the rooting medium. A rex begonia may be propagated like this.

Leaf Sections: This method is frequently used with snake plant and fibrous-rooted begonias. Cut begonia leaves into wedges with at least one vein. Lay leaves flat on the medium. A new plant will arise at the vein. Cut snake plant leaves into 5 cm sections. Consistently make the lower cut slanted and the upper cut straight so you can tell which is the top. Insert the cutting vertically. Roots will form fairly soon, and eventually a new plant will appear at the base of the cutting. These and other succulent cuttings will rot if kept too moist.

Figure 7-B: LEAF CUTTINGS



Root Cuttings

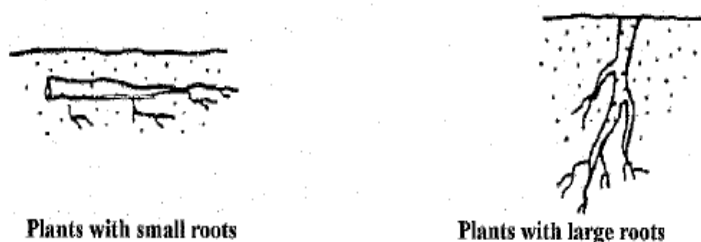
Root cuttings are taken from young, vigorous roots of mature plants. Many trees, shrubs and perennials are suitable for this method.

Cut roots of pencil-thickness into 5 to 10 cm lengths. Thinner roots should be cut somewhat longer (7 to 12 cm) to provide additional food for developing cuttings. Cut the top end - that nearest the plant stem - straight across. Cut the bottom end - that nearest the root tip - on an angle. This difference will help you remember which end is up. Trim any fibrous roots. Dust with fungicide to prevent rot. Roots should be inserted, vertically, into pots of moistened rooting medium. Root tops should be covered with a thin layer of sand or grit. Temperatures should be cool (10°C) to encourage root development and minimize water loss from the cuttings.

Additional water should not be required until new growth is apparent. Several shoots may develop from a single root cutting. These should be separated and potted up individually.

If root cuttings are quite thin and cannot be inserted vertically, they can be laid flat in containers of firmed, moistened mix and covered shallowly with additional mix or grit.

Figure 7-C: ROOT CUTTING



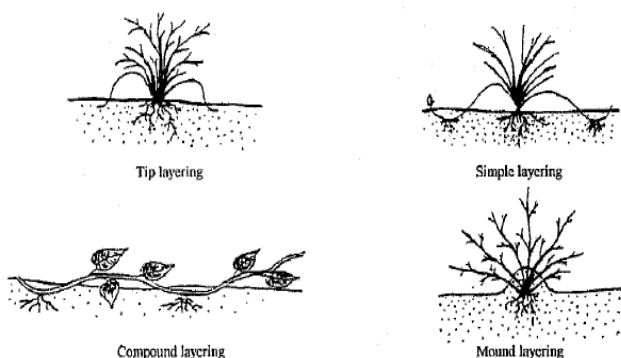
LAYERING

Stems still attached to their parent plant may form roots where they touch a rooting medium. Severed from the parent plant, the rooted stem becomes a new plant. This method of vegetative propagation, called layering, works well because the mother plant provides the necessary water and carbohydrates. Some plants layer themselves naturally, but sometimes plant propagators assist the process. Layering is enhanced by girdling the stem where it is bent, by wounding one side of the stem, or by bending it very sharply. The rooting medium should be well-aerated and moist.

Tip Layering: Dig a hole 8 to 10 cm deep. Insert the shoot tip and cover it with soil. The tip grows downward first, then bends sharply and grows upward. Roots form at the bend, and the re-curved tip becomes a new plant. Remove the tip layer and plant it in the early Spring or late Fall. Examples: purple and black raspberries, trailing blackberries.

Simple Layering: Bend the stem to the ground. Cover part of it with soil, leaving the last 15 to 30 cm exposed. Bend the tip into a vertical position and stake in place. The sharp bend will often induce rooting, but wounding the lower side of the branch or loosening the bark by twisting the stem may help. Examples: rhododendron, honeysuckle.

Figure 7-D: LAYERING



Compound Layering or Serpentine Layering: This method works for plants with flexible stems. Wound the lower side of the stem sections close to nodes. Rooting powder can be applied to the wounds if desired. Bend the stem into the rooting medium as for simple layering, but alternately cover and expose stem sections. The stems may be held in place with U-shaped pieces of wire. Examples: heart-leaf philodendron, pothos, clematis.

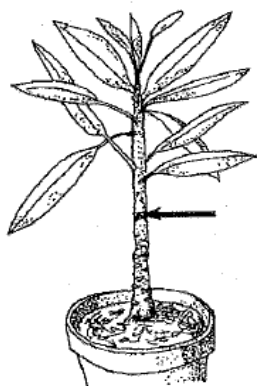
Mound (Stool) Layering: Cut the plant back to 3 cm above the ground in the dormant season; mound soil over the shortened stems. In the spring dormant buds will form into shoots that develop through the soil mound. Rooting will occur at the base of the young shoots. Once rooted, the shoots can be cut below the new root system and planted in a new location. Examples: gooseberries, apple rootstocks.

Air Layering: Air layering is used to propagate some indoor plants with thick stems, or to rejuvenate them when they become leggy. Slit the stem just below a node. Pry the slit open with a toothpick. Surround the wound with wet unmilled sphagnum moss. Wrap plastic or foil around the moss and tie in place. When roots pervade the moss, cut the plant off below the root ball. Examples: dumbcane, rubber tree.

Wrap plastic or foil around the moss and tie in place. When roots pervade the moss, cut the plant off below the root ball. Examples: dumbcane, rubber tree.

Figure 7-E: AIR LAYERING A HOUSEPLANT

1. Score trunk with a knife



2. Wrap in moist sphagnum and plastic



3. Remove top when roots have formed



4. Repot the top plant; stump will sprout



The following propagation methods can all be considered types of layering (the new plants form before they are detached from their parent plants).

Stolons and Runners

A stolon is a horizontal, often fleshy, stem that can root and then produce new shoots where it touches the medium. A runner is a slender stem that originates in a leaf axil and grows along the ground or downward from a hanging basket, producing a new plant at its tip. Plants that produce stolons or runners are propagated by severing the new plants from their parent stems. Plantlets at the tips of runners may be rooted while still attached to the parent, or detached and placed in a rooting medium. Examples: strawberry, spider plant.

Offsets

Plants with a rosetted stem often reproduce by forming new shoots at their base or in leaf axils. Sever the new shoots from the parent plant after they have developed their own root system. Unrooted offsets of some species may be removed and placed in a rooting medium. Some of these must be cut off the parent stem, while others may be simply lifted off. Examples: date palm, haworthia, bromeliads, many cacti.

Separation

Separation is a form of propagation used with plants that produce bulbs or corms (see **Figure 7-F**).

Bulbs

New bulbs form beside the originally planted bulb. Separate these bulb clumps every 3-5 years for largest blooms and to increase bulb population. Dig up the clump after the leaves have withered. Gently pull the bulbs apart and replant them immediately so their roots can begin to develop. Small new bulbs may not flower for 2 or 3 years, but large ones should bloom the first year. Examples: tulip, narcissus.

Corms

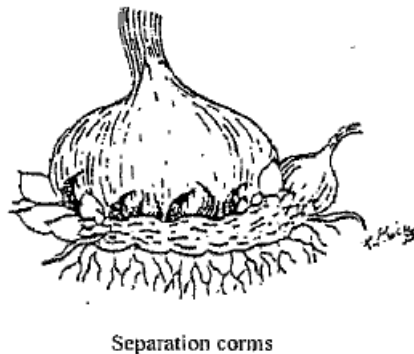
A large new corm forms on top of the old corm, and tiny cormels form around the large corm. After the leaves wither, dig up the corms and allow them to dry in indirect light for 2 or 3 weeks.

Remove the cormels and gently separate the new corm from the old corm. Dust all new corms with a fungicide and store in a cool place until planting time. Examples: crocus, gladiolus.

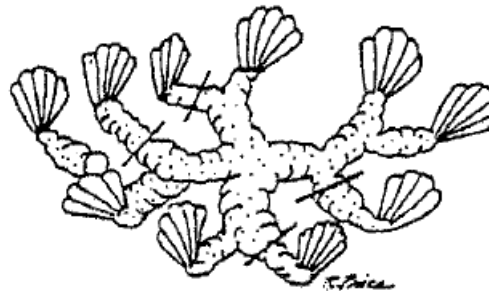
Division

Plants with more than one rooted crown may be divided and the crowns planted separately. If the stems are not joined, gently pull the plants apart. If the crowns are united by horizontal stems, cut the stems and roots with a sharp knife to minimize injury. Examples: snake plant, iris, prayer plant, and day lily.

Figure 7-F: SEPARATION CORMS AND DIVISION



Separation corms



Division

GRAFTING

Grafting and budding are methods of asexual plant propagation that join plant parts so they will grow as one plant. These techniques are used to propagate cultivars that do not root well as cuttings, or whose own root systems are inadequate. One or more new cultivars can be added to existing fruit and nut trees by grafting or budding.

The portion of the cultivar to be propagated is called the scion. It consists of a piece of shoot with dormant buds that will produce the stem and branches. The rootstock, or stock, provides the new plant's root system and sometimes the lower part of the stem. The cambium is a layer of cells located between the wood and bark of a stem and from which new bark and wood cells originate.

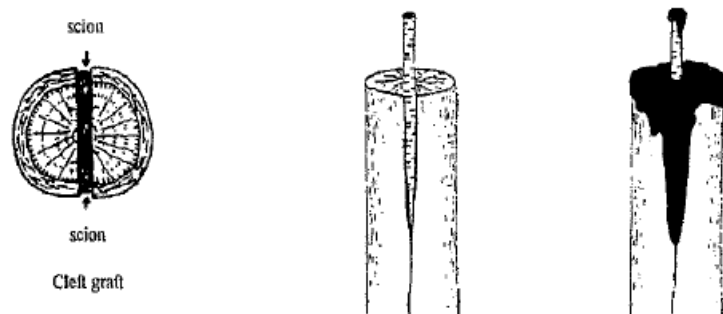
It is essential that all grafting equipment is sterile. Knives should be sterile and sharp so that a single, clean cut can be made. The prepared plant material must also be kept scrupulously clean; cuts must not be touched.

Grafts have traditionally been bound with moistened raffia or a rubberized strip and then coated with special grafting wax to prevent drying. Although rubber strips, raffia and grafting wax are still used in many operations; flexible plastic tape is now common too.

Four conditions must be met if grafting is to be successful: the scion and rootstock must be compatible; each must be at the proper physiological stage; the cambial layers of the scion and stock must meet; and the graft union must be kept moist until the wound has healed.

Cleft Grafting or Apical-Wedge Grafting

Cleft grafting (**Figure 7-G**) is often used to change the cultivar or top growth of a shoot or a young tree (usually a seedling). It is particularly successful if done in the early spring. Collect scion wood 1 to 1.5 cm in diameter. A stock of similar diameter should be selected. This could be either a limb or trunk of a young seedling. Make a clean cut on the stock that is perpendicular to its length. Make a 5 cm vertical cut through the center of the previous cut. Be careful not to tear the bark.

Figure 7-G: BARK, RIND OR SIDE-VENEER GRAFTING

Keep this cut wedged apart. Cut the lower end of each scion piece into a wedge. Cleft or Apical-Wedge grafting can be done with one or two scions of 8 to 10 cm. If using two scions, then insert them at the outer edges of the cut in the stock. Tilt the top of the scions slightly outward and the bottom slightly inward to be sure the cambial layers of the scion and stock touch. Remove the wedge propping the slit open and cover all cut surfaces with grafting wax. If grafting a single scion, it should be of a similar size to the stock and fit tightly into the stock cut.

This method of grafting is used on an existing tree to establish a particular cultivar quickly. Although this method is often used on larger limbs, there is a danger that wounds will become infected before healing is complete.

The stock limb is cut back to within 60-75 cm of a main branch or fork in early spring. Dormant scions of the desired cultivar are collected from previous season's growth. If the scions are collected before grafting can take place, wrap them in moistened paper, and store wrapped in plastic in the refrigerator. Scions should be three buds long, with an angled cut at the bottom. Opposite this bottom cut, a small sliver of bark should be removed or a sharply angled cut made.

On the stock wood, make a 2.5 cm vertical cut through the bark. Carefully ease the bark away and insert the scion with the long tapering cut facing inward against the cambium layer. The stock and scion should be bound firmly and exposed areas sealed with grafting wax. Scion growth is often rapid and ties must be monitored closely to prevent damage. Several scions may be initially grafted to a single stock limb, but only the most vigorous should be retained.

Whip and Tongue Grafting

This is a common method of grafting for tree fruits, and is usually more successful with pome than stone fruits. The scion and rootstock are usually of the same diameter - approximately 0.5 to 1 cm in diameter - but the scion may be narrower than the stock. This strong graft heals quickly and provides excellent cambial contact. Make one 6.5 cm long sloping cut at the top of the rootstock and a matching cut on the bottom of the scion.

On the cut surface, slice downward into the stock and up into the scion so the pieces will interlock. Fit the pieces together, then tie and wax the union.

Caring for the Graft

Very little success in grafting will be achieved unless proper care is maintained for the following year or two. If a binding material such as strong cord or nursery tape is used on the graft, it must be cut shortly after growth starts to prevent girdling and later dying of the graft. Rubber budding strips have some advantages over other materials. They expand with growth and usually do not need to be cut, as they deteriorate and break after a short time. It is also an excellent idea to inspect the grafts after a 2- to 3-week period to see if the wax has cracked, and if necessary rewrap the exposed areas. After this the union will probably be strong enough and no more waxing will be necessary.

Limbs of the old variety that are not selected for grafting should be cut back at the time of grafting. The total leaf surface of the old variety should be gradually reduced as the new one increases, until at the end of 1 or 2 years the new variety has completely taken over. Completely removing all the limbs of the old variety at the time of grafting, increases shock to the tree and causes excessive suckering. Also, the scions may grow too fast, making them susceptible to wind damage.

Budding

Budding, or bud grafting, is the union of one bud and a small piece of bark from the scion with a rootstock. It is particularly useful when scion material is limited. It is also faster and forms a stronger union than grafting.

Caring for Buds

Place the bud in the stock in August. Force the bud to develop the following spring by cutting the stock off 8 to 10 cm above the bud. The new shoot may be tied to the resulting stub to prevent damage from the wind. After the shoot has made a strong union with the stock, cut the stub off close to the budded area.

Patch Budding

Plants with thick bark should be patch budded. This is done while the plants are actively growing so that their bark slips easily. Remove a rectangular piece of bark from the rootstock. Cover this wound with a bud and matching piece of bark from the scion. If the rootstock's bark is thicker than that of the scion, pare it down to meet the thinner bark so that when the union is wrapped the patch will be held firmly in place.

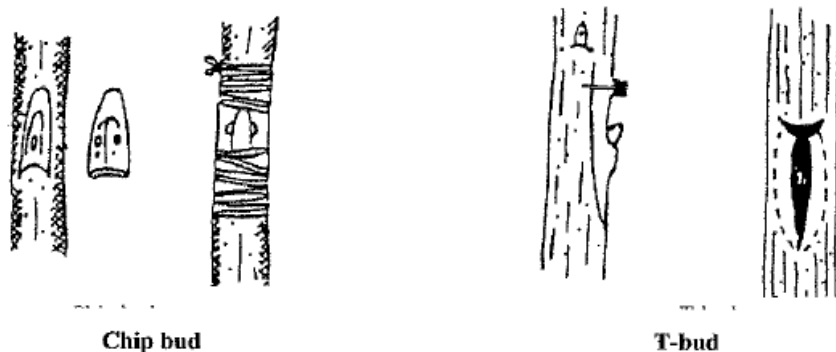
Chip Budding

This budding method can be used when the bark is not slipping. Make a 0.5 cm cut down into the rootstock stem, at an angle of about 45 degrees. Start a top cut 3 cm above the lower cut and angle it down to join the basal cut; remove the chip. Make similar cuts on the scion as on the rootstock, ensuring that the bud is included midway down the chip. Fit the bud chip to the stock and wrap the union.

T-Budding

This is the most commonly used budding technique. When the bark is slipping, make a vertical cut (same axis as the rootstock) through the back of the rootstock, avoiding any buds on the stock. Make a horizontal cut at the top of the vertical cut (in a T shape) and loosen the bark by twisting the knife at the intersection. Remove a shield-shaped piece of the scion, including a bud, bark, and a thin section of wood. Push the shield under the loosened stock bark. Wrap the union, leaving the bud exposed.

Figure 7-H: CHIP BUD AND T-BUD



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CHAPTER 8: PRUNING ORNAMENTAL PLANTS

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PRUNING ORNAMENTAL PLANTS

INTRODUCTION

Pruning is the removal of a part or parts of a woody plant for a specific purpose. All forms of pruning alter the direction and amount of new plant growth. Understanding the basics of plant growth will help you to consciously direct the pruning cuts.

IMPORTANCE OF BUDS

All new growth comes from buds, and pruning manipulates bud growth. Each bud a plant produces grows into a branch, leaf, or flower. Most buds can be classed as dormant, latent, and adventitious. **Dormant buds** form during one growing season and remain dormant until the next growing period when, depending on their type, they grow into stems, leaves, or flowers. New stems arise from dormant **terminal buds** at the branch tip. Side branches emerge from dormant **lateral buds** on the sides of branches. Lateral buds at the base of a leaf: called auxiliary buds, produce either leaves and stems or flowers.

Buds may remain dormant for many seasons as the supporting branch becomes larger and older. These persistent buds are known as **latent buds**; the plant's insurance for the future.

Both dormant and latent buds are strongly connected to the plant's vascular system, which links them to nutrients and water. **Adventitious buds** develop where no buds previously existed, often after a branch is wounded or cut back to mature tissue. These buds differ from dormant or latent buds in that they are not directly connected to the plant's vascular system. Shoots that develop from adventitious buds, such as water sprouts, are not strongly connected to the trunk or main branches and can be easily broken. A number of years must pass before new layers of wood from annual growth rings can support these branches.

ROLE OF TERMINAL BUD

The terminal bud exerts a strong chemical control over the lateral buds lower on the stem. This phenomenon, called apical dominance, is directed by a hormone called **auxin**.

This hormone, located in the terminal bud, suppresses the growth of other buds and keeps them dormant.

Apical dominance is the reason that few, if any, branches develop from lateral buds close to the tip of the branch. As the branch grows, it sends the terminal bud farther out, away from the center of the plant. When a lateral bud is far enough away from the terminal bud, generally after two or three seasons of growth, it receives weaker hormone signals, until it's released from dormancy and begins to grow. This is why branching on unpruned plants occurs near the base, forming a pyramid shape.

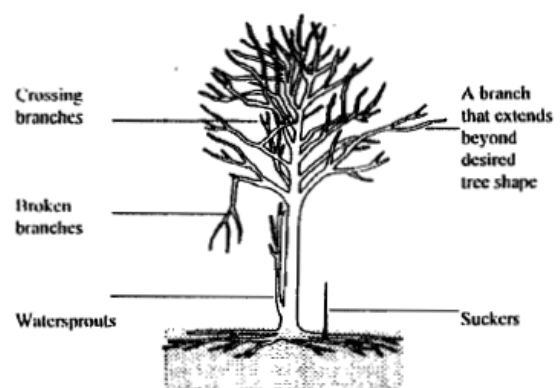
Effective pruning manipulates bud growth to your advantage. Removal of terminal buds releases buds from the growth inhibition caused by apical dominance, creating multiple branches. This type of growth response is easily seen on a sheared hedge or a tree cut flat below an electric utility line.

REASONS FOR PRUNING

Why should you prune?

- To train newly planted trees and shrubs for better establishment.
- To maintain plant health.
- To improve the quality of flowers, fruit, foliage or vigour.
- To restrict growth.
- To alter form.
- To renew or rejuvenate old shrubs

Figure 8-A: PLACES ON A TREE THAT REQUIRE PRUNING



MAINTAINING PLANT HEALTH

In pruning to maintain plant health, the first consideration should be sanitation, which includes eliminating dead, dying, or diseased wood. Any dying branch or stub can be the entry point for insects or fungi that could spread to other parts of the tree. For many diseases, pruning is the best control method. When removing wood infected with a disease, such as a fungal canker or fire blight, it is important that the cut be made in healthy wood below the point of infection.

IMPROVING THE QUALITY OF FLOWERS, FRUIT, FOLIAGE, AND STEMS

The more flowers and fruit a plant produces, the smaller they may become, as can be seen on an unpruned rose bush or fruit tree. Pruning reduces the amount of wood and so diverts energy into the production of larger, though fewer flowers or fruit.

RESTRICTING GROWTH

Over time, trees and shrubs often become overgrown. If pruning does not solve your space problems it may be necessary to redesign the landscape planting and replant with smaller-maturing selections.

TRAINING THE NEWLY PLANTED TREE

Prune trees after purchase to remove broken, crossing, and pest-infested branches.

For properly pruned nursery-grown plants, the practice of pruning away one-third of the top growth to compensate for root loss is not necessary (except in the case of fruit trees; see **Chapter 15**). Excessive pruning at transplanting, according to research, reduces plant size and does not aid in plant survival. Any significant reduction in leaf area slows the manufacture of plant foods needed for optimum root growth and leaf development. A strong root system aids establishment of the plant.

Corrective pruning is frequently needed the second year after planting to remove undesirable, structurally weak branches, and to develop a good arrangement of scaffold branches. Some branches may be left on the tree for 1-3 years and removed as the tree grows.

The best time to prune many species is the late dormant season, before new leaves form. While dead, dying, and broken branches can be pruned anytime, any great amount of corrective pruning should be delayed 1-2 years after planting or until the tree is growing well.

"Thinning-out" is the recommended method of pruning. Branches are cut at the point where they attach to the parent stem or to lateral side branches. It is best to prune back to a lateral branch having a diameter equal to at least twice that of the branch removed. Always prune to a single, central leader. Trees with co-dominant leaders may become structurally weak.

"Heading back" the terminal to a stub is not recommended. It leads to a loss of apical dominance and causes development of upright, dense new growth below the cut. When vigorous, upright-growing laterals assume a vertical position in competition with the leader, they should be reduced in length or cut back to a side bud. If allowed to grow they will out-compete the main leader. Whenever a terminal leader has lost its dominance, select a new one and thin out or cut back the original weakened leader and any stems in competition with the new leader.

Select main scaffold or lateral branches growing at a wide angle to the trunk (60-90 degrees). A narrow-angled crotch (less than 30 degrees) is weaker and is more likely to split during a storm. Scaffold branches with a narrow angle of attachment should be removed as soon as possible or reduced in length over several years.

The height of the first permanent lateral branch above the ground depends on how the tree is used in the landscape. The height of the lowest branch can be a few inches above the ground for a screen or windbreak; 2 m for a shade tree in a lawn or near a patio; or 3.5 m if the tree is planted along a street. Branches below this permanent height can be treated as temporary and reduced in length or removed in stages over several years.

The vertical distance between the main lateral scaffold branches on large trees should be 25 to 60 cm. Select five to seven branches that grow from the trunk in an ascending, spiraling circle up the trunk in one or two rotations. Good vertical spacing should prevent one limb from growing directly over another, and result in branches arranged like shingles on a roof. Overlapping limbs will never reach proper size because of shading or competition for water and nutrients.

When training a young tree, prevent lateral branches from growing faster than the main trunk by reducing their length.

Lateral branches should always be smaller in diameter than the trunk. Whenever a trunk forks, the main branch should be the largest. If the size of a branch is too large in relation to the trunk, prune it more severely to reduce its total growth.

When deciduous trees are planted bare root, some pruning may be necessary. Light pruning of roots may be needed if any are broken, damaged or dead. If roots do not fit into the prepared hole, the hole should be enlarged. Never bend or fold a root into the planting hole.

Container-grown plants that have become root bound need to have their roots thinned or cut at planting time. If circling or girdling roots cannot be eased from the root ball, then several vertical cuts, 2 cm or so deep, down the side of the root ball and across the bottom of the root ball will disrupt the circling root pattern and allow for better root distribution in the planting hole.

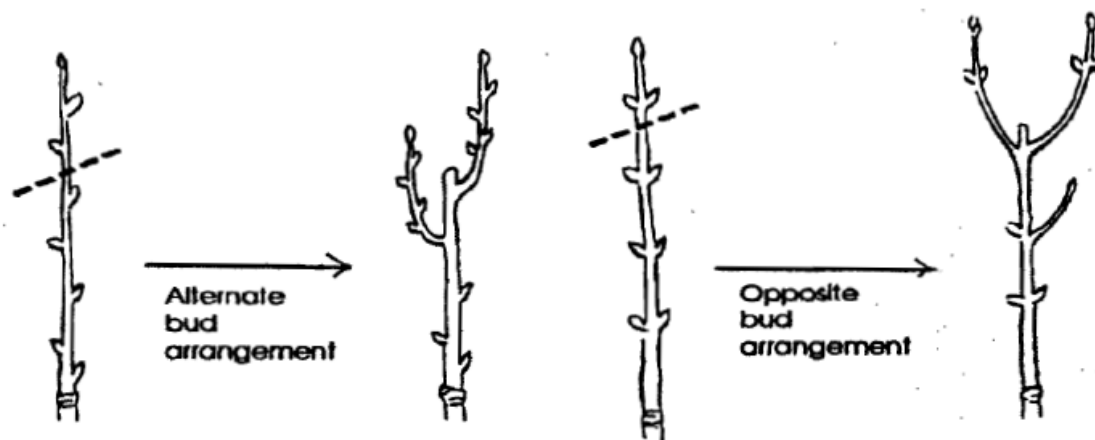
PRUNING DECIDUOUS SHRUBS

Shrubs have different growth habits—fast, medium, or slow with upright, wide-spreading, arching, or horizontal branching. Select the right plant for height and branch spread at maturity within the space allotted to reduce the need for severe pruning over the years. Using proper pruning techniques can enhance a plant's value and appearance. Improper pruning can easily ruin the plant's landscape value and increase your labour.

REASONS FOR PRUNING

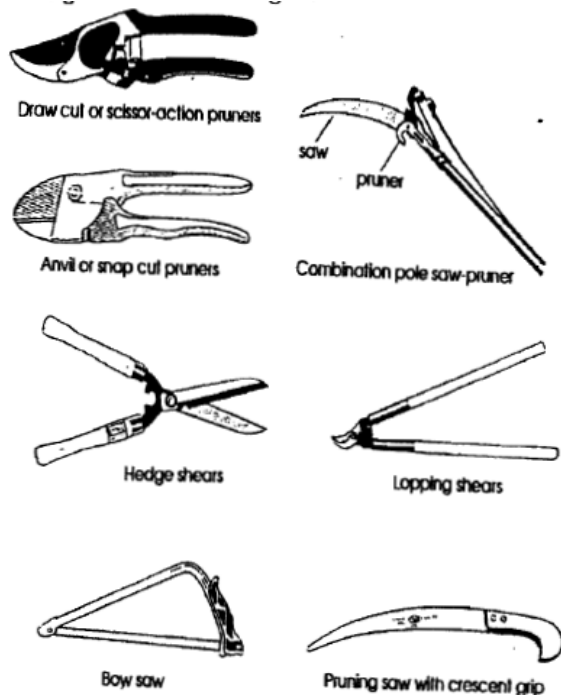
Before you begin to prune, it is important to understand what you wish to accomplish by pruning. Good pruning is the selective removal of branches without changing the plant's natural appearance or habit of growth. Shrubs trimmed to an unnatural shape require more pruning than shrubs pruned to keep their natural shape. Most flowering shrubs will bloom either on 1-year-old growth, or on new growth. Properly timed pruning increases the production of wood that will bear flowers. Prune to improve the vigour of the shrub by cutting out dead, diseased, broken, and overgrown branches that interfere with new growth. Prune to control the shrub's size and shape and to enhance the effect of colored twigs.

Figure 8-B: PRUNING STIMULATES LATERAL SHOOT GROWTH CLOSE TO THE CUT



PRUNING TOOLS

Figure 8-C: Pruning Tools



Some deciduous shrubs, such as red or yellow stem dog wood, are grown for their colored bark in the winter landscape. The best color is produced on young stems. The greatest stem length and most intense color, results from hard pruning in late spring.

TYPES OF PRUNING CUTS

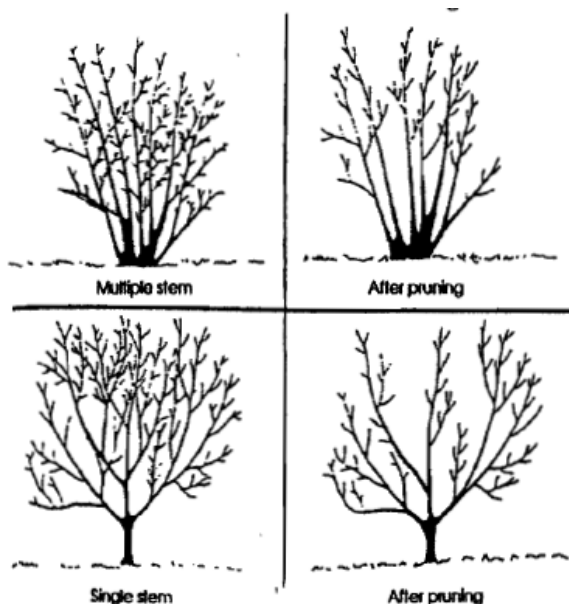
Thinning out is removal of a branch or twig at its point of origin on the next largest lateral branch, or back to ground level. This method of pruning results in a more open plant and does not stimulate excessive new growth. Considerable growth can be cut off without changing the plant's natural appearance or habit of growth. Plants can be maintained in a healthy condition at a given height and spread for years by thinning out. This method of pruning is best done with hand shears, lopping shears or small curved pruning saws. Thinning out allows room for growth of new branches.

Renewal pruning gradually removes the oldest and tallest branches from an overgrown shrub, at ground level. This is best done over a three-year period, leaving the younger, more vigorous branches. On very old plants, it may be best to remove only 15%-20 % of the oldest growth each season until the plant meets your requirements. New shoots will gradually replace the older stems and in time as they age will also be thinned out. Some new growth may need to be thinned out if it becomes crowded.

To completely rejuvenate neglected or overgrown healthy shrubs in one season, cut all the stems to within 2 to 5 cm above the ground before growth begins in the spring. This drastic method can restore an overgrown shrub faster than renewal pruning. Rejuvenation pruning may result in excessive re-growth of stems from the base of the plant or root system. If all the new growth is allowed to remain, plant quality will suffer. Thin out new growth and space it to create a plant with proper density. Long stems can be shortened to stimulate branching within the body of the shrub.

Avoid leaving stubs when pruning. Short stubs may die back and provide a point of entry for insects and diseases. Cuts too far above a bud may destroy the bud by dieback. The proper pruning cut to a side bud is 3 to 9 mm above the bud, and slanted slightly away from the bud.

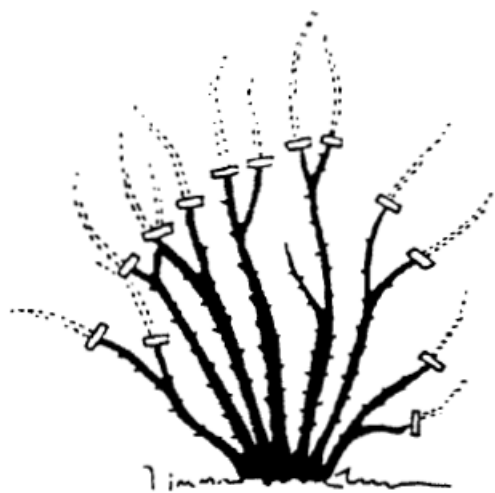
Figure 8-D: **THINNING: COMPLETE REMOVAL OF BRANCHES BACK TO A LATERAL OR THE MAIN TRUNK OR TO THE GROUND**



IMPROPER PRUNING METHODS

Heading back or **shearing** off the tops of shrubs to control height is not recommended. Heading back cuts are performed with hedge shears and without consideration for the shrub's natural form or branching habit. This type of pruning removes the apical dominance in the terminal part of each stem which results in vigorous, upright, new growth, primarily below the cut. When each branch or twig is headed back or sheared, more growth develops than was removed by the initial shearing, changing the shrub's natural shape. Subsequent shearing cuts are usually made above the previous cuts, producing more unmanageable growth. This method is not recommended for pruning landscape plants but is best used to create formal lines of hedges used as a wall or fence.

Figure 8-E: SHEARING OR HEADING BACK: INDISCRIMINATE CUTTING BACK OF TERMINALS RESULTS IN THICK, DENSE GROWTH IN THE OUTER CANOPY



Plants that flower in the spring bloom on the previous season's growth. Prune these soon after flowering during active growth.

Botanical Name	Common Name
<i>Amelanchier</i> spp.	Shadblow, Serviceberries
<i>Azalea</i> spp.	Azalea
<i>Berberis</i> spp.	Barberry
<i>Caragana</i> spp.	Pea shrub
<i>Cercis canadensis</i>	Eastern Redbud
<i>Chaenomeles japonica</i>	Japanese Quince
<i>Chionanthus virginicus</i>	Fringetree
<i>Cornus kousa</i>	Kousa Dogwood
<i>Cornus mas</i>	Cornelian Cherry
<i>Chionanthus virginicus</i>	White Fringetree
<i>Crataegus</i> spp.	Hawthorn
<i>Deutzia</i> spp.	Deutzia
<i>Exochorda racemosa</i>	Pearlbush
<i>Forsythia</i> spp.	Forsythia
<i>Kalmia latifolia</i>	Mountain laurel
<i>Kolkwitzia amabilis</i>	Beautybush
<i>Laburnum x watereri</i> 'Vossii'	Laburnum
<i>Ligustrum</i> spp.	Privet
<i>Kerria japonica</i>	Kerria
<i>Lonicera</i> spp.	Honeysuckle
<i>Magnolia stellata</i>	Star Magnolia
<i>Malus</i> spp.	Crabapple
<i>Philadelphus</i> spp.	Mockorange
<i>Pieris japonica</i>	Andromeda
<i>Pyracantha</i> spp.	Firethorn
<i>Prunus</i> spp.	Flowering cherry, almond and plum
<i>Rhododendron</i> spp.	Azalea and <i>Rhododendron</i>
<i>Rhodotypos scandens</i>	Jetbead
<i>Rosa</i> spp.	Rose
<i>Sorbus</i> spp.	Mountain Ash
<i>Spiraea thunbergii</i>	Thunbeg spirea
<i>Spiraea x vanhouttei</i>	Vanhoutte spirea
<i>Syringa</i> spp.	Lilac
<i>Viburnum</i> spp.	Viburnum
<i>Weigela florida</i>	Old Fashioned Weigela

Late flowering plants bloom on wood produced during the current growing season. These plants should be pruned when dormant in late winter to promote vigorous shoot growth in the spring.

Botanical Name	Common Name
<i>Abelia x grandiflora</i>	Glossy Abelia
<i>Acanthopanax</i> spp.	Aralia
<i>Aesculus parviflora</i>	Bottle brush buckeye
<i>Buddleia davidii</i>	Butterfly-bush
<i>Callicarpa japonica</i>	Japanese Beauty bush
<i>Caryopteris x clandonensis</i>	Bluebeard
<i>Clethra alnifolia</i>	Summersweet Clethra
<i>Cotinus coggygria</i>	Smokebush
<i>Hibiscus syriacus</i>	Shrub Althea
<i>Hydrangea arborescens</i>	Hills of Snow, snowball
<i>Hydrangea paniculata</i>	Peegee Hydrangea
<i>Hypericum</i> spp.	St. Johnswort
<i>Hypericum kalmianum</i>	Goldflower
<i>Koeleruteria paniculata</i>	Goldenrain tree
<i>Potentilla fruticosa</i>	Cinquefoil
<i>Ribes odorata</i>	Flowering currant
<i>Rosa</i> spp.	Rose
<i>Sambucus</i> spp.	Elderberry
<i>Sophora japonica</i>	Japanese Spirea
<i>Sorbaria sorbifolia</i>	False Spirea
<i>Spiraea x bumalda</i>	'Anthony Waterer' Spirea
<i>Spiraea japonica</i>	Mikado Spirea
<i>Symphoricarpos albus</i>	Coralberry or Snowberry
<i>Tamarix</i> spp.	Tamarisk

PRUNING DECIDUOUS TREES

Limit your pruning of shade and flowering trees to removal of smaller branches that can be reached from the ground. Leave trimming of larger branches and use of ladders to professional tree people who have the proper equipment and insurance.

REASONS FOR PRUNING

Trees planted in the landscape may need corrective pruning to:

- Prevent them from growing too high.
- Reduce shade.
- Prevent branches from rubbing against vehicles, wires, buildings, or other limbs.

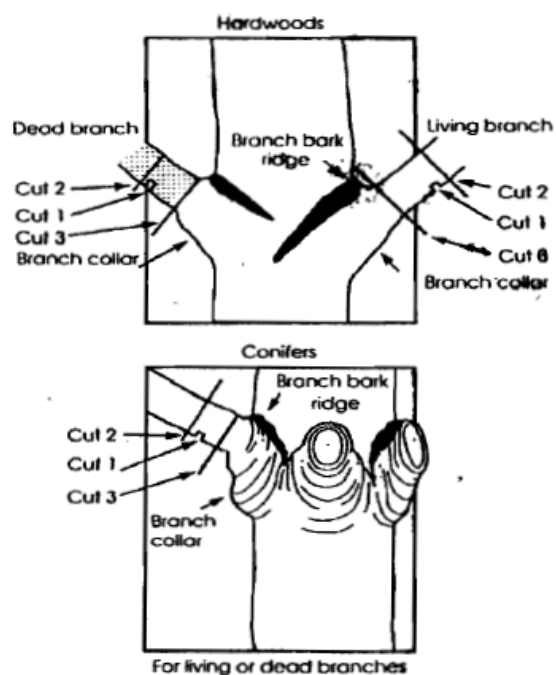
Early removal of double leaders or narrow, V-shaped crotches will reduce broken branches in storms and split trunks as the trees mature.

WHEN TO PRUNE

The best time to prune most deciduous trees is during the dormant season, between leaf fall and spring growth. Light pruning and removal of dead or diseased branches can be done anytime. The least desirable time for moderate to severe pruning is from mid-summer through autumn. Spring flowering trees should be pruned near the end of their blooming season.

Sap may flow from pruning wounds made late in winter or early spring on such trees as maple, dogwood, birch, elm, walnut, and yellowwood. This "bleeding" is not harmful but is unsightly. On these trees, select branches that need to be cut out and mark them for removal in the late spring or early summer after the sap flow has slowed, or early in the dormant season. Trees pruned in late fall will not be actively growing and wounds will not heal sufficiently before possible freezing damage.

Figure 8-F: PROPER PRUNING CUTS



PRUNING METHODS

The general principle in pruning trees is to cut branches back to the point of origin or the next lowest lateral branch. This results in a more open tree and encourages growth of internal branches.

Do not "**Head back**" or "**top**" the central leader to reduce the height of the tree. This will result in a proliferation of weakly attached shoots arising from adventitious buds. Branches that compete with the leader should be removed or, if large, gradually cut back over several years.

When pruning twigs and small branches, cut back to a vigorous bud or the next largest lateral branch. When cutting back to a bud, choose a bud that is pointing in the direction you wish the new growth to take. Don't leave a stub over the bud or cut too close to the bud.

When cutting back to the next largest lateral branch, choose a branch that forms an angle of no less than 45 degrees with the branch to be removed. Cut back to a branch that is at least twice the diameter of the branch that is removed. This type of pruning is called **Drop Crotching**. Make slanting cuts when removing limbs that grow upward to prevent water from collecting in the cut and to speed healing.

Pruning thick or heavy branches involves more observation and planning than removing smaller stems. Large branches should be removed 0.5 cm from the collar at the base of the branch, not flush with the trunk. The branch collar is an area around the base of branches. It produces healing tissue that will form around the cut (see **Figure 8-F**). If the collar is removed, a serious trunk wound may form and wood-decay fungi can easily infect the trunk. **Pruning cuts do not need to be protected with paints or coatings.**

When cutting branches over 3.5 cm in diameter, use a three-part cut (see **Figure 8-F**).

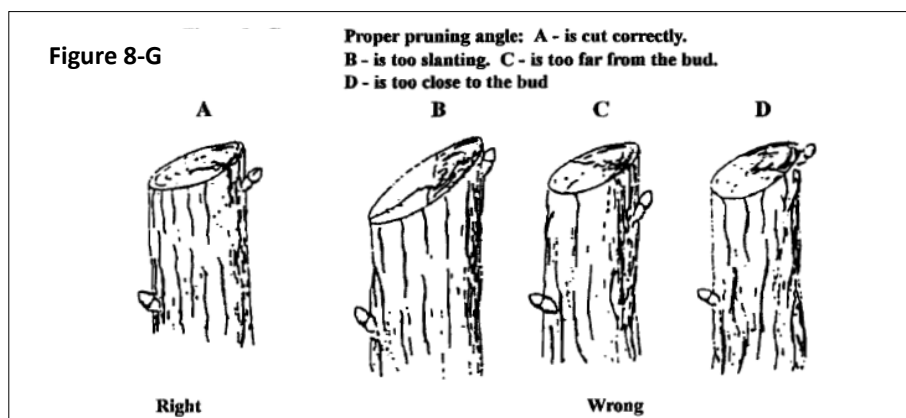
1. Saw an undercut from the bottom of the branch about 15 to 30 cm out from the trunk and about a ¼ of the way through the branch.
2. Make a second cut from the top, about 8 cm from the undercut. The branch will fall away. (If there is danger of the branch damaging other limbs below or objects on the ground; it must be properly roped and supported, then carefully lowered to the ground after the second cut.)
3. Cut the remaining stub back to within 0.5 cm of the collar of the branch

PRUNING EVERGREENS

Evergreen trees and shrubs in the landscape have either narrow or broadleaved foliage. Most trees are conifers and have either needle or scale leaves. Narrow leaved evergreen shrubs commonly planted around the home include yew, juniper, arborvitae (cedar), and false cypress. Broadleaved evergreens are represented by rhododendron, Japanese pieris, holly, boxwoods, euonymus, mountain laurel, bearberry, cotoneaster and paxistima.

PRUNING BROADLEAVED EVERGREENS

The best time to prune most evergreens, with the exception of pines, is in late winter or early spring before new growth starts. Some evergreen shrubs continue to grow during the summer. A light pruning may be desirable in late July to shorten long branches. Avoid heading-back pruning for this purpose because it will stimulate too many new shoots just below the cut. If heavy pruning is delayed until summer, the dormant buds already present will stay dormant and not grow until spring.



Prune broadleaved evergreens in early spring by the thinning-out method already described. For optimal flowering on rhododendron, pinch and flower clusters as soon as the petals wilt and flower colour fades. This prompt removal prevents seed formation and encourages new growth and flower buds for the following season.

A few broadleaved evergreens, such as boxwood, euonymus, and Japanese holly species, can be lightly sheared on occasion to promote fullness if they are used as hedge plantings in the landscape. However, these respond well to periodic thinning-out to encourage growth from within the plant. None of these have significant flower or fruit qualities and can be pruned in the late dormant season before growth starts.

JUNIPER AND YEW (*TAXUS*)

Selectively thin out the branches of narrow leaved evergreen plants to maintain a natural shape and reduce foliar density. Lateral branches should generally be longer at the bottom of the plant and shorter at the top. Upright forms of *Taxus* and juniper should be thinned out by pruning to create the shingled or tiered effect described above. Pyramidal plants should be pruned to eliminate multiple leaders. Most multiple, upright stems can be subordinated by cutting back to a lateral side branch, leaving one dominant leader. Nurseries often trim *Taxus* and juniper into tightly shaped plants with hedge shears. This method is not recommended unless a formal hedge of various *Taxus* species is desired. Prune *Taxus* just before new growth starts in the spring. A second flush of growth may occur in late summer. A light pruning in July will shorten long growth and retain the plant's natural form.

Even the low-growing, groundcover types of juniper require some thinning to restrain their lateral spread. Lift and remove the longest branches deep inside the crown of the plant. Take care not to cut all the horizontal stems to the same length; this will destroy the natural form and spread of the plant.

PRUNING CONIFERS

Most pine and spruce trees are not recommended for plantings near homes and other buildings. These tall-growing evergreens normally develop into broad, pyramid shaped trees with a single leader or trunk and reach heights of 20 to 30 metres or more. It is very difficult to keep such a plant restrained with any degree of pruning and dwarf or smaller species should be selected when possible.

If conifers must be restricted in size, limit pruning to cutting back terminal growth of the longest branches with hand pruning shears, retaining the natural shape.

Branches of spruce grow in layers or whorls around the main trunk. New growth occurs only once a year, from existing buds. New buds or shoots generally do not develop from cuts made on older wood. When terminal growth is too rapid, open spaces can develop between branches that form along the main trunk of the plant. This can be remedied by reducing the length of the new terminal growth.

PINES AND SPRUCE

The best time to prune pines and spruce is after growth has been completed, but before stem tissues have hardened off. June to early July is the usual timeframe, depending on the pine species and your geographic area. Restrict the height and width of pines and spruce through annual pruning of the new soft growth and side laterals in late spring. One-half to two-thirds of the candle-like terminal growth can be pinched off by hand or removed with pruning shears before the needles unfold. Avoid using hedge shears around candle tips. The young needles will be damaged, causing the branch ends to brown.

Both spruce and pine are large trees. Do not encourage too much density in the lower portions of the trees by excessive pruning and shortening of the side branches. As the tree becomes taller it will be more difficult to reach the side branches to maintain a uniform density in the entire tree.

PRUNING VINES AND GROUNDCOVERS

The general principles of pruning ornamental shrubs also apply to vines. Always prune back to a lateral branch, twig, or bud, and do not leave a stub. Remove dead and weak wood back to healthy wood. Annual thinning of old and weak stems encourages new growth. Thin any crowded stems by cutting them to the ground. Some fast growing vines can be severely pruned to induce growth close to the ground. If done early in the spring before new growth starts, it causes no harm. Some common vines make rapid, vertical growth with few lateral branches except near the top. These vines can be pinched or the leaders pruned back during the growing season to develop more horizontal-growing branches.

Then, vertical growth can be allowed to develop where needed. Horizontal branches tend to grow more slowly and produce more leaves, flowers and fruit than vertical branches.

The best time to prune most vines is before new growth begins. Prune early, spring flowering vines soon after they flower. New growth that develops after pruning will produce buds for the next bloom season.

Pruning requirements of some familiar vines:

- **Boston ivy Virginia creeper** (*Parthenocissus*) - Prune branches to control spreading; cut back near or to the ground.
- **Bittersweet** (*Celastrus*) - Prune stems each year, leaving three or four buds to promote new growth. Remove the tops to encourage branching.
- **Clematis** - If vines bloom in spring, prune after they flower. For vines that bloom later in the season, prune while they are still dormant.
- **Dutchman's pipe** (*Aristolochia*) - A rapid grower, cut the top back to control size and induce branching. Thin out older stems to promote new growth.
- **Honeysuckle** (*Lonicera*) - Thin stems and branches to encourage new growth. Can be cut back to the ground if overgrown.
- **Silverfleece vine** (*Polygonum*) - Can be cut back to the ground each year.
- **Trumpet creeper** (*Campsis*) - Each year cut stems back to three or four buds to promote new growth. Remove tops to encourage vine branching.
- **Winter creeper** (*Euonymus*) - Prune branches to control spreading.
- **Wisteria** - Prune back stems to three or four buds each year to promote new growth and flowers. Tops can be shortened to induce branching.

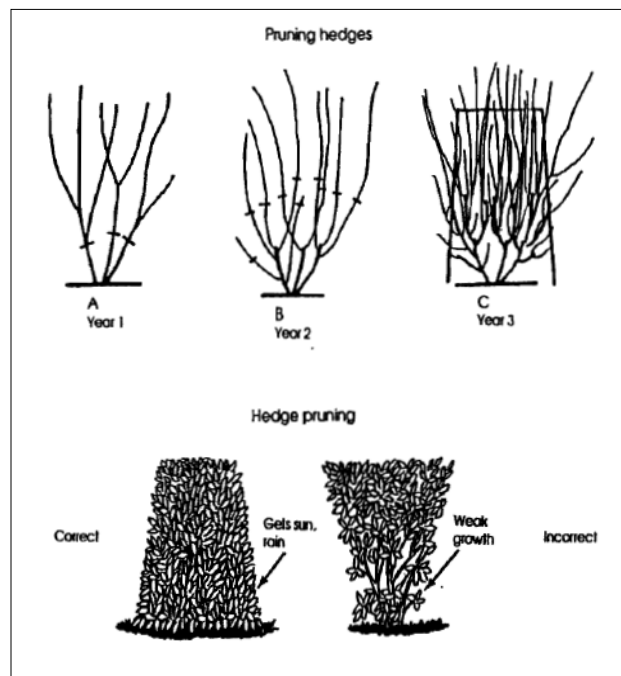
Groundcovers are often selected for difficult sites. They are considered relatively maintenance free, but occasionally require some pruning for the following reasons:

- Deadwood removal to rejuvenate growth.
- General pruning to keep them within bounds.
- Overall shearing to control insects or diseases.

Groundcovers can be pruned whenever necessary. A number of them are highly recommended for various sites. See **Chapter 12, "Woody Ornamentals"** for a listing.

PRUNING HEDGES

There are two types of hedges: formal and informal. The formal hedge is pruned with hedge shears to a definite size and shape, one or more times a year. The informal hedge, often a row of shrubs planted close together but allowed to grow normally, is pruned annually to thin out the oldest wood and to maintain a desired height and width.



STARTING A FORMAL HEDGE

After planting, small shrubs 1 to 3 years old should be cut back to about 8 to 13 cm above the ground. This will force new shoots at the base of the plant to develop into a thick, bushy shrub.

No additional pruning is needed on newly planted hedges until the next spring. Older shrubs used to start a hedge can be cut about one-third from the top and sides. This helps develop a thick, bushy hedge of many twiggy stems.

PRUNING FORMAL AND INFORMAL HEDGES

The most important step in starting a formal hedge is the first shearing the next season after planting. A narrow pyramid or inverted V is the recommended shape. For example, a hedge 1.5 m high could be 0.6 m at the base and about 0.3 m at the top.

The top of the formal hedge may be trimmed slightly rounded or pointed. If the top becomes as wide as or wider than the base, the lower portion is too shaded and produces thin, weak growth.

Formal and informal hedges can be kept vigorous for years by annually cutting out one-third to one-fourth of the oldest branches near, or a few inches above, the ground before new growth starts. Use hand pruners, toppers, or curved pruning saws. This method encourages new growth at the base of the plant. Along with regular shearing, formal hedges can also be kept vigorous by thinning out upper branches.

WHEN TO PRUNE

Prune hedges in the late dormant season, before new growth starts. Slow-growing hedges may require only one annual pruning, either before new growth starts or after they have completed spring growth in late May to mid June. Fast-growing hedges can be sheared two or three times during the growing season to maintain the desired height and width.

REJUVENATING OLD HEDGES

Restore overgrown, neglected hedges with either complete rejuvenation or by renewal pruning methods (see “Types of Pruning Cuts”, page 8-4).

EVERGREEN HEDGES

Narrow leaved evergreens such as *Taxus* (yew), *Arborvitae* (white cedar) and false cypress, make good hedges. They seldom require more than one pruning in early spring and again in mid-July if desired. No initial pruning is needed after planting young broadleaved evergreen shrubs. For the first 2 years after planting, prune back only the terminals and laterals as needed to begin the desired shape and taper. This recommendation applies to plants such as boxwood, Japanese holly, American holly, and cotoneaster.

PRUNING ROSES

Proper pruning of roses encourages new growth from the base, making the plant healthy, attractive and productive. When neglected, roses deteriorate in appearance; develop disease and insect problems, and the flowers become smaller than desired.

'Hybrid Tea,' 'Grandiflora,' 'Floribunda' and 'Large Flowered Repeat Blooming Climber Roses' should be pruned in early spring, preferably before or just after bud break. Early pruning followed by very cold weather can kill the new shoots. A reasonably good time indicator for pruning is the blooming of forsythia

Necessary tools are sharp hand pruning shears and heavy gloves. If the rose collection is large, add a small saw with pointed blade and toppers to cut out large dead canes.

First, remove branches that are dead, damaged, diseased, thin, weak and growing inward, and branches that cross or interfere with other branches. Cut at least 2.5 cm below damaged areas. Remove all weak shoots. If two branches rub or are close enough that they will do so soon, remove one. On old, heavy bushes cut one or two of the oldest canes each year.

Next, cut back the remaining canes. Make cuts at a 45 degree angle about 0.5 cm above a strong outer bud. Aim the cut upward from the inner side of the bush to push growth outward and to promote healthy shoots and quality flowers. Dab the cut ends with weather-proof glue, such as carpenter's glue to prevent infestation of rose cane borers.

The extent to which a rose should be cut back will vary, depending upon the degree of cane dieback caused by winter weather.

- The principal guideline for pruning should be to cut down to "good", solid wood. After a cut is made, inspect the end of the cane. If the end shows excessive discoloration or is not firm, cut down further. Cuts all the way to the bud crown are not unusual for Ontario conditions.
- Canes may be left at lengths of 30 to 60 cm depending on the severity of winter weather.
- Prune tree roses or rose standards as you do hybrid teas, cutting the branches to within 15 to 25 cm of the base of the crown. This will encourage rounded, compact, vigorous new growth.
- Miniature roses are 15 to 30 cm high, with tiny blooms and foliage. They do not need special pruning. Just remove dead growth and the rose hips.
- Climbers with blooming characteristics similar to those of the hybrid teas are officially classified as Large Flowered Climbers (LCL). They should be pruned at the same time of the year as the hybrid teas. LCL plants perform best when the main canes are tied to a support horizontally. The main canes are pruned back to the base when they are diseased, damaged or unproductive.

The principal pruning is done on the lateral growth leaving 4 to 8 bud eyes. Some in the LCL class are known as "pillar climbers" because they bloom reasonably well when the main canes are grown vertically. Horizontal positioning of these main canes, however, will improve their blooming characteristics.

- Old Fashioned Ramblers and many Old Garden Roses only bloom in the spring. Since all blooms occur on canes at least one year old, these roses should be pruned only after the blooming period.

ROOT PRUNING

A tree may develop long roots running 5 to 8 m or more away from the plant, which, along with many-branched side roots, physically support the tree. The area in a 1 m radius of the tree trunk contains very few of the small feeding roots essential to gathering nourishment for the tree. These roots are usually located quite some distance from the trunk, branching off the long main roots and in the top 30 to 45 cm of the soil. As a consequence, if the tree were to be dug and moved, the necessary feeding roots would be cut off in the balling operation, and the tree might die when transplanted. For this reason nursery operators root prune nursery-grown plants, to force them to grow small feeding roots near the base of the plant. These small roots are then moved in the balling operation to ensure growth after transplanting.

To enable safe digging of small trees or shrubs, root-prune plants a year or so before transplanting.

1. In the spring, sever half the roots by forcing a sharp spade into the soil around the plant, alternately leaving a shovel width of untouched soil in between cuts. The circle of cuts should be slightly smaller than the size of the ball that will eventually be dug.
2. In the early fall, sever the other half of the roots, thus cutting all the roots growing at a depth of a foot or less.
3. Move the tree in the following spring. Recent research indicates that most of the new roots grow from the cut end. Therefore, a root ball 5 to 15 cm larger than the root-pruned area must be dug to include the newly developed roots.

Root pruning will also force a vigorous-growing fruit tree, Wisteria vine, lilac, or dogwood into bloom. Using a spade to cut the roots early in spring, as explained above, is all that is sometimes necessary to force a tree, shrub, or vine into bloom the following year.

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CHAPTER 9: WILDLIFE MANAGEMENT

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WILDLIFE MANAGEMENT

GARDEN FRIENDS

In the typical suburban and urban neighbourhood you can find a wide variety of wildlife species. Wild animals are an important part of the environment. They not only are part of the "balance of nature," but also provide us with much enjoyment. As development continues to encroach on woodland and farmland, it is truly amazing to see how many wild animal species adapt and even learn to thrive in close proximity to human activity. Certain species, such as the raccoon and squirrel, seem to thrive and reproduce in larger numbers than they do in the wild because of shelter and plentiful food provided by people.

Some gardeners might compare animals in the garden to weeds. Just as a tomato in the petunia bed is a weed, many wild animals out of their native habitat can be just as unwanted in the garden or landscape.

This chapter will cover both the animals we want to encourage and those we want to discourage. We'll discuss horticultural, chemical and physical means of attracting or repelling them.

BIRDS

Birds are one of the more welcome additions to a landscape. We benefit from their diet of insects or weed seeds during the growing season and winter months. Most birds tend to be seasonal inhabitants of the garden. Many others migrate through the region adding colour and interest to our surroundings. Birds that remain in the garden through the winter are often the most welcome. Their only disadvantage might be the few seedlings snapped off or the strawberries eaten in spring.

You can increase the number and variety of birds visiting your garden by providing food, water, and cover. Bird feeding is a popular and enjoyable hobby during the winter months. Bird feeders maintained during the spring help keep some birds in the garden before natural supplies of food become available in your area.

Water can attract birds in any season, especially during winter when natural sources may be frozen, or during summer droughts. Traditional bird baths, pools, or other shallow containers can be placed around the garden or near a food source to help attract and retain birds.

The third way to attract birds to the garden is to supply cover where birds can rest. One of the best forms of cover can be provided by planting a variety of woody trees and shrubs, both deciduous and evergreen. If these plants produce an edible fruit crop, that is an additional incentive for birds to remain in the area.

Plants with high twig densities seem to be most attractive to roosting birds. Lilac, Spirea, Viburnum, and Potentilla are several species of shrub that provide needed twig density for birds. Narrow leaved evergreens are equally desirable for cover during feeding and at night. Mugo pine is a low shrub that works well, as do hemlock, spruce, and taller pines.

FEEDING BIRDS

Bird feeding is an enjoyable way to observe and learn about birds from the comfort of your home. The number of birds that visit your feeder is influenced by the type of habitat around your home. The greatest diversity of birds can be found at feeders in wooded rural areas. The lowest number is found at feeders in urban areas. Diversity of birds is bolstered by an abundance of trees and shrubs, a heated bird bath, and numerous feeders. You can enhance the probability of attracting many species of birds by planting trees and shrubs that provide food and cover.

Different bird species have different food and feeder preferences. The best way to attract a variety of birds is to offer a varied fare. A feeding station should be comprised of several kinds of feeders containing different seed in a location that is near (less than 6 to 7 m from) cover such as conifers or bushes. Place millet and cracked corn on the ground for mourning doves and sparrows. Raisins or dried fruit can be placed on a stump to attract fruit eating eastern bluebirds and cedar waxwings. At least one feeder should be reserved to attract birds such as woodpeckers and chickadees. Niger seed (thistle), dispensed from a Niger feeder, is a favorite of goldfinches, house finches, and purple finches. Black oil sunflower seed is popular with many birds. A suet feeder will provide many birds, including woodpeckers, with needed fat.

Most people feed birds primarily during the winter months, but you can feed birds during the summer or year round. Providing nectar-dispensing feeders in the summer is a good way to attract ruby-throated hummingbirds and northern orioles. Keep feeders clean and fill with fresh solution every 2-4 days to avoid spoilage.

FEEDERS AND SEEDS FOR ATTRACTING BIRDS		
Species	Food Preference	Feeder Preference
Mourning dove	Cracked corn, millet	Ground, low tray*
Red-bellied woodpecker	Suet, orange/apple halves, peanuts	Almost all feeders
Yellow-bellied sapsucker	Suet	Suet feeder
Downy, hairy woodpeckers	Suet, sunflower seeds, peanuts	Suet feeder, hanging feeder
Northern flicker	Suet, orange/apples halves, peanuts	Suet feeder
Blue jay	Corn, sunflower seeds, suet, peanuts	Platform feeders*
Black-capped chickadee	Sunflower seeds, suet, peanuts	Almost all feeders
Tufted titmouse	Sunflower seeds, suet	Small hanging feeders
White-breasted nuthatch	Sunflower seeds, suet	Almost all feeders
Red-breasted nuthatch	Sunflower seeds, suet	Suet feeders, hanging feeders
Brown creeper	Suet	Suet feeder
American robin	Apple halves, raisins	Ground, low tray*
Eastern bluebird	Peanuts, suet, raisins, apple	Suet feeder, tray*
Northern cardinal	Sunflower seeds, cracked corn, millet, raisins, peanuts	Ground, low tray*
Song sparrow	Sunflower seeds, millet, peanut hearts	Tube feeder with tray
White-throated and white-crowned sparrow	Millet, cracked corn, hulled sunflower seeds, peanuts	Ground, low tray*
Dark-eyed junco	Millet, cracked corn, hulled sunflower seeds, peanuts	Ground, low tray*
Purple finch	Sunflower, niger, peanuts, suet millet	Hanging tube, niger feeder
House finch	Sunflower, niger, millet, fruit, suet	Tube, niger feeder, ground
Pine siskin	Niger, hulled sunflower, millet	Tube, niger feeder
American goldfinch	Niger, sunflower, nutmeats	Niger feeder, hanging tube, ground
Ruby-throated hummingbird	Sugar water (4:1 ratio, boiled)	Hummingbird feeders
Northern oriole	Sugar water, orange halves, millet	Oriole feeders

* Food in platform feeders or open trays can become spoiled from bird droppings and moisture. To avoid problems, offer only enough food for one day and clean the feeders on a regular basis. Drilled weep holes in the bottom help to drain rain and melting snow.

WATER FOR WILDLIFE: BIRD BATHS

Excessive heat and shortage of water cause problems for birds and other wildlife just as they do for people. Many species of birds require water for drinking and bathing. Others do not normally drink water but instead obtain it in the fruit and vegetation they consume. During most summers, small ponds, streams, and rain puddles provide sufficient water. In periods of excessive heat and drought, many of these water sources disappear, and birds appreciate baths filled with clean water.

Bird baths come in a variety of sizes, shapes, and prices. They range from the ornate, to a single garbage can lid. They may be purchased at most lawn and garden stores or be made at home from a variety of materials. Terra-cotta saucers used under large plants make excellent bird baths. A garbage can lid with a few stones placed inside also can be used. Whether you decide to purchase your bird bath or make it from items found at home, follow these following guidelines for success:

Depth: Bird baths should be no deeper than 7.5 cm at the deepest point and should have sloping sides down to this point. An edge along the top will provide a place for birds to perch while taking a drink.

Surface: The surface of the bath should be rough so that birds can maintain sure footing. Pebbles, stone, and concrete all provide the needed traction. Plastic is generally too slippery.

Height: Bird baths may be placed on the ground, on a raised pedestal, or hung from a branch a few feet off the ground. Ground level baths have the added benefit of providing water for many small mammals such as chipmunks and rabbits. However, bathing birds are extremely vulnerable to predators. If cats are in or around your yard, your bird bath should be raised above the ground.

Dripping water: Nothing that attracts birds as quickly as, dripping water. Some bird baths have fountains, but a water drip can be made easily by making a hole with a nail in the bottom of a jug or can. Attach the container to a branch about 1 m above the bird bath and fill it with water. This should provide a slow, steady drip that will attract birds to your bath. Once they have found the bath, they will continue to visit it even when the water isn't dripping.

Location: Ideally, your bath should be placed near a tree with overhanging branches so the birds will have a place to sit and preen after bathing. Place the bath away from dense shrubbery where cats can hide and surprise the bathers. Different species will be attracted to the bath depending on the height and location. You may want to experiment to see what works best.

Care: Keep your bird bath filled with clean, fresh water at all times. Dump the water out and refill it every couple of days, scrubbing to remove any algae that may have grown. Never use any chemicals to control algae.

Now sit back and enjoy your bird bath. Once the birds have located this water source, they will visit it on a daily basis and give you a welcome diversion as you watch their bathing antics.

LANDSCAPING FOR WILDLIFE: TREES, SHRUBS, AND VINES

Native trees, shrubs, and vines that produce berries or nuts provide a feast for birds and furnish them with shelter and a place to raise their young. Plant a variety of shrubs and trees so that food and cover are available throughout the year. For example, a yard planted with five native species - Serviceberry (*Amelanchier* spp.), Dogwood (*Cornus* spp.), Hawthorn (*Crataegus* spp.), Grape (*Vitis* spp.) and Junipers (*Juniperus* spp.) could supply food, cover and nesting sites for many species. As a source of cover for birds, plant conifers in groups and, where light levels and soil types permit, plant acid-loving shrubs such as blueberry and groundcover such as bunchberry.

The greatest variety of birds will be attracted to a yard with multiple layers of vegetation. Plant shrubs, small trees and tall trees in clusters. Increase vegetative diversity by adding vines to a fence, stone wall, or tree trunk. Avoid raking this area, and create the leaf-litter preferred by certain birds such as Rufous-sided towhees. In autumn, leaving seed heads on perennials will provide a food source for migrants and winter residents. In creating a landscape for birds it is important to remember that many birds eat insects and these species can be especially valuable for controlling pests in the garden. Some birds, like swallows and purple martins, catch insects in the air. Others like warblers or nuthatches may pick insects off trees. Others such as robins or woodcocks require bare ground or turf to forage for grubs and worms.

Table 9-1: CHARACTERISTICS OF SHRUBS AND FRUITING TREES

NAME	HT. (M)	WILDLIFE VALUE	EXPOSURE	SOIL	FRUITING PERIOD
LEGEND					
Exposure: FS = full sun; PS = part shade; S = shade • Soil: D = dry; M = moderate; W = wet; A = all					
SHRUBS					
Highbush cranberry (<i>Viburnum trilobum</i>)	5	The beautiful red berries of this native shrub are often left uneaten by birds until winter when the fruit rapidly disappears.	FS-PS	M-W	Fall to Spring
Coralberry (<i>Symphoricarpos orbiculatus</i>)	2	Purple-red fruit eaten by numerous songbirds, ruffed grouse, and wild turkey. Also useful for cover and nesting.	FS-S	W-D	Fall to Winter
Serviceberry (shrub form) (<i>Amelanchier</i> spp.)	2-3	One of the first native trees and shrubs to flower in the early summer woods. An excellent choice for shady yards, it provides fruit for many woodland birds as well as squirrels, chipmunks, raccoons, and red fox. Eastern cottontail and whitetail deer browse the twigs.	FS-S	M	Early Summer
Highbush blueberry (<i>Vaccinium corymbosum</i>)	4	Native shrub with fruits taken by many songbirds. Dense form provides cover and nest sites.	FS	A	Mid to late Summer
Common elderberry (<i>Sambucus canadensis</i>)	4	The native shrub provides food cover, and nesting sites.	FS-S	D	Late Summer
Common spicebush (<i>Lindera benzoin</i>)	4	Native woodland shrub with red aromatic berries that are eaten by numerous birds and mammals. Whitetail deer and eastern cottontail browse twigs.	PS-S	M	Late Summer to Fall
Brambles (raspberry and blackberry) (<i>Rubus</i> spp.)	2	These native shrubs provide cover, nest sites, and produce berries that are eaten by nearly all birds and mammals.	FS	M	Early to late Summer
Dogwoods (<i>Cornus</i> spp.)	Ground cover to 10 m	The many species of Dogwood can provide a variety of food, shelter and nesting sites for many species of birds.	FS-S	W-D	Mid Summer to late Fall
Winterberry (<i>Ilex verticillata</i>)	3 m	Native deciduous holly with persistent attractive berries.	FS-PS	W	Fall to Winter
Honeysuckle (<i>Lonicera</i> spp.)	Vines to 4 m	Flowers provide a good source of nectar and fruits attract many different species.	FS-PS	M	Late Spring to Summer
SMALL TREES					
Choke Cherry (<i>Prunus virginiana</i>)	9	Purple fruit favored by songbirds, game-birds, and many mammals.	FS-S	D	Late Summer
Red mulberry (<i>Morus rubra</i>)	12	With a long fruiting season, this native is an excellent choice. Berries provide food for birds and mammals.	FS-PS	M-D	Early Summer
Serviceberry (<i>Amelanchier</i> spp.)	4-9	One of the first native trees and shrubs to flower in the early summer woods. An excellent choice for shady yards, it provides fruit for many woodland birds as well as squirrels, chipmunks, raccoons, and red fox. Eastern cottontail and whitetail deer browse the twigs.	FS-S	M	Early Summer

Table 9-1: CHARACTERISTICS OF SHRUBS AND FRUITING TREES

NAME	HT. (M)	WILDLIFE VALUE	EXPOSURE	SOIL	FRUITING PERIOD
LEGEND					
Exposure: FS = full sun; PS = part shade; S = shade • Soil: D = dry; M = moderate; W = wet; A = all					
American crabapple (<i>Pyrus coronaria</i>)	9	Both native and cultivated varieties exist. Select trees with small fruits that are available into winter.	S	M-D	Fall
Flowering Dogwood (<i>Cornus florida</i>)	12	This native tree is as ornamental as it is valuable to wildlife. Unfortunately, it is currently being attacked by a disease known as dogwood anthracnose.	FS-PS	D	Fall
American mountain-ash (<i>Sorbus americana</i>)	12	Orange fruit of this ornamental native tree is often available through winter.	FS	D	Late Summer
TALL TREES					
American elm (<i>Ulmus americana</i>)	30	Buds, blossoms, and winged seeds invite birds during the spring months when little else is available. However, this tree is susceptible to Dutch elm disease.	FS-PS	M-W	Spring
Black cherry	18	A superb choice for attracting birds. At least 47 species eat the fruit of this native tree.	FS-S	D	Summer to Fall
Eastern red cedar (<i>Juniperus virginiana</i>)	12	This hardy native provides food, cover, and nest sites. The small blue fruits are eaten by at least 54 species.	FS	D	Fall to Spring
Easter white pine (<i>Pinus strobus</i>)	30	The large cones of this native species provide a highly nutritious seed that is eaten by at least 38 bird species. Its evergreen foliage provides cover throughout the year and nest sites in summer.	FS-PS	M	Fall
Eastern hemlock (<i>Tsuga canadensis</i>)	20	This native evergreen tree provides food, cover, and nest sites. Twigs browsed by whitetail deer and eastern cottontail.	FS-S	M	Fall
Oak (<i>Quercus</i> spp.)	18-30	These trees provide nest sites, and the acorns are consumed by a variety of mammals and birds.	FS-S	M-D	Late Summer to Fall
VINES					
Virginia creeper (<i>Parthenocissus quinquefolia</i>)		This native vine produces blueberries that are a favorite for 35 species of birds.	S	M	Late Summer to Spring
Wild grape (<i>Vitis</i> spp.)		At least 52 species of birds and mammals eat the fruit from this native vine. Grape tangles are also common nest sites.	FS-PS	M	Late Summer to Fall

HUMMINGBIRDS AND BUTTERFLIES

Only a single species of hummingbird is common in Ontario - the Ruby-throated hummingbird. They are named for the crimson, iridescent throat feathers of the male. Well adapted for sipping nectar from flowers, they have long, tubular or brush-tipped tongues and can fly forward, backward, to the left and right, hover, and propel themselves upside down. Ruby-throated hummingbirds supplement a diet of nectar with insects, spiders, and tree sap.

Hummingbirds are often found near water in deciduous woodlands. Hummingbirds can be lured to your yard with a hummingbird feeder that dispenses sugar water from red plastic "flowers." Feeders should be filled with a boiled solution of 4 parts water to 1 part white sugar. It is unnecessary to add red dye to the sugar water. Hummers can also be attracted to a garden planted with nectar producing red, orange, or pink tubular-shaped blossoms, such as cardinal flower (*Lobelia cardinalis*).

Butterflies feed on many of the same flowers as hummingbirds but find milkweed (*Asclepias* spp.) and dogbane (*Apocynum* spp.) particularly attractive. Butterflies that visit Ontario gardens include the tiger swallowtail, monarch, black swallowtail, and viceroy. An attractive moth that is active by day is also often seen. Sphinx or hummingbird moths are often mistaken for hummingbirds since they move from flower to flower searching for nectar with similar movements. Sphinx moths are the adult stages of several species of large-bodied caterpillars, some of which can cause considerable damage to home gardens e.g., Tomato Hornworm.

To landscape for hummingbirds and butterflies, plant flowers in large clumps to make conspicuous displays. Select a variety of plants so that flowering is continuous from May through September. A good garden design is one with layered vegetation; large shrubs in back with flowers in front, and a fence or arbor planted with flowering vines.

To create a landscape that will attract butterflies, it is important to consider not only the flowers that will provide nectar for the adults, but also plants that will serve as larval food sources. Flower structure is also an important consideration. Tubular flowers are preferred, as are flat topped clusters. The tubular flowers are ideally suited to the proboscis of butterflies and moths. Flowers of varying sizes should be provided to encourage a variety of butterfly species. The flat-topped flower clusters provide appropriate landing platforms for butterflies.

Water is a final consideration in a butterfly garden. Butterflies don't drink directly from open water and some species such as Tiger Swallowtails and Skippers prefer drinking from wet sand or mud puddles. A water source that can accommodate the needs of butterflies should be incorporated into the garden design. A garden pond can be constructed or modified to include a gently sloping edge of wet gravel.

Table 9-2: PLANTS FOR HUMMINGBIRDS (h), BUTTERFLIES and MOTHS (m), and BEES (b)

PLANT SPECIES	h	m	b	COMMENTS
<i>l</i> = larval food source • <i>n</i> = nectar source				
<i>Achillea</i> spp. yarrow		n		Perennial, to 1.5 m, white, yellow, pink, average to dry soil, sun.
<i>Alcea rosea</i> hollyhock	X	l	X	Perennial/biennial, to 3 m, red to white, average to dry soil, sun
<i>Allium</i> spp. ornamental onions, chives, garlic chives	X	n	X	Perennial, to 1.5 m, white to purple, average to dry soil, sun.
<i>Amelanchier</i> spp. serviceberry, shadblow			X	Shrub or tree; white, pink, average soil, sun/part shade.
<i>Anaphalis</i> spp. pearly everlasting		l		Perennial, to 1 m, white average to dry soil, sun.
<i>Antirrhinum majus</i> snapdragon	X			Annual, less than 1 m, range of colours, average soil, sun.
<i>Apocymum</i> spp. dogbane		n		Perennial, to 1 m, red to white, average to dry soil, sun.
<i>Aquilegia</i> spp. columbine	X			Perennial, to 1 m, many colours, average soil, sun/shade, especially <i>A. canadense</i> .
<i>Asclepias</i> spp. milkweed	X	l, n	X	Perennial, to 1.5m, white, pink and orange, average to wet soil, sun/part shade.
<i>Aster</i> spp. aster		l	X	Perennial, to 2 m, late white to purple flowers, moist to dry soil, sun/part shade.
<i>Baptisia australis</i> false indigo		n	X	Perennial, to 1.5 m, blue/purple, average to dry soil, sun.
<i>Borago officinalis</i> borage		l	X	Annual, to 1.5 m, blue, average to dry soil, sun.
<i>Buddleja davidii</i> butterfly bush	X	n	X	Shrub, white to purple, average soil, sun.
<i>Campanula</i> spp. bellflowers	X		X	Perennial or biennial, many sizes and forms, white, pink, purple, moist to dry soil, sun/shade.
<i>Campsis radicans</i> trumpet vine	X		X	Vine, yellow, orange or red, average soil, sun/part shade.
<i>Caryopteris x clandonensis</i> bluebeard	X	n		Shrub, to 1.5 m, blue, purple, average soil, sun/part shade.
<i>Ceanothus americanus</i> New Jersey tea		l		Shrub, to 1 m, white, average soil, sun.
<i>Centaurea</i> spp. knapweed, cornflower		l, n	X	Annual or perennial, to 1.5 m, white to purple and yellow, average to dry soil, sun.
<i>Chaenomeles</i> spp. quince	X		X	Shrub, to 3m, orange to scarlet, average soil, sun.
<i>Chelone glabra</i> turtlehead		l		Perennial, to 1.5 m, pink, moist to average soil, part shade.
<i>Cimicifuga</i> spp. snakeroot, cohosh		l		Perennial, to 2.5 m, white, fragrant, average to moist soil, sun/part shade.
<i>Cleome hassleriana</i> spider flower	X			Annual, to 2 m, white to purple, average soil, sun.
<i>Coreopsis</i> spp. tickseed		n	X	Perennial, to 1 m, yellow, average to dry soil, sun/part shade.
<i>Cornus</i> spp. dogwood		l, n	X	Shrub to tree, many sizes and forms, red to white, sun/shade.
<i>Cosmos</i> spp. cosmos		n		Annual, to 2 m, white to red, average soil, sun.

Table 9-2: PLANTS FOR HUMMINGBIRDS (h), BUTTERFLIES and MOTHS (m), and BEES (b)

PLANT SPECIES	h	m	b	COMMENTS
<i>l</i> = larval food source • <i>n</i> = nectar source				
<i>Crataegus</i> spp. hawthorns			X	Tree, white to red, average soil, sun.
<i>Crisium</i> spp. thistle	X	l, n	X	Perennial/biennial, pink, purple, average to dry soil, sun.
<i>Daucus carota</i> Queen Anne's Lace		l, n		Perennial, to 1 m, white, average to dry soil, sun. Queen Anne's Lace
<i>Delphinium</i> spp. delphinium	X	n	X	Perennial to 2.5m, white to purple, average soil, sun.
<i>Dianthus</i> spp. pinks, sweet William	X	n	X	Perennial/biennial, to 1 m, white to red, yellow, average soil.
<i>Dicentra</i> spp. bleeding heart	X			Perennial, to 1 m, deep pink to white, average soil, part/full shade.
<i>Digitalis</i> spp. foxglove		n	X	Perennial/biennial, to 2m, white, yellow, purple, average to moist soil, sun/shade.
<i>Echinacea</i> spp. purple cone flower		n	X	Perennial, to 1.5 m, white to purple, average soil, sun.
<i>Echinops</i> spp. globe thistle	X	n	X	Perennial, to 2.5 m, purple, blue, average to dry soil, sun.
<i>Echium vulgare</i> blueweed, bugloss			X	Biennial, to 1 m, blue, purple, average to dry soil, sun.
<i>Epilobium angustifolium</i> fireweed			X	Perennial, to 2 m, white to pink, moist to dry soil, sun.
<i>Erigeron</i> spp. fleabane		n		Perennial, to 1 m, white to purple, average soil, sun.
<i>Eryngium</i> spp. seaholly		n	X	Perennial, to 2 m, green, silver, purple, average to dry soil, sun.
<i>Eupatorium</i> spp. Joe-pye weed, Boneset		l, n	X	Perennial, to 3 m, late flowers white to pink and purple, moist to dry, sun.
<i>Fuchsia</i> cultivars	X		X	Annuals, usually less than 1 m, red, purple and white, average sun.
<i>Geranium</i> spp. cranesbill			X	Perennial, to 1 m, white to purple, average to dry soil, sun/shade.
<i>Heliotropium arborescens</i> heliotrope		n		Annual, less than 0.5 m, white to purple, average soil, sun.
<i>Hemerocallis</i> spp. daylily	X			Perennial, to 2 m, many varieties, average soil, sun/part shade
<i>Heuchera</i> spp. coral bells	X			Perennial, to 1 m, white to red, average soil, sun to shade.
<i>Hieracium</i> spp. hawkweed		n		Perennial, less than 0.5 m, orange or yellow, average to dry soil, sun.
<i>Humulus lupulus</i> hops		l		Perennial vine, greenish flowers, average soil, sun.
<i>Hyssopus officinalis</i> Hyssop		n	X	Perennial, to 1 m, purple, pink, white, average to dry soil, sun.
<i>Iberis sempervirens</i> candytuft		n	X	Perennial, to 0.5 m, white, average soil, sun.
<i>Impatiens</i> spp. impatiens, jewelweed	X	n		Annual, less than 1 m, white, orange, scarlet, average to moist soil, shade, especially <i>I. capensis</i> .
<i>Ipomoea tricolor</i> morning glory	X	n		Annual vine, many colours, average soil, sun/part shade.

Table 9-2: PLANTS FOR HUMMINGBIRDS (h), BUTTERFLIES and MOTHS (m), and BEES (b)

PLANT SPECIES	h	m	b	COMMENTS
<i>l</i> = larval food source • <i>n</i> = nectar source				
<i>Kolkwitzia amabilis</i> beauty bush	X			Shrub, to 3 m, pink, average soil, sun.
<i>Lavendula angustifolia</i> lavender			X	Perennial, to 1 m, white to purple, average to dry soil, sun.
<i>Leucanthemum</i> spp. shasta or ox-eye daisy		n		Perennial, to 1.5 m, white or yellow, average to dry soil, sun.
<i>Lilium</i> spp. Lily	X			Perennial, to 2 m, white to red, average soil, sun/part shade.
<i>Lindera benzoin</i> spicebush	X	l, n		Shrub, to 3 m, yellow, green, average soil, sun/part shade.
<i>Lobelia cardinalis</i> cardinal flower	X			Perennial, to 1.5 m, late red flowers, moist to average soil, sun/part shade.
<i>Lonicera</i> spp. honeysuckle	X	n		Shrub, vine, many different species and forms, pink, white, red or yellow, average soil, sun/shade.
<i>Lupinus</i> spp. lupine		l	X	Perennial, to 1.5 m, many colours, average to dry soil.
<i>Malus</i> spp. apples, crab apples		l, n	X	Tree, white to red, average soil, sun.
<i>Malva</i> spp. mallow		l	X	Annual or perennial, to 1.5 m, white, pink, purple, average soil, sun.
<i>Matthiola</i> spp. stocks		n		Annual, to 1 m, many colours, average soil, sun.
<i>Mentha</i> spp. mint		n	X	Perennial, to 1 m, white to purple, moist to dry soil, sun/part shade.
<i>Monarda</i> spp. bee balm	X	n	X	Perennial, to 2 m, pink/purple, moist to average soil, sun.
<i>Nepeta</i> spp. catmints		n	X	Perennial, to 1 m, blue and purple, average to dry soil, sun.
<i>Nicotiana</i> spp. and hybrids flowering tobacco	X	n	X	Annuals, to 2 m, white, red, lime, average to moist soil, sun/shade.
<i>Penstemon</i> spp. beard tongue	X	n	X	Perennial, to 1.5 m, white, scarlet, blue, average to dry soil, sun.
<i>Petroselinum crispum</i> parsley		l		Biennial culinary herb, to 1 m, cream to yellow, average soils, sun.
<i>Petunia x hybrida</i> petunia	X			Annual, to 0.5 m, range of colours, average soil, sun.
<i>Phaseolus coccineus</i> scarlet runner bean	X		X	Annual, vine, scarlet, average soil, sun.
<i>Phlox</i> spp. phlox	X	n		Perennial, less than 0.5 m, early white, pink or purple flowers, average soil, sun or shade depending on species.
<i>Physostegia virginiana</i> false dragonhead	X		X	Perennial, to 1.5 m, white or pink, average to dry soil, sun.
<i>Platycodon grandiflora</i> balloon flower	X		X	Perennial, to 1 m, white, pink or blue, average soil, sun.
<i>Polygonatum</i> spp. Solomons seal	X		X	Perennial, to 1 m, early white flowers, moist, shade.
<i>Prunus</i> spp. cherry		l		Shrub to large tree, many sizes and forms, white, pink, sun.
<i>Rhus</i> spp. sumac			X	Shrub to small tree, yellow to red, average to dry soil, sun.

Table 9-2: PLANTS FOR HUMMINGBIRDS (h), BUTTERFLIES and MOTHS (m), and BEES (b)

PLANT SPECIES	h	m	b	COMMENTS
<i>l</i> = larval food source • <i>n</i> = nectar source				
<i>Ribes</i> spp. current, gooseberry	X		X	Shrub, to 2 m, white to red, green to yellow, average soil, sun/part shade.
<i>Robinia pseudoacacia</i> black locust			X	Tree, white, average to dry soil, sun.
<i>Rosa</i> spp. roses			X	Shrub, to 3 m, white to pink, yellow, average soil, sun.
<i>Rubus</i> spp. brambles, raspberries			X	Shrub, to 2.5 m, white to red, average to dry soil, sun.
<i>Rudbeckia</i> spp. coneflower, black-eyed Susan		n		Perennial, to 3 m, yellow/orange, average to dry soil, sun.
<i>Salix</i> spp. willows		l	X	Shrub to large tree, yellow, green, wet to average soil, sun.
<i>Salvia</i> spp. salvia, sage	X	X	X	Annual or perennial, many species and colours from intense red to white to deep purple, average to dry soil, sun.
<i>Sedum</i> spp. sedum, stone crop		n	X	Perennial, less than 1 m, yellow, white, pink, average to dry soil, sun.
<i>Solidago</i> spp. goldenrod		n	X	Perennial, to 2 m, yellow, late blooming, average soil, sun.
<i>Symphoricarpos</i> spp. snowberry, coralberry	X		X	Shrub, to 2 m, white to pink, average soil, sun.
<i>Tagetes</i> spp. marigold		n	X	Annual, to 1 m, yellow to orange, average to dry soil, sun.
<i>Thymus</i> spp. thyme			X	Perennial, less than 0.5 m, white to purple, average to dry soil, sun.
<i>Tilia</i> spp. linden basswood, lime			X	Tree, white to pale yellow, average soil, sun.
<i>Tithonia rotundifolia</i> Mexican sunflower		n		Annual, less than 0.5 m, scarlet to orange, average to dry soil, sun.
<i>Trifolium repens</i> Dutch white clover		l, n	X	Perennial, less than 0.5 m, white, average soil, sun.
<i>Tropaeolum majus</i> nasturtium	X	l		Annual, sprawling, scarlet to yellow, average soil, sun/part shade.
<i>Valeriana officinalis</i> valerian	X	n	X	Perennial, to 1.5 m, white or pink, average soil, sun.
<i>Verbena hastata</i> verbena			X	Perennial, to 1.5 m, purple, average to moist soil, sun/part shade.
<i>Viola</i> spp. and hybrids violets, pansy		l		Annual or perennial, less than 0.5 m, many colours, moist to average soil, sun/shade.
<i>Weigela florida</i> weigela	X	n	X	Shrub, to 3 m, pink, red, average soil, sun.
<i>Zinnia elegans</i> zinnia		n		Annual, to 1 m, many colours, late flowering, average soil, sun.

WILDLIFE PROBLEMS

The damage caused by some types of wildlife can be costly and discouraging to any gardener or homeowner. Unfortunately, there is no single, quick, guaranteed solution to any serious animal pest problem.

There are basically three solutions to most animal problems:

1. The problem animal can be trapped, and either relocated or killed.
2. A barrier of some fashion can be constructed to prevent animal access.
3. Repellents can be used to discourage animal activity.

CONTROLLING ANIMAL PESTS

Effective control depends on three prime factors: timing, persistence and diversity.

Timing

Proper timing is crucial to most animal control problems. Gardeners should install barriers around gardens before an animal problem occurs. Unlike insect pest control, a gardener cannot wait to correct a problem. If left unattended, some animals will destroy a garden in a very short time. It is important to act at the very first indication of their presence.

Persistence

Many animals are intelligent and can foil your various attempts to discourage them. A single attempt at constructing a barrier or using a repellent may not work. Keep trying until you find an effective control or a combination of control strategies.

Diversity

In many cases, a single approach to control may not work, and no single control method continues in effectiveness just because it worked before. Animals differ in their habits and can use their ingenuity to get into a garden. Typically, you will need a variety of strategies and devices for animal control.

In this chapter you will find a brief biological and behavioural description of some of the most common wildlife problems and suggested control measures.

NUISANCE BIRDS: CROWS, PIGEONS, WOODPECKERS

Many homeowners enjoy the beauty and song of birds. However, some bird species can directly conflict with human activity. A few may actually create adverse health conditions because of their roosting and nesting activities.

Bird species most often considered a nuisance by homeowners are crows, pigeons, and woodpeckers. The management of these birds depends on the manipulation of the birds' habitat.

CROWS



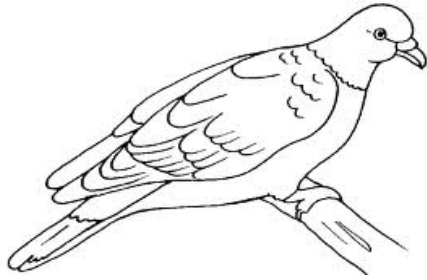
Crows can cause considerable damage to fruit and vegetable gardens by eating seeds, fruit and young transplants. They also eat the eggs and young of songbirds. They thrive in areas with large trees for nesting or roosting and that adjoin open fields where they can search for food. Since crows are omnivorous, they will eat almost anything and can readily adapt to seasonal food supplies.

Control

When crows are a problem in home gardens, nylon netting can be draped over small fruit trees and plants to protect them. Ripening ears of corn can be protected by placing a paper sack over each ear after the silk has turned brown.

Various visual or sound "frightening" techniques; such as loud noises, lights and bright sunny objects, can also be very effective. The crows, however, can become accustomed to them over time. Ultrasonic sounds are not effective because birds cannot hear them. Toxic baits, repellents and shooting are not suitable for homeowners.

PIGEONS



The common pigeon found in Ontario is a descendent from the European Rock dove, originally introduced into America as a domesticated bird. The pigeon is now probably the most important bird pest in human habitations in cities and around farms.

Pigeons feed on grain, garbage and other food associated with humans. The average life span for a typical city pigeon is only about three or four years, but in captivity they may live longer than fifteen years. They produce several broods each year and both the male and female care for the young. The female feeds the young special liquid called pigeon milk.

Pigeons are attractive birds and feeding them entertains many people. The problem arises with pigeons when they are present in large numbers and their droppings deface and damage buildings and statues. They may carry and spread several diseases to humans through their droppings. In addition, their many parasites, such as mites, ticks and lice also bite people.

Control

Since pigeons are so accustomed to living around people, "frightening tactics" often do not work well. Blocking pigeon access to roosts and nesting sites is an important part of pigeon management. Use heavy hardware cloth or porcupine wire, a special attractive product which fastens to ledges and window sills. It is made of stainless steel and is expensive, but it works very well. The sharp pointed wires inflict temporary discomfort and cause pigeons to avoid landing on these surfaces.

Toxic baits mixed with their food at the correct doses will cause distress in the bird without killing it. The ailing bird sends out distress calls that frighten other members of the flock away. These products, however, can only be bought and applied by licensed, certified pest control operators. Naphthalene moth flakes are registered as a pigeon repellent and work well when spread on an attic or shed floor. However, this product is poisonous and should be used with caution around young children and animals.

WOODPECKERS



Woodpeckers belong to a group of birds that also includes flickers and sapsuckers. There are nine species of woodpeckers in Ontario. Among the species in Ontario are the downy woodpecker, red-headed woodpecker, and yellow-bellied sap sucker. All have short legs with two sharp clawed backward-pointed toes and stiff tail feathers that serve as a supportive prop. These traits enable them to cling easily to the trunks of trees. They have stout, sharply pointed beaks for pecking into wood and a specially developed long tongue which can be extended a considerable distance, effectively dislodging insect larvae or ants from their burrows in wood or bark.

Since woodpeckers are dependent on trees for shelter and food, they are found on the edge of wooded areas. Many woodpeckers utilize manmade structures for nesting, and have thus extended their habitat to include wooden fence posts, utility poles, and buildings.

One commonly held misconception is that they only peck holes in search of insects. Many species will drill holes in sound wood where no insects exist. Sapsuckers drill numerous 0.5 cm holes in healthy trees to feed on sap.

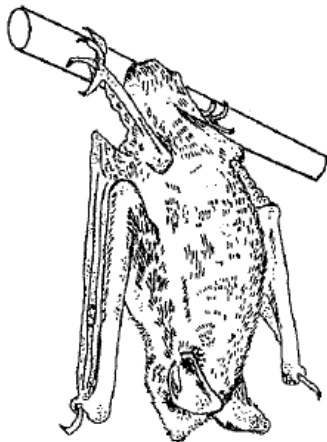
Occasionally, woodpeckers will try to nest in a person's home. Wooden buildings in the suburbs or rural wooded settings are most apt to suffer pecking and hole damage, since woodpeckers favor this habitat. Generally, damage to a house is caused by one or two birds. Houses with expensive cedar and redwood siding are singled out for woodpecker damage. Some birds have been known to peck on aluminum siding. This is known as drumming, predominately a springtime activity. This sound is made by woodpeckers pecking in rapid rhythmic succession on metal or wood.

Control

Combine both protecting and frightening tactics when solving a woodpecker problem on houses and trees. The northern flicker and red-headed woodpecker are migratory, while many other species live year round in the same area. They are persistent and not easily driven from their territories. For this reason, visual or sound types of repellents for protecting buildings should be employed as soon as the problem is identified and before territories are well established.

One of the most effective methods to prevent woodpecker damage to siding beneath the eaves is to cover the area with lightweight netting. Apply metal barriers over the pecked areas on building sidings to offer protection from continued damage as soon as it begins. While visual repellents such as model owls and snakes are ineffective, toy twirlers and plastic reflective strips have been successful. Loud noises such as hand clapping or banging on metal trash can lids have also been useful. Many bird watchers place beef suet near buildings and trees that are attacked by woodpeckers, providing an attractive alternative to pecking. Don't offer suet in warmer seasons because it may become rancid and harm woodpeckers.

BATS



Bats are the only mammals that can truly fly. Contrary to folklore, they are not related to mice, but are in a separate group of animals. Much mystery and folklore surrounds the bat because of its nocturnal habits. Although 900 species live worldwide, most are located in the tropics. Several species of bats live in Ontario, the most common of which is the little brown bat.

The natural habitats of most bats are caves and hollow trees. Day roosts are dark and secluded. Bats in our area are insect feeders that forage around water, forests, fields, ravines and buildings. They consume up to half their weight in insects each night.

In cold weather, bats migrate or hibernate in caves, mines, and sometimes in houses. Many gardeners have built roosting boxes to help encourage their presence in the garden.

Bats, however, may become a nuisance to people when they roost in houses, revealing their presence with fecal droppings and stains near eaves, beneath entrance holes, and below roosts. In old, loosely constructed buildings with an attic roost or a space between a wall and a chimney, bat guano may seep through cracks and stain ceilings and walls of homes. Bat guano, if present in large quantities, can present a health concern for humans.

Bats commonly enter houses under the overhang of the roof or eaves. They are often found in attics, in ceiling or roof spaces, in cornices, behind shutters, fascias or other crevices around the roof. Bats can also get into walls, chimneys, drainpipes, and inside other small openings.

Rabies is the most important public health hazard associated with bats, but its impact has been greatly exaggerated. Rabies in bats is quite similar to rabies in other carnivores, but is less dangerous since bats fly and are rarely aggressive. Misleading information often brings on intense public reactions and demands for complete bat destruction.

Control

The best control for bats that have entered attics or wall voids is exclusion. However, bats have to be evicted from the building before bat proofing so they won't be sealed inside. The best time to start is in the fall after young bats have learned to fly and before the onset of cold weather. Block holes after dark, or in the early evening, after the bats have gone to feed. The following evening, remove plugs to allow any remaining bats to leave before the last exit is sealed. This routine must be repeated if any bats are left inside.

Exclusion also entails caulking, the application of weather stripping and flashing or screening of any openings. Bats can squeeze through openings with diameters as small as 1 cm.

Sometimes moth crystals are used as repellents for bats, but their vapors are lethal to bats. We do not endorse the killing of bats but only the discouragement of unwanted bats from an attic. Bright lights in the attic may be helpful to chase them out. Drafts from a fan will also chase bats from their roost. In severe infestations contact an exterminator or a member of a bat conservancy group in your area.

CATS AND DOGS



Although most cats and dogs bring joy to their owners, these same animals can cause strife for neighbours. Both can quickly become a nuisance when tearing open trash bags set out for pickup, digging holes in gardens, destroying plants, killing native wildlife and defecating on other people's property. Dogs can sometimes become a safety concern for both adults and small children when they roam in packs. Rural areas frequently see these packs of dogs kill small livestock such as sheep.

Local regulation of these pets allows for protection of people and property. Municipal by-laws can vary from area to area so it is always best to consult with local authorities to help solve a recurring problem.

Local by-laws usually require the leashing of dogs and cats at all times. However, unless enforced by pet owners, these pets can be a prevailing problem.

Cats and dogs may be a problem to home gardeners when they damage ornamental plants as well as vegetables by digging, defecating or urinating. Large dogs are particularly destructive if they "mark" their territory on shrubs. Cats will also prey on a wide variety of small wildlife.

Control

The control of nuisance cats and dogs can be a very uncomfortable problem since the gardener has to connect an owner with the pet. If there is a recurring problem, approaching the pet's owner with tact is the best solution. The owner may not even be aware that the pet is causing a problem. Responsible pet ownership is the only long term solution.

When necessary, various types of commercially prepared cat and dog repellents can be bought at pet shops and garden centers. Repellents are not always reliable and are most effective in very localized or confined areas. Large scale use is expensive and not very helpful. Most commercial repellents cannot be used in vegetable gardens.

DEER



Deer are the most widely distributed and best-recognized large mammals in North America. The deer found in our area are the white-tailed deer. They are creatures of the forest edge rather than the dense, old growth forest. They thrive in agricultural areas interspersed with woodlots. Deer browse on leaves, stems and buds of woody plants and fruits and nuts in season, and are most active in the early morning and evening.

Deer can have a home range of many hectares, but this varies with the season, sex, and habitat quality. They may move long distances from their summer range to a winter- gathering area. The average life span of the white-tailed deer is about 20 years.

Deer are at an all-time population high throughout many areas of Ontario, causing them to frequent urban and suburban areas more than ever before.

Damage

Deer will damage a wide variety of crops, fruit trees, nursery stock and ornamentals in home gardens. Deer can severely damage trees and shrubs in both nurseries and home landscapes by feeding or by rubbing their antlers to remove the velvet. One or two deer can destroy a garden in one feeding visit.

Control

The only sure way to eliminate deer damage in rural areas is to fence out the deer. However, the cost of constructing special deer fences limits it to areas of intensive agriculture such as orchards and private gardens. A wire mesh fence is effective if it is solidly constructed and at least 2.5 m high. Slant the fence away from the crop to be protected.

Attach the angled posts at a 45 degree angle so that the high ends are at least 2.5 m from the ground. Deer can walk under the overhang but will be unable to jump over the wire strands. In suburban areas use a solid 2.5 m privacy fence or wall. Although deer can jump over it, they seldom go into an area they can't see into first.

Another idea used with some success is to build two 1 m tall fences made of three strings. The fences should be 1 m apart. This double fence confuses deer and they generally won't jump over it. Tie bright tape on the strings to make them more visible to the deer. In areas with significant snowfall, the heights of effective fencing will need to be increased.

"Frightening techniques" and repellents are effective if they are used at the first sign of a problem. It is difficult to break deer behavior patterns or movements once they are established. On farms, gas exploders set to detonate at regular intervals are the most common scare devices. A dog on a long run can keep deer out of a limited area.

In the home landscape, repellents are best suited for use in orchards, gardens, or on ornamental plants. Repellents need to be kept fresh for maximum effectiveness. The two kinds of repellents are contact and area. Contact repellents are applied directly to the plants and repel by taste. Area repellents are applied near the plants and repel deer by smell alone. There are several brands of animal repellents to choose from that are helpful in deterring deer. Not all can be used around vegetable gardens.

Some of the commercially available repellents are:

Deer Away - A highly effective product made from eggs. Reapply after heavy rains.

Bonide Rabbit-Deer Repellent - It produces a very bad taste. Can be sprayed or brushed onto plants.

Chew-Not - Also repels by taste. Primarily used on fruit trees and some varieties of evergreen. Its disadvantage is that it leaves an unsightly residue.

Hinder - A soap-based product that repels by odour. It needs to be reapplied after heavy rain.

Ro-Pel - This has both odour and taste repellent properties. Spray it on both sides of the leaves of landscape plants.

These products are usually available in farm supply stores and some garden centers. A repellent technique very suitable for home gardeners is to hang small nylon bags of human hair or deodorant soap on fences or branches.

Hang them 1 m from the ground and no more than 1 m apart.

A formulation of 15 to 30 ml of Tabasco sauce in 4 litres of water with an additive to promote retention like Wilt pruf or Vapour guard has also been successful when applied to plants.

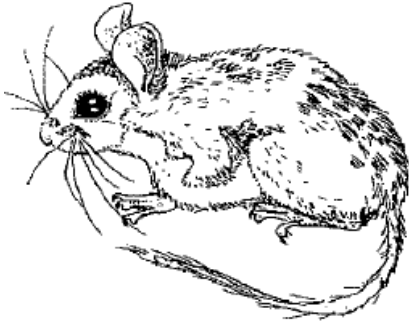
Raw eggs mixed with water and sprayed on plants have also been found to be effective in repelling deer. Researchers in Louisiana found that 18 eggs mixed in 18 litres of water kept deer out of their soybean fields. At this dilution, the deer were repelled, but the dilution was too faint for humans to detect.

Resistance of Woody Ornamental Plants to Deer Damage

1. *Deer are selective feeders. They forage on plants or plant parts with considerable discrimination.*
2. *Landscaping based on the knowledge of deer feeding preferences can provide an alternative to the use of expensive chemical repellents and unsightly physical barriers.*
3. *Whether or not a particular plant species or variety will be eaten depends on the deer's previous experience, nutritional needs, plant palatability, seasonal factors, weather conditions, and the availability of alternative foods. Deer are creatures of habit, and prior movement patterns or foraging experience can foretell where damage will occur. Deer are known to feed selectively on fertilized plantings and managed croplands. New plantings added to an existing landscape already severely damaged by deer will likely suffer from browsing.*
4. *In general, the most damage takes place when winter snow cover or extreme cold has reduced food availability. Rather than face starvation, deer will browse even the most resistant plants during the periods of food shortage. **No plant species will be avoided by deer under all conditions.***

See Chapter 12, pages 23-24 for a list of plants not usually damaged by deer.

THE HOUSE MOUSE



Various species of mice live in our area and some can cause considerable damage outdoors to bulbs and young tree bark during winter. During fall, many mice move into homes in search of warmth and food. The most common indoor mouse is the common house mouse. It is a small, slender rodent that is generally grayish-brown with a gray belly. Similar mice include the white-footed mice and harvest mice.

House mice are found around homes, farms, and commercial buildings, as well as in open fields. House mice will eat any kind of food but prefer seeds and grain. They may nibble on other foods high in fat, protein, or sugar even when grain and seed are available. Unlike the Norway rat, they can get by with little or no free water. Mice can obtain all of their water needs from the food they eat. A single mouse eats only about 3 grams of food per day. Because they nibble on many foods and discard partially eaten items, mice ruin considerably more food than they actually eat. Mice are also known to damage insulation in a house and may gnaw on electrical wiring.

Control

Mouse control involves a multi-faceted approach that includes sanitation, habitat modification, traps and selective bait placement.

- Remove all sources of food, including food crumbs behind and underneath kitchen appliances.
- Seal all openings around the house such as spaces near vents, basement doors and under the bottom edge of siding.
- Don't leave cat or dog food out at night.

Traps

Ordinary snap mouse traps are economical and work quite well if placed in the right spot. Set snap traps along walls, cabinets and in suspended ceilings, perpendicular to the wall with the trigger next to the wall. There usually are several mice in one house so place several traps out in one evening.

Trying to catch mice with just one or two traps takes a long time. Good baits include peanut butter, cheese or bacon. It is a good practice to get mice used to feeding from the traps by baiting the traps for two or three nights without setting them.

Baits

Severe infestations of mice may require baits containing anticoagulants. If taken in a high enough dose, they can work after one feeding. The anticoagulant, warfarin, is very effective against both rats and mice. To prevent non-target animals from getting into the bait, place the bait in a bait station along a wall.

A newer type of mouse bait that gives effective results is bait with a lethal dose of vitamin D. The high dose of this vitamin causes a calcium imbalance in the blood and mice stop feeding and die in a few days. This bait is only toxic to rodents.

If an infestation is so severe that your efforts do not seem to work, you should consult with a professional exterminator.

RATS



The rat species commonly found in both the city and country is the Norway rat. It is sometimes called the wharf rat, sewer rat or brown rat. Like the house mouse, it was accidentally introduced into North America around 1775. Rats are much larger than mice. They require more drinking water and they nest under the ground. Rats are usually associated with unhealthy conditions and poor sanitation.

- They like living near people although they are quite shy and usually are only active during the night.
- Rats burrow under buildings and sidewalks and other suitable structures, where they rear their young.
- Four to six litters are born each year with 6-12 young apiece. Young rats are independent at about 3-4 weeks and sexually mature at 3 months.
- Rats stay within a 45 m diameter area of their nest. In that space they memorize every object, passage and location of food and water.

- They avoid new objects placed in their domain until they become familiar with them.
- Rats will eat nearly any type of food but prefer cereal grain, meat, fish, nuts and some fruit.
- Rats need to drink water if they are feeding on dry materials. Food items found in household garbage will offer a fairly balanced diet that can also satisfy their moisture needs.

Because rats are familiar with their environments, they quickly notice and shy away from baits that contain toxins. If a rat eats a sub-lethal dose of toxic bait and becomes ill, it will stay away from that bait for weeks or months. Pre-baiting an area with non-toxic bait can fool the rats into eating the bait, prior to application of toxic bait.

Control

- Physical barriers that are "gnaw-proof" can prevent rats as well as mice from entering a building. Holes 1 cm or larger in diameter are large enough for young rats to squeeze through.
- Habitat modification that will eliminate poor sanitation and hiding places in urban areas is important. Sanitation will not always eliminate rat populations in rural areas, but it will prevent them from flourishing in large numbers.
- Unusually loud and novel sounds, including ultrasonic sounds, will frighten them and disrupt their behavior. This approach seems to be temporary and lasts only a few weeks or months.
- Baiting, in conjunction with sanitation and habitat modification, is the recommended control technique. Various brands of anti-coagulant baits are available to homeowners. When used according to directions they are an effective part of a rodent control program. The anticoagulant baits are also relatively safe to use around livestock, pets and humans.

MOLES AND VOLES

Moles and voles can be quite troublesome to homeowners throughout the year. Their peak activity is June and again in the fall. Voles often cause significant damage to trees and shrubs over winter. These animals look somewhat similar but they pose two different problems in the lawn and garden.

THE MOLE



The mole lives under ground and feeds on earthworms, beetles and grubs, which are their favorite food. Moles eat 70 to 100 percent of their body weight each day. Moles do not eat bulbs, plants or roots but do damage lawns and gardens as they tunnel through plant roots in search of food.

Moles differ in appearance from voles:

- They have naked pointed snouts, small, almost hidden eyes and lack external ears.
- Their powerful forefeet are very large and broad, well designed for digging through the soil.
- Their feet, noses and tails are light pink and their fur is velvety.

Seldom seen above the ground, moles prefer to live in the seclusion of underground burrows. Moles must cover a wider area than most underground-dwelling animals to satisfy their food requirements. Most of a mole's runway system is a network of shallow burrows dug just beneath the surface of the ground. Some slightly deeper burrows are highways leading from the mole's home to its hunting grounds. The shallow burrows may or may not be used again. Old tunnels are eventually abandoned when they become blocked up with soil, especially after heavy rains. In wet weather, mole burrows are shallower than during dry periods since they frequently follow the course of earthworms.

Moles have just one litter of four young a year in burrows which are located in high, dry spots, often under sidewalks or buildings.

The mole often acts as host to a large number of guests. The maze of passages that threads through the soil provides protection, cover and lines of traffic for several species of small mammals, mainly voles, which feed on the seeds, roots, and tubers uncovered by the mole.

Control

Mole control can be accomplished with several strategies. Since grubs are their preferred food, reduction of the grub population usually controls moles. Without a ready food supply, they will go elsewhere.

Mole traps can also be used for more control but require a lot of attention and are very hit or miss. The way to set a mole trap is to first tamp down all the tunnels, then place the traps in the new tunnels that reappear since these are the most active tunnels. Traps take precise placement, daily attention, and aren't to everyone's liking. Moles very rarely eat seeds, so they ignore poisoned grain. Products containing castor oil or other repellents may prove effective in some instances. Always follow label directions.

THE VOLE



Voles, also called meadow or field mice, are members of the rodent family. They are compact animals with stocky bodies, short legs and a short tail. Their eyes are small and their ears are partially hidden. They usually are brown or gray, though many colour variations exist. Voles have always been a serious pest problem in commercial orchards and nurseries, where they feed on the lower bark of trees and shrubs.

Voles are becoming increasingly common in the home landscape. The meadow vole lives primarily above ground, in runways at the surface, or in mole tunnels.

Voles eat a wide variety of plants, and, in the late summer and fall, they store seeds, tubers, bulbs and rhizomes. They eat bark during the fall and winter, and can girdle ornamental plants and young trees. Homeowners also notice vole feeding damage in the spring, when bulbs fail to sprout.

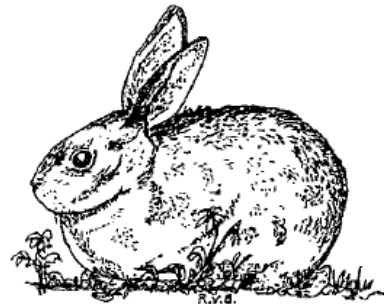
Voles are active both day and night and throughout the year, since they do not hibernate. They construct many tunnels and surface runways with numerous burrow entrances. A single burrow system may contain several adults and young. Voles have 1 to 5 litters per year with an average litter of 3 to 6.

Control

Control voles by cultural methods, habitat modification and by trapping.

- Mow lawn and turf areas regularly, and pull mulch away from the trunks of trees and ornamentals to prevent voles from hiding in the mulch and chewing bark.
- Voles will avoid digging in pea gravel. Lay it at the base of fruit trees before winter.
- Till garden soil prior to winter to reduce vole damage. It removes cover, destroys existing runway-burrow systems and kills a percentage of the existing vole population.
- Use mouse snap traps. Place the trap perpendicular to the surface runways with the trigger end in the runway. A peanut butter-oatmeal mixture or apple slices make good baits.

RABBITS



Rabbits can be very abundant locally and are quite adaptable, making them equally at home in rural areas, suburbs or cities. Rabbits damage flowers, vegetables, trees and shrubs with their constant gnawing. Rabbits do not distribute themselves across the landscape but prefer to live in bushy fence rows or at the edge of fields. They rarely live in dense forests or open grassland. Rabbits generally spend their entire lives in an area of 5 ha or less and only relocate when food is scarce.

In the garden, rabbits love to eat rows of peas, beans or beets. They don't generally bother corn, squash, cucumbers, tomatoes, peppers or potatoes. Equally annoying, and much more serious, is the damage that rabbits do to trees and shrubs when they gnaw bark during the winter.

In the wild, rabbits only live about 15 months, but during their life they may raise as many as 3 litters in a year or a total of 18 young in a breeding season. However, their breeding potential usually is not met because of weather, disease, predators and encounters with cars.

Control

One of the best ways to protect a backyard garden is to construct a 0.7 m high fence of chicken wire with the bottom tight to the ground or buried several centimetres. Cylinders of heavy wire hardware cloth will protect valuable young trees. The cylinders should be higher than a rabbit's reach standing on the expected snow depth. Commercial tree wrap is another alternative in preventing rabbit damage to tree trunks.

Effective repellents for rabbits act upon their senses of taste and smell. Dried blood can be used as a scent repellent. Repellents are available in hardware stores as formulated products. Sprinkling these mixtures around plants helps keep rabbits away until rain dilutes their effect.

Some gardeners have reported effective results with sprinkling vinegar, hot pepper flakes and liquid chili pepper sprays on and around plants. One method of application is to soak corn cobs in vinegar for five minutes and then scatter them throughout the gardens. After two weeks, you can re-soak the cobs with the vinegar.

Another repellent technique is to sprinkle soiled cat litter around the edge of the flower garden, shrub beds or trees. The smell of a natural predator is quite effective. Do not apply cat litter to vegetable gardens because of the potential for disease transmission to people. Such a technique may, however, encourage local cats to frequent your garden.

RACCOONS



Raccoons are attractive, stocky animals familiar to homeowners throughout rural, suburban and urban areas. These very adaptable animals inhabit most of North and Central America. Raccoons can grow up to 1 m long and weigh between 4 to 14 kg. Occasionally, very old, well fed animals may weigh as much as 23 kg.

- The average life span for a raccoon is about 12 years.
- Raccoons normally breed in February or March. However, breeding may begin as early as December and last through June.
- The gestation period is approximately 63 days with most litters born in April or May. Late-breeding females will produce young in June or July.
- Only one litter of 3 to 5 young is produced annually. Family groups stay together for the first year and then the offspring venture out on their own.
- They usually spend their entire life within a limited territory. Males have a range up to 50 square kilometres while the females will range up to 15 square kilometres.
- In nature, raccoons live in hollow trees, under large logs and in underground burrows.
- In urban neighborhoods they readily make their homes in storm drains, under porches and sheds, and even in chimneys.

Raccoons adapt well to living in close proximity with humans, but their adaptability and their curiosity sometimes causes them to be a problem. Although raccoons look friendly, wild raccoons should always be treated with caution. They will fight fiercely when cornered or trapped. Raccoons are nocturnal, and if a raccoon is observed wandering during daylight hours it may have been flushed from its den, is injured or possibly sick with rabies.

Their typical diet includes fruit, vegetables, carrion, dog and cat food and small animals, including crayfish, snails, insects, turtles, snakes, mice and rabbits. Their favorite foods include fish, poultry and eggs. Sweet corn grown in home vegetable gardens is frequently damaged by raccoons. Raccoon damage on sweet corn is characterized by torn-open ears revealing partially eaten corn. The stalks may also be broken from the weight of the animal climbing on them.

Control

Repellents and frightening devices do not prove very effective once raccoons become accustomed to them. The best way to keep a pest raccoon out of a garden, attic, shed or garbage cans is exclusion through proper screening or fencing. A two-strand electric fence, positioned 15 cm above the ground, is useful in keeping them out of vegetable gardens and away from goldfish ponds. Electric fence wire, posts, insulators and transformers are available from farm supply stores.

Stop garbage can raiding by using metal cans or tough plastic containers with tight fitting lids. To keep raccoons out of a chimney, install a tight fitting screen cap.

A cap will also keep rain and birds from going down the chimney. If you remove a raccoon from an attic or chimney in the spring or summer, be sure there are no babies left trapped inside. Do not attempt exclusion practices until you know that all the raccoons are out of the structure.

When all deterrents fail, the only solution is to trap and remove the troublesome animal from the property. Raccoons are usually easy to trap with a large cage trap. It must be large enough to comfortably hold the raccoon, about 25 x 30 x 80 cm. Use raw fish, chicken, sardines, or canned cat food as bait. Trapped raccoons should not be released, but turned over to local animal control authorities.

SKUNKS



Skunks, large members of the weasel family, can grow to be about 75 cm long (tail included), and weigh about 3.5 kg. Their natural habitat is around clearings, pastures and along the edges of forests where their homes usually are under a hollow stump or log. In suburban areas they live under low porches and decks or behind stone retaining walls.

Skunks are primarily carnivorous and will eat plant or animal matter and pet foods, but their favorite foods are insects and their larvae. To find insects, skunks dig small cone-shaped holes in lawns and gardens, usually smaller than 8 cm across and as deep. A skunk lives in an area ranging from 0.8 to 2.5 km in diameter. During the breeding season males may travel up to 8 km per night in search of a mate.

Skunks become a concern to homeowners when they damage lawns in search of grubs or when they release their scent near the house. Rabies is a concern where skunk populations are high because it is occasionally carried by skunks. Abnormal behavior towards people or activity during the day should be viewed cautiously because these activities are typical of a rabid skunk.

Control

Skunks can usually be controlled without harming them. Take preventative measures to keep skunks from making a den under structures by sealing off all foundation openings with heavy hardware cloth. Since skunks are poor climbers, fencing will also serve to prevent skunks from going into certain areas. Prevent skunks from invading garbage cans by putting garbage bags into containers with tight fitting lids. Repellents are helpful as a temporary deterrent.

Skunks may also be successfully caught in live traps that are set close to their den. Use fish-flavored cat food or bread with peanut butter as bait. Cover the trap with a heavy cloth to make the trap more secure to the skunk and to reduce the chances of it discharging its scent. Turn the caged skunk over to local animal control authorities.

SQUIRRELS



There are two species of squirrels in Ontario - the larger eastern gray squirrel and the smaller red squirrel. Squirrels eat a variety of foods ranging from tree fruits, seeds, nuts, buds, shoots, insects and fungi. Often, in their search for food, they destroy the growing tips of young trees and shrubs, strip bark from trees and dig up flowers and bulbs. Squirrels are most active in the early morning and late afternoon. Gray squirrels can be gray, brown or black in colour and can grow quite large. Gray squirrels are common in southern parts of Ontario. The red squirrel is a much smaller animal and generally a rusty red colour. The red squirrel is more common in northern Ontario.

Squirrel populations periodically rise and fall. A squirrel's habitat can range from 1 to 40 ha. During periods of high populations gray squirrels often go on mass migrations in the fall, traveling up to 80 km in search of better habitat. During these mass migrations many animals die crossing roads.

Although captive squirrels can live ten years or more they usually have a life span in nature of only about four years. They breed when one year old in mid-December or early January and again in June. There may be three to five young in a litter with a gestation period of 45 days. Therefore, when food is plentiful, gray squirrels have a great potential for rapid population growth.

Damage

Homeowners have problems with squirrels chewing through siding and tearing open attic vents to gain access into the house. Once inside the attic they can ruin insulation by digging through it. Squirrels also chew on wiring and damage stored items. Garden related problems include damage to bulbs, fruits, tomatoes, and flower buds of rhododendrons.

Control

Securely cover attic vents with hardware cloth to prevent squirrels' entry. Leave the lights on in the attic or in other hiding places to chase out squirrels.

A live box or cage trap is useful for catching a nuisance squirrel. Bait the trap with apples, seeds or peanut butter. Put the baited trap out but do not set it for a few days so that the squirrels will become accustomed to feeding from it. After a few days, set the baited trap for capture. Captured squirrels should be turned over to animal control or released at least 8 km from your home, or else they will come back. Wear gloves and do not handle the squirrel.

In the garden, control is more difficult. Squirrels will find newly planted bulbs, so soak them in a repellent such as Ro-Pel before planting. It smells and tastes very bad to them. When planting new bulbs, they can be enclosed in a loose cage of heavy but open-mesh hardware cloth or chicken wire. Construct metal barriers or apply Tangle Foot on trunks to prevent them from climbing the trees. Of course, this only works if they can't jump from tree to tree. Special types of "squirrel proof" bird feeders are available to foil their attempts at robbing bird feeders.

CHIPMUNKS



Chipmunks are small ground-dwelling rodents with distinctive stripes on their rusty-red to chestnut-brown fur. Five dark-brown stripes line the back one down the backbone from neck to rump and two on each side from shoulder to rump. A creamy-buff stripe separates the dark side stripes. Mature chipmunks are 20 to 25 cm in length and weigh about 85 grams. The flattened tail is roughly one-third the animal's total length.

Chipmunks have forefeet adapted for holding and eating food while they sit upright. Their heads are blunt and squirrel-like, with unique furred cheek pouches in which they carry food and other material. The front teeth are chisel-shaped. Chipmunks may range over half a hectare, but their individual territories often are much smaller.

Chipmunks are omnivorous, eating both plants and animals. Plant material such as acorns, hickory nuts, beechnuts, cherry seeds, Juneberries, raspberries, dogwood seeds, corn, and plant bulbs are favorites. The main animal foods are birds' eggs, insects, snails, and occasionally mice and young birds.

Chipmunks gather and store food in the fall. Hard foods are stuffed into their cheek pouches and stored in food caches. They climb shrubs and trees to look for food and to escape enemies.

When chipmunks move into an urban setting, they may conflict with humans. In their normal activities, they may dig seeds from the garden, feed on flower bulbs, and burrow into lawns, especially near dry rock walls. In lawns, the 5 to 8 cm diameter burrows descend almost vertically. Burrow openings cut neatly through the turf and lack excavated soil at the entrance. If a higher value is placed on the garden, lawn, or flowers than on seeing chipmunks, control measures will offset the conflict.

Control

Homes with wooded lots, thickets of ornamental shrubbery, and dry rock walls are very attractive to chipmunks. Make this habitat less attractive to the animals by altering the pattern of natural and ornamental plantings. However, most people value their trees and shrubs too highly for drastic modification of the landscape, and may opt to tolerate the chipmunks as a part of the natural community.

They may be trapped at any season. Live trapping with small commercial or homemade box traps can remove a particularly troublesome chipmunk. Once trapped, they should be released at least two kilometres from the capture area. Rat-sized snap traps are effective but they kill the animals. Baits attractive to chipmunks include peanut butter, nut meats, sunflower seeds, and rolled oats. Place either type of trap in areas where chipmunks travel or feed. Pesticides are not suggested for use with chipmunks. Chipmunk numbers can be reduced locally, but new animals may move into vacated habitats. Thus, chipmunks can seldom be eliminated from an area unless their living conditions are radically changed.

Chipmunks occasionally enter homes, where they are generally more bothersome than destructive. Their entry can be prevented by closing holes in foundation walls, and by screening windows, vents, and other ground-level openings.

WOODCHUCKS (GROUNDHOGS)



Woodchucks are common in rural areas but are also making themselves at home in suburban areas near open land. Woodchucks or groundhogs are very large members of the squirrel family, growing to a length of almost 60 cm and weighing 2 to 5 kg. Their colour is brown and their short tail is covered with fur. The front feet have powerful claws well adapted for digging deep burrows.

Groundhog burrows can be as deep as 1.5 m with more than one entrance hole. Entrance holes, about 30 cm wide with a mound of soil around them, are usually well hidden and difficult to see. The network of tunnels can cover an area underground as large as five square kilometres.

In these underground homes woodchucks hibernate, raise their young and hide from danger. A burrow system is maintained, kept clean of debris and used for several years. Woodchucks usually travel between 15-30 m from their den in search of food. They breed in March and produce a single litter of two to six young.

Woodchucks may become a problem to farmers and gardeners when they feed on trees, shrubs, flowers and vegetables. The mounds of soil and large holes also present a hazard to farm equipment, cattle and horses.

Control

In rural areas homeowners shoot woodchucks when they become numerous and destructive. However, this is not a safe or legal method of control for suburban homeowners. A strong, 1-1.5 m high wire fence buried 25-30 cm in the ground will help to keep them out of a vegetable garden. Woodchucks are rather good climbers. An electric hot-shot wire placed 10 to 12 cm off the ground and the same distance outside the fence will prevent their climbing and burrowing. These wires and transformers are available at farm supply stores. You can live-trap woodchucks with apples or vegetables such as carrots and lettuce. Locate the trap at the main entrance. Contact your local animal control facility for proper removal of a captured woodchuck.

Often woodchucks will burrow under garden sheds or other outdoor structures. In these situations they can sometimes be discouraged from living under a building by using strong repellents. Fencing or electric fence wire around the base of the shed is also useful.

SNAKES



Close relatives of the lizards, snakes are considered the most highly-evolved reptiles. They are cold-blooded, or "ecto-thermic," meaning that they depend on their surroundings to maintain body temperature. Snakes hibernate in the winter and often aestivate, or go through a resting period during the heat of summer, when one meal can last them for several weeks.

They once had small legs and through evolution lost them. They do remarkably well without legs, and can climb, swim, catch and consume their prey.

They move by contracting the rib muscles attached to belly scutes, large plate scales which grip the surface much like the treads on a caterpillar tractor. This slow, relaxed movement is called the "caterpillar crawl." When a snake is frightened or pursuing prey it will pick up its pace by moving its entire body in an "S" shape, pushing itself against the ground and moving more rapidly.

Mating season is April through June. The females give birth to live young or lay their eggs in a protected warm place and then leave them to hatch. The young are self-sufficient at birth.

All snakes are predators and can swallow food larger than their heads. This is because the two halves of the lower jaw are not joined as in other animals, but are in two halves attached by elastic ligaments. The lower jaw can temporarily dislocate itself to accommodate large prey.

The larger species of snakes in Ontario include the milk snakes, fox snakes, northern water snakes, and eastern hognose snake. These species eat rodents and amphibians. There are many smaller species of snakes in Ontario including various garter snakes, green snakes and northern ring-necked snakes. These feed on a variety of small amphibians and insects. There is only a single species of dangerous snake in Ontario - the Massasauga Rattlesnake.

Snakes like to stay in secluded places where they can find food. Areas that are attractive to snakes are stacked firewood, old lumber piles, heavily-mulched planting beds, and un-mowed lawns where there is a rodent population. Snakes are beneficial in the garden and help to control the population of rodents.

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CHAPTER 10: TURFGRASS MANAGEMENT

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TURFGRASS SPECIES USED IN ONTARIO

Only a few grass species produce acceptable turf in Ontario. Generally grasses can be divided into two groups, the cool-season and the warm-season grasses.

Cool-season turfgrasses:

- Include species that are adapted to the cooler climatic regions.
- Make maximum growth during cool spring and fall weather.
- May become semi-dormant during hot and/or dry periods of summer.
- Include Kentucky bluegrass, the fine fescues, and tall fescue.

Warm-season turfgrasses:

- Make maximum growth during hot weather and are dormant during late fall, winter, and early spring.
- Zoysiagrass and Bermudagrass are hardy only in southwestern Ontario and are not considered acceptable species for lawns because they produce a low quality turf that is brown and dormant in both spring and fall seasons.

Turfgrass species vary in their adaptation to soil moisture, temperature extremes, soil fertility and pH levels, disease and insect resistance, and tolerance to shade, wear and mowing. They also vary in characteristics such as leaf texture, colour, growth habit, density, growth rate, and uniformity. Considerable variation in these attributes can also occur within an individual species.

KENTUCKY BLUEGRASS

(*Poa pratensis*)

Kentucky bluegrass is the most widely grown turfgrass in Canada. It has a medium to fine leaf texture and a medium to dark-green colour when properly fertilized. It produces extensive underground stems, called rhizomes, which provide good sod-forming characteristics and have superior recuperative potential when compared to most other cool-season turfgrasses. Kentucky bluegrass is cold tolerant, wear tolerant, and moderately heat and drought tolerant.

The species performs best when grown in well-drained soils with a near neutral pH and in open, sunny areas. This grass does not tolerate poorly drained soils or heavily shaded areas.

In soils with high fertility levels and poor drainage, thatch build up can be significant.

Kentucky bluegrass generally requires a higher amount of nitrogen (N) fertilizer than other cool-season turfgrasses. The germination and establishment period for Kentucky bluegrass is slower than for most other turfgrasses, (requiring up to three weeks for emergence). Kentucky bluegrass is generally seeded at a rate of 1-2 kg/100 m².

There are many named varieties of Kentucky bluegrass registered in Canada. These varieties or cultivars are selected because of outstanding characteristics such as hardiness, drought tolerance, improved colour, or disease resistance.

THE FINE FESCUES

(*Festuca* spp.)

The fine fescues are composed of narrow-leaved species in the genus *Festuca*. The most common turf-type fine fescues include creeping red fescue (*Festuca rubra*), and chewings fescue (*Festuca rubra* var. *commutata*). Other fescues such as sheep fescue (*Festuca ovina*) are more appropriate for low maintenance areas such as slopes, right-of-ways or vacation home properties.

During cool weather (and when properly maintained), the fine fescues produce an attractive, uniform stand of a medium to dark green colour. They are extremely fine textured and are compatible in mixtures with most cool-season turfgrasses. As a group, the fine fescues tolerate soils of low fertility and low pH, droughty soils, and shaded conditions. They are not well adapted to high heat and humidity, poorly drained soils, high-traffic areas such as athletic fields or playgrounds, and do not tolerate high rates of nitrogen fertilizer. Like Kentucky bluegrass, the fine fescues become semi-dormant under prolonged periods of high temperatures and drought but recover quickly with a return to cooler temperatures and adequate soil moisture. Fine fescues can produce a significant amount of thatch and may require periodic dethatching.

Fine Fescue Tips

Creeping red fescue produces rhizomes, allowing it to fill in thin areas of turf and to make a good recovery from injury. This species has good seedling vigour, as compared with sheep fescue. Chewings fescue lacks strong rhizome development but has a greater tolerance for low mowing. Hard fescue (Festuca longifolia) has received much attention in recent years for its tolerance of low fertility soils and drought. It has a dark-green colour and good density once established. Its major disadvantage is its relatively slow rate of germination and establishment. Sheep fescue is a bunch-type grass used primarily in low-maintenance situations. It is the least used of the turf-type fine fescues.

TALL FESCUE***(Festuca arundinacea)***

Tall fescue forms an acceptable turf for commercial grounds, parks, playgrounds, and athletic fields. It is commonly used in low-maintenance situations such as utility areas, highway medians, airstrips, and fairgrounds. Many new and improved varieties have a finer texture, higher tiller densities (tillers are side shoots arising from the plant base) and a darker green colour. Tall fescues are not reliably hardy in the colder parts of Ontario (-30°C).

Except for sod production, tall fescue is considered to be incompatible with the finer textured and darker green Kentucky bluegrass, perennial ryegrass and fine fescues, because it tends to form coarse-textured clumps in an otherwise uniform stand.

This is primarily a bunch-type grass that occasionally produces short rhizomes. It is somewhat slow to establish extensive root systems and has only fair recovery potential. Of the cool-season turfgrasses, tall fescue is the most tolerant of heat and drought, which is a function of its ability to produce a deep root system. It also produces a minimal amount of thatch.

Tall fescue performs well in open, sunny areas and is moderately shade tolerant. It is less suited to heavily shaded conditions than the fine fescues, but is more shade tolerant than Kentucky bluegrass and perennial ryegrass. It grows best in well-drained soils. Dwarf-type tall fescue varieties are in demand for their reduced growth rates and increased tiller densities. Although some of these varieties are being used successfully, the reduced rate of growth may slow recovery from disease, insects and/or wear.

ZOYSIAGRASS***(Zoysia japonica)***

Zoysiagrass is a warm-season species that makes optimum growth during periods of high temperatures. It can form an attractive turf in the southern climates where it is used primarily for home lawns. Zoysiagrass has a medium to fine leaf texture and tends to have a light to medium green colour. This species produces extensive, thick stolons that spread rapidly giving it good recuperative potential. However, it may also spread into areas where it is unwanted.

Although drought tolerant when established, Zoysiagrass performs best under moderate moisture levels on fertile, well-limed soils. It will not tolerate poorly drained soils. Its green colour is completely lost with heavy fall frosts, and plants remain dormant until late spring or early summer. In cooler regions of the province or in years with a late spring (or early fall frost), Zoysiagrass may produce an unacceptable turf. Zoysiagrass performs well under low rates of nitrogen fertilizer. The best time to fertilize this species is late spring and in mid-summer (unlike cool season grasses). Because Zoysiagrass produces extensive amounts of thatch, dethatching should be done frequently.

Zoysiagrass must be propagated vegetatively by planting sod plugs or sprigs. The development rate depends on plug size, competition from other grasses and weeds, and the growing environment. Quickest establishment is with 10 cm diameter plugs planted in late spring or early summer. Three to six years may be required to develop a solid stand of Zoysiagrass. The cost of establishing this grass is relatively high.

ESTABLISHING TURFGRASS

The quality of your new lawn depends on the time, effort, and expense you are willing to devote to proper planning and site preparation. A number of basic steps should be taken to ensure successful establishment. If any of these steps is omitted or done improperly, the resulting stand may be thin and could deteriorate over time.

Common causes of lawn establishment failures include:

- The use of poor-quality seed or sod.
- Improper selection of turfgrass species or varieties.
- Unsuitable soil conditions, inadequate site preparation or lack of moisture during seedling establishment.
- Failure to establish the lawn at a time of year when weather conditions favour seedling growth.

SELECTING AND PURCHASING HIGH QUALITY SEED

Select high quality seed and a seed mixture that is adapted to the site conditions and intended use of the turf. Poor quality seed may have a poor germination rate and contain weed seeds and undesirable grass species. If the species in the seed mixture are not adapted to your conditions, the resulting stand may become thin and subject to soil erosion and weed encroachment.

When purchasing turfgrass seed it is important to read the label to determine the kind, amount, and quality of seed in the container. All seed sold is required by law to bear a tag or label indicating basic information about the seed quality. The basic information that should appear on the label is as follows:

- Name and address of labeller.
- Lot number.
- Kind and variety of turfgrass seed listed in order of predominance.
- Percentage by weight of pure seed of each species and variety (percentage purity).
- Germination percentage (percentage of viable seed).
- Percentage by weight of other crop seed.
- Percentage by weight of weed seed (should be less than 0.5% by weight).
- Percentage of undesirable grass seed (should not contain any).
- Percentage by weight of inert matter (chaff mostly).
- Date on which the germination test was conducted.

The name and address of the labeller represents the party responsible for the container's contents. The lot number is listed so that the contents can be traced back to the original source of production.

Endophytes are fungi or bacteria that live within plants and are transferred through seed. Fungal endophytes in fescue and perennial rye varieties help control sod webworm and chinch bugs and seem to make plants more resistant. When selecting turf cultivars look for those rated with high endophyte levels. New cultivars are often labelled as endophyte enhanced. [OMAFRA Reference](#)

SELECTING SOD

Sod produces mature turf in days instead of the months required to establish turf from seed. Sodding is more expensive than seeding because the "finished product" is purchased instead of the "ingredients". Provided adequate water is available, sod may be laid during periods that are typically not conducive to seeding. If, for example, a home is completed in late spring or early summer, sod can be laid immediately, whereas seeding should be delayed until fall. Also, sod can be used successfully in areas prone to soil erosion, such as steep banks or culverts.

Most of the sod produced is predominantly Kentucky bluegrass. Some growers produce tall fescue sod and sometimes a very small amount of fine fescue sod. If Kentucky bluegrass sod is used, it should consist of three to five varieties and must not be placed in heavily shaded areas. Sod for heavily shaded areas should consist mostly of fine fescues.

A successful sodding operation depends on the quality of sod and the care used in both preparing the sodbed and laying the sod. Sod should be dense and well knit so it can be cut thinly into strips that can be handled easily. Thin-cut sod weighs less, lies better, and roots more quickly. High quality sod should have a maximum root and soil thickness of 1 to 2 cm. If the sod is to be held for several days before laying, spread it out in a cool, shaded area, grass side up, and keep it moist.

STEPS IN SITE PREPARATION AND TURFGRASS SEEDING

1. Have a soil test done.
2. Rough grade.
3. Lime if needed.
4. Apply basic fertilizer.
5. Incorporate organic matter, if needed.
6. Till above materials into top 10 to 15 cm of soil.
7. Finish grade.
8. Distribute seed.
9. Rake or drag to cover seed lightly.
10. Roll lightly.
11. Mulch.

1. Soil test results will indicate the soil's pH and lime requirements and the amounts of phosphorus, potassium, and organic matter present in the soil. Recommendations for liming, basic fertilizer, and starter fertilizer will be returned to you along with the test results. Soil test mailing kits may be obtained from your local OMAFRA office. These kits provide all the necessary information on taking a soil sample and a mailing container for forwarding the sample to a reliable soil testing laboratory.
 2. Rough grading involves removing all debris, including large stones or wood left by construction work. Till the soil and bring the area to a rough grade before liming or fertilizing. Where topsoil is to be replaced or brought in, grade the area to the contour of the desired finished grade to facilitate uniform distribution of topsoil.
 3. Grass growth will be unsatisfactory if soil pH is not in the 6.0 to 7.0 range. If the soil is too acidic as indicated by a soil test, broadcast and work into your topsoil the recommended amount of ground or pelletized limestone. If soil test results are not available when you are ready to seed, postpone lime application until you find out the soil pH level.
 4. If a soil test has been taken, broadcast the required amount of recommended fertilizer and till into the topsoil. Failure to correct a soil phosphorus deficiency or low soil pH is a common reason for poor establishment. If a soil test cannot be done before seeding, work a starter fertilizer into the topsoil. A starter fertilizer has a high level of phosphate relative to the nitrogen and potash (NPK). The NPK ratio of the product should be approximately 1:2:1 or 1:4:2. For example, products with 9-17-9 or 5-20-10 NPK contents are suitable. Follow the directions on the fertilizer package for new seeding application rate.
 5. If necessary, work organic matter into your topsoil along with the lime (if required) and the fertilizer. Make sure all three are uniformly mixed. Sources of organic matter include leaf compost, composted sewage sludge, well-rotted manure and mushroom compost.
 6. Rake area to finish-grade just before seeding. Light rolling will indicate any low spots or other irregularities in the area.
 7. Late summer to early fall is the best time for seeding turfgrass. Early August to late September is the best time for bluegrass and fine fescue.
- Divide the total seed quantity into two equal lots, sowing one lot in one direction and the second lot at right angles to the first with a mechanical seeder or spreader.
8. Rake lightly or drag the area to cover seed no deeper than 0.5 cm.
 9. Firm soil around seed using a seed roller or footsteps.
 10. Mulch the seeded area with clean straw or marsh hay. Light mulches (some soil showing through the mulch) may be left on the area to decompose.
 11. A light fertilizer application at a rate of 250 g of nitrogen per 100 m² should be made just before or after the first mowing. Do not apply after June 1 for a spring seeding or later than 6 weeks after the first frost for a fall seeding.

INSTALLING SOD

Prepare your sodbed the same as for seedbeds. It is particularly important that the soil type and texture that the sod was grown on approximates the soil on which it will be installed.

Lay the first strip of sod parallel to the longitudinal axis of the area. Lay the next strip against the first so that the joints between the pieces are staggered, similar to the laying of bricks. This provides additional strength, and holds the sod firmly.

As each strip is laid, the edges should be tightly fitted against adjacent strips and lightly tamped to ensure good contact with the soil. Fill any openings that remain in the seams with soil to prevent drying and facilitate knitting of rhizomes. Use a knife or spade to trim off any excess sod or to straighten strips that may be uneven. Use kneeling boards (plywood or planks) to prevent excessive walking and tracking over the prepared sod. Lightly rolling the sod immediately after laying will ensure a good contact between the new sod and the soil surface.

When laying sod on a slope, keep your strips perpendicular to the slope and secure each strip with stakes until root development is strong enough to hold the sod in place.

Immediately after rolling, water to thoroughly wet the soil below the new sod to a depth of 10 to 15 cm. During the initial rooting period (usually 2 to 3 weeks) irrigate daily to maintain adequate soil moisture. Do not allow the sod to wilt or dry during this period.

FERTILIZING FOR TURFGRASS MAINTENANCE

Grass plants normally need nitrogen, phosphorus, and potassium (potash) in larger amounts than can be supplied naturally from the soil. Nitrogen, an essential nutrient for vegetative growth and strong green colour, is a constituent of plant proteins, chlorophyll, amino acids, and other plant substances. Phosphorus is necessary for good root development and is important in many vital growth processes. Potassium is required for physiological functions and promotes disease resistance and winter hardiness in grasses.

Fertilizer should be bought on the basis of its quality rather than on bag size and price. Value depends on the total amount of plant nutrients contained in the bag and the source of the nitrogen-carrying portion of the fertilizer.

The law requires that the total amount of plant nutrients be shown on the bag. The bag may or may not indicate the source of nitrogen used. If the fertilizer contains slow-release nitrogen materials, the percentage of water-insoluble nitrogen (WIN) must be stated on the bag. A guarantee that 40% or more of the total nitrogen is water insoluble nitrogen indicates a quality turfgrass fertilizer.

Some products, called controlled release nitrogen (CRN) sources, are manufactured to release nitrogen slowly even though the nitrogen is water-soluble. This type of product may also be considered a quality turfgrass fertilizer and is explained in more detail below.

TYPES OF NITROGEN

The ideal fertilizer program provides for uniform turfgrass growth over the entire growing season. Although this ideal is never fully reached because of temperature and moisture fluctuations, the types of nitrogen-carrying materials in a fertilizer are important in achieving steady, season-long growth. Nitrogen sources are divided into two broad groups - quickly available and slowly available.

The **quickly available nitrogen sources** are water-soluble; the nitrogen is immediately available to plants provided there is adequate soil moisture. They produce a sudden flush of growth and a rapid depletion (three to six weeks) of the available nitrogen. It is necessary to make frequent light applications of these materials to obtain uniform growth. Heavy applications of most quickly available sources of nitrogen may cause "burning" (dehydration) of the turf.

Quickly available nitrogen materials are ammonium sulfate, ammonium nitrate, ammonium phosphate, and urea.

Slowly available nitrogen sources release a major portion of their nitrogen over an extended period. These materials depend on microbial decomposition, physical processes, and/or chemical reactions to provide nitrogen in a form available to the plant. The activity of soil microorganisms is highly dependent on soil moisture, pH, and temperature. Under high temperatures and adequate moisture, microbial breakdown of these materials is accelerated. Under low temperatures, or high temperatures with low moisture, the breakdown is much slower. Materials dependent on physical processes (such as hydrolysis) for nitrogen release are relatively unaffected by temperature but are highly dependent on adequate soil moisture. Among the slowly available sources of nitrogen are natural organic, synthetic organic and coated nitrogen products.

Natural organic nitrogen sources include activated or processed sewage sludge, animal and/or vegetable tankage (residues left from commercial processing), manures, various composted products, soybean meal, and cottonseed meal. Because the natural organic sources vary greatly in their chemical composition, there is a wide variation in the rate of breakdown, although all of them release their nitrogen at a slower rate than the quickly available nitrogen sources.

Ureaform compounds are synthetic nitrogen sources made by the chemical union of urea and formaldehyde. Within a given ureaform product there are a series of chemical compounds with varying degrees of solubility and/or resistance to decomposition. As the ratio of urea to formaldehyde increases, the length of the methylene urea chains, or polymers, decreases. As soil microorganisms decompose these materials, the short-chained compounds break down first, followed in succession by each longer-chained compound. Thus, the nitrogen is released over a relatively long period.

"Standard" ureaform has a urea to formaldehyde ratio of approximately 1.3:1.0. It contains about 25% water-soluble nitrogen and 75% water-insoluble nitrogen. These materials may be applied at heavy rates and at relatively infrequent intervals. Currently, compounds called methylene ureas are becoming available commercially. These nitrogen sources have higher urea to formaldehyde ratios (shorter-chained compounds). They contain approximately 75% water-soluble nitrogen and 25% water-insoluble nitrogen. As the amount of water-insoluble nitrogen decreases, the application rate should be decreased and the frequency of application increased.

Follow these tips to make sure the fertilizer you use stays on the lawn and out of the water:

- Keep or sweep fertilizer off paved surfaces.
- Use a drop spreader instead of a rotary spreader in restricted spaces, especially when near water, driveways or sidewalks.
- Fill and wash spreaders over grassy areas, not on hard surfaces.
- Avoid getting fertilizer into natural drainage areas on your property.
- Never apply fertilizers to frozen ground.
- Do not use fertilizer to melt ice and avoid ice melting products that contain nitrogen.

CULTURAL PRACTICES

MOWING

Of the tasks involved in maintaining any turfgrass area, cutting grass consumes the most time. Good mowing practices are perhaps the most important factor in the appearance and longevity of any turf area. Among the factors that should be considered when evaluating a mowing program are:

1. Height of cut.
2. Frequency of cut.
3. Maintenance of mowing equipment.
4. Whether to return or collect clippings.

The height at which a grass plant can be cut and still survive for extended periods is directly related to its ability to produce enough leaf surface to keep up the photosynthetic production of food. Basically, this ability is related to the type and habit of growth found in the grass. Plants that creep over the ground surface (stoloniferous plants), such as bentgrass, when properly fertilized and watered, are able to produce adequate leaf surface at very low heights of cut. Kentucky bluegrass, fine leaf fescues, and tall fescue must be cut relatively high because they cannot produce enough leaf mass at low heights to sustain the plants.

Most lawn grass mixtures (bluegrass, red fescue and perennial ryegrass) should be mowed to a height of 5 to 7.5 cm. Mowing height influences many aspects of turf health. A lawn mowed at an optimal height will have a deeper and more extensive root system than one that has been cut, for example, at 2.5 cm. This lower mowing height will influence turf health, and ability to withstand stress and injury.

Frequency of mowing is also an important consideration in the maintenance program. Infrequent mowing allows the grass to grow tall. Subsequent mowing removes too much leaf surface and may shock the plants. Mow your lawn frequently so that clippings break down rapidly. Weekly mowing may not be enough, especially during the peak period of leaf growth in spring.

Low and infrequent mowing can be a major cause of lawn deterioration. Remove no more than a third of the grass blade each time you mow. For example, to maintain a 5 cm height, mow before the grass gets taller than 8 cm. Mowing to the proper height can reduce weeds and diseases by 50% to 80% in tall fescue. Removing larger amounts of leaf surface may result in physiological shock to the plant, cause excessive graying or browning of leaf tips, and greatly curtail photosynthesis. In addition, the accumulation of clippings may smother the grass and provide an environment conducive to disease and insect damage. The rate of growth will depend on weather, season, soil fertility, moisture conditions, and species.

Mower Maintenance Tips

- *Sharpen mower blades annually.*
- *When servicing the mower, move it onto a non-turf surface such as the driveway.*

GRASSCYCLING

Grass clippings and other yard debris represents around 20% of the annual solid waste deposited in landfills. In addition to the demand for landfill space, collecting and disposing of this waste material is expensive.

The obvious solution to the clipping disposal problem is recycling by returning the clippings to the lawn. If performed correctly, returning grass clippings will not detract from the appearance of the lawn or cause an accumulation of thatch. In fact, this practice will reduce the labour involved in bagging and return essential nutrients to the soil. When clippings are returned, a substantial amount of nitrogen and other nutrients can be used by the turf, thus reducing fertilizer requirements by 25% to 35%.

Turf clippings are succulent leaves that decompose rapidly, and do not contribute to thatch. To ensure that adequate microbial decomposition of clippings occurs, maintain soil at a pH between 6.0 and 7.0.

Mulching mowers are rotary mowers designed to keep clippings circulating under the mower deck so that leaf blades will be chopped into finer pieces. This will hasten clipping decomposition and reduce the amount of residue on the lawn. Whereas most mulching mowers have special features that aid in mulching (e.g., multiple rippled blades and dome-shaped decks that allow better circulation of clippings), some lawn mower manufacturers are offering mulching "kits". These are essentially plates that block discharge shoots and force the clippings back through the blades.

Occasionally, periods of prolonged rainfall make mowing difficult or impossible. In such cases, the turf becomes overgrown and large clumps of grass may remain on the lawn after mowing. Once dry, the clumps of grass can be re-mowed to facilitate dispersal or can be removed, air-dried, and used as mulch in garden beds.

WATERING

Once you have an established lawn, it's best to water only when needed rather than on a schedule. Water if the grass begins to wilt, develops a blue-gray colour or leaves footprints after being walked upon. Water slowly, preferably in the early morning. Wet the soil to a 10 to 15 cm depth. You can check the depth with a screw-driver. Don't allow water from a sprinkler or hose to run onto paved surfaces.

Frequent, shallow watering tends to keep the upper layers of soil near a point of saturation most of the time. This encourages shallow rooting and disease and insect problems as well as damage from foot traffic.

It's okay to let your lawn go dormant during dry periods. Dormancy is an important survival mechanism and your lawn will recover quickly when rainfall returns. Dormant lawns continue to protect water quality by holding soil and potential pollutants.

THATCH

Thatch may be defined as a tightly intermingled layer of partly decomposed stems and roots of grasses that develops between the actively growing green vegetation and the soil surface. Thatch accumulations are undesirable in many respects. Thatch decreases the vigour of turfgrasses by restricting the movement of water, air and plant nutrients into the soil. During wet periods, thatch may act as a sponge and hold excessive amounts of water, reducing the oxygen supply to the roots. On the other hand, if the thatch becomes dry, it is extremely difficult to rewet the soil below it.

Many turfgrass disease organisms and insects may be harboured in thatch. The effectiveness of biopesticides is reduced because these materials cannot get to the organisms causing the problem. Height of cut can be affected by thatch. As the thatch layer builds up, mowers tend to ride on the thatch and do not cut at the desired height. If the cutting height is lowered in an attempt to overcome this problem, a mass of brown stems may result because of the unusual growth habit that has developed.

The rate of thatch buildup is dependent on several factors. Certain grasses tend to thatch much faster than others, some because of their vigorous growth, others because of the resistance of their tissues to decomposition. Management practices also play an important role in thatch buildup.

Thatch control should be considered from two perspectives: preventative control to avoid excessive buildup and curative control where a serious thatch problem already exists.

Preventing Thatch

From a preventative standpoint, liming, fertilizing, optimal irrigation, mechanical dethatching, and aerating should be considered. The soil pH most favourable for micro-organisms that decompose thatch is in the range of 6.5 to 7.0. Applications of ground limestone are required when pH levels drop below this range. Avoid over-fertilizing your lawn. An optimal irrigation plan for your lawn will consider soil type and maintain adequate levels of soil oxygen for the micro-organisms which decompose thatch. Periodic mechanical dethatching carried out in a prevention program need not be as drastic as in a curative program. Dethatching a lawn every two or three years will result in much less debris and less damage to established plants. Aeration results in the physical removal of thatch and helps stimulate microbial decomposition by providing oxygen.

Removing Thatch

In a curative program, the question is how much thatch can be removed in one treatment without permanent damage to the desirable grass. This must be determined by the general vigour of the plant, the root system, climatic conditions, and the amount of thatch present.

Turfgrasses that have a relatively good root system and are growing vigorously can tolerate more abuse during thatch removal than unhealthy turf.

Climatic conditions, primarily temperature and moisture, are extremely important. If temperatures are ideal for growth, and adequate moisture is available, the treatments can be much more drastic than under high temperatures and/or low moisture conditions. Where large amounts of thatch have accumulated, it is unwise to attempt to remove all of the thatch in one treatment.

Mechanically removing thatch should be attempted only when growth conditions are adequate for rapid recovery of the grass.

Machines for mechanically removing thatch accumulations fall into three basic groups: machines having revolving swinging knives, those having revolving stationary knives, and those having revolving spring tines.

AERATION

Mechanical aeration provides an excellent means of alleviating soil compaction in established turf. Compaction occurs primarily in the soil surface. A compacted layer as thin as 0.5 to 1 cm can greatly impede water infiltration and gas exchange between soil and atmosphere. Compaction in the surface layer of soil can be reduced using suitable aerating equipment.

Aerating machines remove plugs of soil from the turf, creating a system of large pores by which moisture and plant nutrients can be taken into the soil. They also provide a system through which carbon dioxide can escape and oxygen can enter the soil. Root growth is also enhanced by aeration. Finely decomposed organic matter (leaf compost) can be spread over the lawn after aeration to improve the soil's physical qualities.

Fall is the best time to aerate lawns. Summer aeration of cool-season grasses, such as Kentucky bluegrass and fine fescues, is not generally recommended because these grasses will be semi-dormant. A general rule is to aerate only when the desirable grasses are growing vigorously.

Equipment having solid tines or spikes should not be mistaken for aerating equipment. Aerators always remove a soil core, whereas solid tine spikers do not. Spikers actually increase soil compaction by forcing the soil into a denser mass.

PEST CONTROL

DISEASE MANAGEMENT

Turfgrass pathogens are present in most turfgrass stands. In most cases, however, these organisms exist in a dormant or saprophytic state. (An organism that obtains nutrients from dead organic matter is termed a saprophyte.) Diseases become a problem when environmental conditions become favourable for the buildup of pathogen populations and/or cause an increase in the susceptibility of the host plant.

It appears there is a set of turf disease problems for every environmental situation that may arise. Some turfgrass diseases occur during the frigid months of winter under a blanket of snow, while other diseases occur only during the hottest and most humid conditions of midsummer. Some diseases occur more frequently when soils are saturated with water, while others are more likely to take place under drought stress.

The first step in managing a turfgrass disease is to get an accurate diagnosis. While this is more of a straight forward task in dealing with turfgrass pests that are relatively easy to observe (weeds and insects), the pathogens that cause turf diseases are often visible only under a microscope. A few turfgrass pathogens, mushrooms for example, produce large fruiting structures, spores, or massive amounts of threadlike filaments called mycelium that can be seen without the use of a microscope. Plant pathologists refer to these fungal structures as the **signs** of the pathogen. More often, **symptoms** (the characteristics of the plant indicating that it is diseased) are used as diagnostic features. Symptoms of turfgrass diseases can take on a variety of sizes, shapes, and colours. On individual plants they may appear as small, circular, tan coloured lesions surrounded by brown or purple halos on leaves, as a yellowing of the entire leaf blade, or as a brown or black rot on the crowns and roots. Symptoms can also be observed on populations of plants and may take the form of circular patches, rings, or irregular areas of blighted turf.

Traditionally, disease management strategies have been grouped into three categories: cultural control, using disease-resistant species and varieties and chemical control.

Cultural Control

Cultural control measures should be the first line of defense against turfgrass diseases. These measures are geared towards modifying the environment of the turfgrass stand. Cultural practices that play a role in the development of turf diseases include mowing, fertilization, soil pH, irrigation, thatch removal, aeration, and any other practice that modifies the turf environment. Every time a mower removes leaf tissue a wound is created through which a pathogen may enter the plant. In some cases mowers may actually spread the pathogen from one location to another. Mowing below the height at which the turfgrass species is best adapted can place stress on the grass and make it more susceptible to some diseases (especially during the summer months).

Fertilization of turfgrasses is an important factor in disease development. Some pathogens favour lush, succulent leaf growth that may occur as the result of heavy applications of nitrogen fertilizer. Diseases favoured by large applications of nitrogen fertilizer include leaf spot, brown patch, Pythium blight, stripe smut, and the snow mould diseases. Certain diseases are more prevalent in low fertility soils. Nitrogen-deficient turfgrass plants are more susceptible to dollar spot, red thread, pink patch, and the rust diseases.

Most fungal pathogens require free water to infect a plant. Irrigation can contribute to disease problems. Night watering should be avoided if possible since it leaves a film of water on plants for an extended time. Watering during periods of disease activity should be performed early in the morning.

A moderate amount of thatch (less than 2 cm) can act as an insulating layer between the turf canopy and the soil and provide resiliency on sports turf surfaces. An excessive amount of thatch can prevent wetting of the soil. Excessive thatch accumulation results in weakened plants that may be more susceptible to diseases and can provide a habitat for disease organisms. A regular program of thatch prevention is an essential component of a disease management program.

Compaction of soils leads to poor infiltration and reduced oxygen diffusion into the root zone. Some root and crown diseases, such as summer patch and anthracnose, are frequently associated with compacted soils on putting greens. Aerating compacted soils allows for improved rooting and, thus, increased resistance to root diseases.

Disease resistant varieties

The second means of managing turfgrass diseases is by using disease-resistant species and varieties. While turfgrass breeders have made tremendous strides in developing grasses with improved disease resistance, no turfgrass is resistant to all diseases. One way to increase a turf stand's overall resistance is to plant mixtures of different grass species and/or blends of cultivars of an individual species. If one cultivar or species is damaged by a disease, the others will fill the void.

Chemical Control

In April, 2009, the Ontario government banned the use of chemical pesticides and herbicides for cosmetic purposes on lawns, vegetable and ornamental gardens, patios and driveways.

Many products that had frequently been used are no longer permitted. There are biopesticides and other organic alternatives that are allowed. See list on [Ministry of Environment website](#).

Chemical control of turfgrass diseases is usually accomplished by using fungicides. Turf fungicides can be divided into two broad categories: contact and systemic. The contact fungicides are generally applied to the leaf and stem surfaces of turfgrass plants and do not move appreciably within the plants. These materials may be washed or mowed off plant surfaces. They are only effective for short durations (usually 7-14 days) and do not protect new foliage. These fungicides are usually used to control foliar diseases, not root and crown diseases. As a group, the contact fungicides have a broad spectrum of control and have been used extensively in the turf industry for a number of years.

The systemic fungicides are absorbed and translocated within the plant. Thus, they are not as likely to be removed from the plant by rainfall and mowing. Systemics may protect plants for a period of 2-4 weeks and will protect new growth. Most systemic fungicides will control both foliar and root and crown pathogens. To control root pathogens compounds should be watered into the root zone for maximum effectiveness. Systemic fungicides tend to have a rather narrow mode of action; thus, they encourage pathogen resistance.

WEED CONTROL

Any management practice that increases the density and vigour of desirable turfgrasses tends to discourage competition from weeds. Cultural practices for controlling summer annual grasses and broadleaved weeds are aimed at shading and crowding the young weed seedlings by producing a dense sod. Effective cultural control measures include the proper selection and establishment of turfgrasses, adequate liming and fertilization, proper mowing and watering practices, and insect and disease control.

Grass Weeds

The most common weed grasses in turf include crabgrasses (*Digitaria* spp.), quack grass (*Agropyron repens*) and annual blue grass (*Poa annua*). These weeds can be controlled satisfactorily by cultural and chemical methods, provided the gardener understands the plant's life cycle.

Two species of crabgrass, the hairy or large (*Digitaria sanguinalis*) and the smooth or small (*Digitaria ischaemum*) crabgrass are commonly found in Ontario. Both are true summer annuals. Their seed germination period ranges from mid-spring to mid-summer and all plants are killed by frost in the fall.

Flowering and subsequent seed set take place from mid-summer to early frost and are the means of perpetuating the species. Seed can be produced at mowing heights as low as 0.5 cm. Abundant quantities of seed are produced.

Once established, crabgrass plants tolerate high temperatures, compact soils, and dry soils better than most turfgrasses. They do not survive shade created by buildings, trees and shrubs, or dense turf.

Crabgrass control cannot be completely accomplished in one growing season because of the great number of viable seeds in the soil from previous years of infestation. The basic principle of crabgrass control is to prevent re-infestation through seeding. If seed production is controlled for several years, the viable seed supply in the soil will diminish until it is no longer a serious threat to the lawn. Using a grass catcher to remove seeds will help prevent re-infestation.

Other summer annual weeds, such as foxtails and barnyard grass, have the same general life cycle as crabgrass. Although these species are less common in turf, they can be very unsightly, particularly in newly seeded or immature stands.

Summer annual grass weeds can be managed with pre-emergent herbicides. Pre-emergence control refers to the use of a product that will prevent germination or kill very young seedlings early in the season without injury to established turfgrasses. These products act by forming a chemical barrier in the soil prior to seed germination. The barrier effectively prevents grass seedlings from emerging and developing normally.

There are several factors to consider when choosing a pre-emergent herbicide. The first is the safety of the chemical for turfgrass species and cultivars. Some compounds may injure fine fescues but are generally safe on Kentucky bluegrass, ryegrass, and tall fescue. Most pre-emergent herbicides have long residual activity in the soil and may affect newly seeded turfgrasses. Thus, seeding of turfgrasses should be postponed for the amount of time specified on the manufacturer's label. For maximum effectiveness, pre-emergent herbicides should be applied uniformly at the label-recommended rates.

The timing of pre-emergent herbicide applications is the most critical component of an effective chemical control program. As a general rule, the best time to apply pre-emergence materials is approximately 10-14 days prior to the expected germination period in spring.

Summer annual grass germination is determined by moisture and temperature. Highly variable temperatures in early spring often cause concern about the best time to apply these materials. One factor to consider when contemplating an early application is that frost will kill any summer annual grass that has begun to germinate.

Crabgrass begins to germinate when temperatures in the upper 2.5 cm of soil reach 14° to 15°C. Indicators such as forsythia bloom are not consistently reliable for determining crabgrass herbicide application or germination.

Consult product labels to determine if two applications are allowed. Poor control also may occur with late applications. In these cases, post-emergent herbicides may be required.

Post-emergence control of crabgrass and some other summer annual weeds involves using products that can kill growing plants after they have appeared in the turf.

Quack grass, also known as couch grass or twitch grass, is a perennial grass that spreads rapidly by white rhizomes with many nodes. Quack grass is resistant to chemical herbicides so must be controlled culturally. Repeated mowing at 5 cm will place considerable stress on quack grass.

A good turf fertilization and management program combined with several seasons of consistent mowing stress will weaken quack grass plants. In cases where small isolated patches exist, thorough removal of all plant parts may be feasible.

Annual blue grass reproduces only by seed; therefore by controlling the production and germination of seed, this grassy weed can be effectively managed. Regular mowing causes annual blue grass to branch near the ground surface and produce flowers and seeds below mowing height. These low inflorescences and seeds give the lawn a light green appearance that is unsightly. If there are only a few isolated plants, they can be removed manually. With larger numbers of established plants, it is important to prevent seed from germinating. Using a grass catcher to collect clippings and seed will help at times of the season when seed production is high.

Broadleaved Weeds

A large number of broadleaved weeds can occur in turfgrasses. Most are adapted to withstand low mowing heights by forming rosettes or creeping growth habits. Examples of broadleaved weeds that form rosettes include dandelion, broadleaved plantain, and curled dock. A few weeds having creeping growth habits are chickweed, clover, ground ivy, and creeping speedwell.

Broadleaved weeds can be controlled with selective post-emergent herbicides. There are various formulations and mixtures of commercially available compounds. It is extremely important to identify the weed(s) to be controlled, since susceptibility to the various products will differ among species. All of these herbicides have the potential to damage trees, shrubs, flowers, and vegetables.

Check the [Ontario weeds website](#) to help you identify weeds.

Broadleaved weeds are controlled most effectively when the herbicide is applied as a spray to the foliage (and is not washed off) during periods when the weeds are actively growing (spring and fall). At these times, absorption and translocation of the herbicide is at a peak, and desirable turf species have a chance to grow into the voids left by the weeds. A few annual broadleaved weeds are controlled with pre-emergent herbicides typically used for preventing summer annual grasses.

INSECT CONTROL

Insect pests of turfgrasses can be grouped into two categories: root feeders and leaf and stem feeders. The primary root-feeding insects in Ontario are grubs. Several species of grubs damage turf including Japanese beetles and European chafers.

Chinch bugs are one of the most common leaf-feeding insects found in Ontario lawns. Other stem and leaf feeding insect pests include Sod Webworms and Black Cutworms. OMAFRA Publication 162, Diseases and Insects of Turfgrass in Ontario, provides a complete description of many common insect pests as well as alternatives for control.

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CHAPTER 11: HERBACEOUS PLANTS

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INTRODUCTION

Flower gardening is the horticulturalist's reward for hard work. Flowers and flower borders are pleasing accents that enliven the landscape and provide colour against the bulk of green. They complement conventional landscaping features such as trees and shrubs. They visually alter heights and slopes, adding depth and dimension, form and texture.

In this chapter, we'll discuss herbaceous flowering ornamentals. We'll begin with guidelines to follow for all herbaceous plants, followed by the specific needs of annuals, perennials, biennials and bulbs.

First, a few definitions: An herbaceous perennial is a hardy plant which will remain in the garden for years, although the top portion dies back each winter. It seldom blooms for more than a few weeks. An herbaceous annual blooms all season, but is killed by freezing temperatures. It remains in the garden for only one growing season, although it may self-seed and return to your garden as a "volunteer." Like the annual, a biennial is a short-lived plant, but it completes its life cycle in two years; like the perennial, it blooms for a limited period of time.

PLANNING THE HERBACEOUS GARDEN

An herbaceous garden has many purposes:

- Enhancing much-used outdoor areas
- Creating a privacy screen
- Softening and utilizing an unmowable steep slope
- Creating a bog garden where it's too wet for a lawn
- Producing flowers for fragrance
- Making your home entrance more inviting
- Screening unattractive aspects of the yard
- Utilizing a rocky outcropping as a rock garden
- Attracting birds and butterflies to the garden

Much of the excitement of creating an herbaceous border, or flower bed lies in its great flexibility of design. Planning a border is best done to scale on graph paper.

The hardest task, organizing the selection of plants, will be simplified if only two main mass forms are considered: drifts - elongated groupings of a plant; and clumps - circular groupings of a species, or a single large accent plant, such as a peony. For best effect, vary the length of drifts and the diameter and height of clumps.

Dimensions should always be in proportion to the overall size of the border.

TIPS:

1. In choosing a site, consider sunlight (full sun to heavy shade), slope of the site (which affects temperature and drainage), soil type, and the role the plants will play in the garden.
2. Locate a traditional herbaceous garden in front of a suitable background, such as a fence, row of tall flowers, shrubbery, or a building. Take advantage of the shape and topography of the land in laying out lines. More contemporary designs include the island bed and the incorporation of flower beds with architectural features such as pools, decks, and paths.
3. Avoid a ruler-straight front edge. Edge the garden with a curve, easily laid out with a garden hose. The deeper the curve, the slower the eye moves and the greater the visual enjoyment. Outline the border with bricks or flat stones set flush with the soil to minimize trimming after mowing and to prevent encroaching grass.
4. Select key plants for:
 - Line - the silhouette or outline of a plant (form)
 - Mass - the shape or denseness of the plant
 - Colour
 - Dependability - the plant's ability to remain attractive with a minimum of problems
5. Establish plants in groups large enough to form irregularly-shaped masses of colour or texture. Five or so small plants or a single large plant, such as a peony, will create the desired effect. Use plants with different flower or foliage characteristics (texture) and different growth habits (form) to provide contrast and create interest. A random collection of different small to medium-sized plants will present a disorganized, checkerboard appearance. Don't set in rows but in groups, as they would grow in nature.
6. Allow enough space for each group to grow comfortably, but manipulate the space for effect. Reduce the spacing if you want a solid mass of plants for an "instant" garden. Increase it if you want individual plants to be conspicuous as specimens.

7. Place tall flowers in the back part of the bed, medium height species in the middle, and dwarf varieties along the front. Limit plant height to two-thirds the width of the bed; for example, no plants taller than 2 m in a bed 3 m wide (scale). Break up height lines by letting some tall plants extend into the medium-height groups, giving a more natural effect.
8. Consider each plant's period of bloom. The longer the bed has flowers in bloom, the more you will enjoy it. Vary the blooming season for a steady succession of colour. Foliage colour should also be considered.
9. You have great latitude in choosing and combining colour, considering the enormous colour range in perennials and the ease of transplanting them. Many books give excellent suggestions for compatible colour schemes; these, plus a garden notebook and camera, are invaluable for planning and revising colour schemes.
10. When selecting herbaceous plants, the important restrictions on any given plant will be environmental: a lack of tolerance to winter or summer temperature extremes; special soil, moisture or light needs; and your time limits for maintenance.
11. Put the plan to scale on graph paper. It's far easier to move plants using an eraser than to physically shift them with a shovel. You might make a plan for each season, indicating which plants will be actively blooming during that time. A master plan with layers of tracing paper works very well.

CULTURE AND MAINTENANCE

Soil Preparation

Preparing the soil is important for flowers, especially perennials. While some annuals can grow and flower in poorly prepared soil, few perennials survive over one year if the soil is not properly prepared. Prepare the soil in your flower bed in the fall before you plant.

1. Have the soil tested early and adjust the pH if needed.
2. Materials to adjust pH need time to work.
3. Check and adjust drainage. To test drainage, dig a hole about 25 cm deep and fill with water. The next day, fill hole with water again and see how long it remains. (It should not exceed 8 hours).

If drainage is poor, dig furrows along the sides of the bed and add soil from the furrows to the bed. This raises the level of the bed above the general level of the soil, allowing excess water to seep from the bed into the furrows. Prevent washing during rains by surrounding raised beds with wooden or masonry walls.

4. Dig the bed. Add 10 to 15 cm of organic matter to improve soil texture. Dig to a depth of 30 to 45 cm and leave "rough."
5. In spring, add fertilizer, working any phosphorous deeply into the soil for easy root uptake. Spade again, and rake surface smooth.

Seed Selection

To get a good start toward raising vigorous flowering annuals or perennials, buy viable seed packaged for the current year. Include some newer varieties which have desirable traits. Seed saved from previous years may also be used but old seeds may germinate slowly and erratically and produce poor seedlings.

For detailed seed starting information, refer to **Chapter 7: "Propagation"**.

Planting Times

Do not rush to start seeds outdoors or to set out started plants. Delay this until after the last frost date. Most seeds will not germinate well in soils below 15°C. If soil is too cold when seed is sown, seeds will remain dormant until soil warms and may rot instead of germinating. However, some cold-loving annuals like larkspur or Shirley poppies can be sown in late fall or very early spring.

Sowing Seed Outdoors

Annuals seeded in the garden frequently fail to germinate properly because the surface of the soil cakes and prevents entry of water. To prevent this, sow seed in vermiculite-filled furrows.

- Make furrows in soil about 1 cm deep. If soil is dry, water the furrow, then fill it with fine vermiculite and sprinkle with water.
- Then make another shallow furrow in the vermiculite and sow the seed at the rate recommended on the package.
- Cover the seed with a layer of vermiculite. Using a nozzle adjusted for a fine mist, water the seeded area thoroughly.

- Keep seed bed well watered, or cover with a fine mulch to keep the sprouting seeds moist.

Thinning

After outdoor-grown annuals develop the first pair of true leaves, thin them to the recommended spacing. Thinning allows plants enough light, water, nutrients, and room to develop fully.

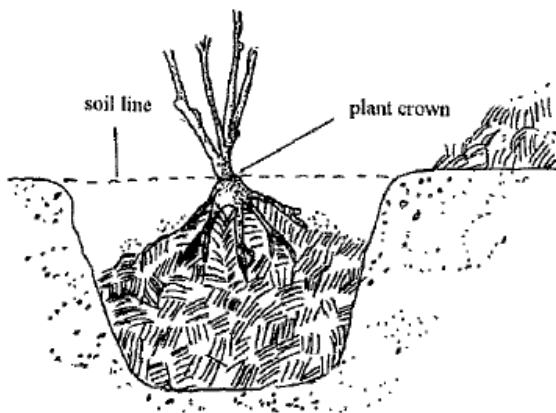
If they have been seeded in vermiculite-filled furrows, excess seedlings can be transplanted to another spot without injury. Zinnias are an exception to this rule. In many varieties of zinnias, transplanted plants will flower as a large nearly naked corolla with a few colourful petals, a phenomenon referred to as "Mexican hats". To avoid such zinnias in your garden, sow two or three seeds at each planned location. Wait until the plants bloom for the first time, then, remove the plants with this undesirable characteristic. Thin the remaining plants to the recommended 20 to 30 cm spacing.

Setting Out Transplants

You can begin a flower display several weeks earlier if you set out transplants rather than sow seeds. This is especially useful for annuals that must grow several months before blooming. Buy healthy, vigorous annuals or start your own.

Before setting out transplants, harden them off by exposing them to gradually increasing time outside. The plants will receive more light and cooler temperatures, improving their vigour.

Figure 11-A: Set a bare-rooted perennial into the soil according to how the roots grow, and then fill in.



Set out annual plants after the last frost date for your area.

1. For each plant, dig a hole large enough to accept its root system comfortably.
2. Remove transplants from flats by slicing downward in the soil between the plants. Lift out each plant from its flat with a block of soil surrounding its roots. If the plant is in a fiber or peat pot, remove the paper from the outside of the root mass and set the plant in a prepared planting hole. Roots should be gently eased from the soil block.
3. Set the plant in a planting hole and backfill it so the plant sits at the same level that it was in its pot.
4. Water individual plants as they are planted.
5. After setting all plants out, water them all once again.
6. Allow plenty of space between plants to give them room to develop.

Protect young plants against excessive sun, wind, or cold while the plants are getting settled in their new locations. Cover with inverted pots, newspaper tunnels, "Hot Kaps®" or cloches. One litre plastic strawberry baskets or the open, top half of 2 litre soft drink bottles make excellent homemade cloches.

Planting Times for Perennials

Plant late summer or fall flowering perennials in the spring and spring flowering perennials in late summer or early fall. Regardless of the time of planting, allow perennials sufficient time to establish themselves before they are expected to bloom or endure the onset of cold weather. If perennials are planted in spring, regular watering will be necessary if hot or windy weather occurs. If planted in late summer, protection from an early frost may be required.

Transplanting Herbaceous Perennials

If you need to transplant a perennial plant, do it on a cloudy day to reduce heat and light stress. If you are careful, perennials can be transplanted even when they are in bloom; but it's best to do it when they are dormant or just starting growth. Early spring or fall, are the best times to transplant them.

Tips:

- Dig the new hole first, amending the soil with organic matter if possible. Fill it with water and let it drain.
- Dig the perennial up carefully, saving as large a root ball as possible.
- Settle the transplant into the hole, filling in with soil.
- Water the new transplant, mulch it and protect it, if necessary, with a cardboard screen.

Watering

Municipal restrictions on water use for lawns and gardens are common in many Ontario communities during hot summer months. From both an ecological and financial perspective, it makes sense to design a landscape and select plants which will require as little water as possible once the garden is established.

When it is necessary to water a garden, there are several points to consider.

- Watering is necessary for new plants. The sooner they become well established, the sooner you can begin to wean them of regular irrigation.
- Moisten the entire bed thoroughly, but do not water so heavily that the soil becomes soggy or water begins to run off. Allow the soil to dry moderately before watering again.
- A soaker hose is an excellent watering system; it allows water to seep directly into the soil without waste and without splashing leaves and flowers.
- Water wands and drip systems are also good as water can be applied specifically to those plants that need extra moisture.
- Hand-watering with a nozzle allows you to custom water plants and monitor them while they drink. Direct water to the root systems of disease-susceptible plants. Give new transplants or other vulnerable plants extra water.
- Water from sprinklers wets the flowers and foliage, making them susceptible to diseases. Soil structure may be destroyed by the impact of water drops falling on its surface; the soil may puddle or crust, preventing free entry of water and air. Avoid sprinklers whenever possible.

Mulch

Mulch gives an orderly look to the garden and cuts down on weeding. In addition, mulches maintain uniform moisture and temperature conditions in the garden. Organic mulches add some nutrients and humus to the soil, improving tilth and moisture-holding capacity.

Tips:

- Use summer mulches after ground has warmed up.
- Grass clippings make good mulch for annuals, if they do not mat.
- Other attractive organics for mulching include bark, pine needles, or shredded leaves.
- Spread inorganic mulches such as black plastic or paper before planting, when soil is damp.
- Apply organic mulches after plants are well-established, when soil is damp.

Winter Mulch and Perennials

Perennials are permanent plants. They need special care to protect them against repeated freezing and thawing in winter. But be careful - improper mulching can damage the plant. Don't pile mulch heavily over the plant's crown, as this encourages rotting. Wait until late fall, after several killing frosts to apply mulch. If you apply it too early, the retained warmth may cause new growth to start, resulting in severe damage to the plant. Remove winter mulch when growth starts in the spring, assuring the plant of much needed light.

Weeding and Cultivating

- After plants are set out or thinned, cultivate only to break crusts on the surface of the soil.
- When the plants begin to grow, stop cultivating and pull weeds by hand. As annual plants grow, feeder roots spread between the plants. Cultivation is likely to injure these roots. In addition, cultivation stirs the soil and uncovers weed seeds that then germinate.

Deadheading**(Removing Old Flowers)**

To maintain vigorous growth of plants and ensure neatness and continuous blooming, remove spent flowers and seed pods.

Pinch Them If You Love Them!

It's a good idea to snip the tops off perennials several times during the growing season to encourage bushier growth and reduce their tendency to fall over. For fall-blooming flowers, the first pinch is usually done in early May. Perennials which profit from a little pinch include chrysanthemums, sedum, and asters.

Staking

- Tall-growing annuals like larkspur, or tall varieties of marigold or cosmos, need support to protect them from strong winds and rain.
- Stakes can be made from wood, bamboo, or reeds large enough to hold the plants upright but not large enough to be conspicuous. Stakes should be about 15 cm shorter than the mature plant so that their presence will not interfere with the beauty of the bloom.
- Begin staking when plants are about one-third their mature size by placing stakes close to the plant, taking care to minimize damage to the root system. Secure the stems of plants to stakes in several places with paper-covered wire or other materials that will not cut into the stem.
- Plants with delicate stems (like cosmos) can be supported by a framework of stakes and strings in criss-crossing patterns.
- Tie the plant by making a double loop of the wire with one loop around the plant and the other around the stake. Never loop the tie around both stake and plant. The plant will hang to one side and the wire may girdle the stem. Add ties as the stem lengthens.

Fertilizing

If you incorporate organic matter (i.e., compost, rotted manure) into your soil on a regular basis, your plants may be adequately nourished. With less fertile soils, add fertilizer according to recommendations given by soil sample analysis. Apply fertilizer in the spring so it will not leach out before plants can benefit from it. Water the bed after applying fertilizer. This washes the fertilizer off the foliage, prevents burn, and makes fertilizer available to the plants quickly.

Your garden may need a small amount of additional nitrogen if you use straw, raw sawdust or wood chip mulches because micro-organisms decompose the mulch, taking up available nitrogen in the process.

If soil test results indicate it, add lime. Use dolomitic limestone rather than hydrated lime, adding it in the fall so it will have time to raise the pH.

Annuals: Once annuals have germinated and begin to grow, they may need additional fertilizers. Work 5 ml of 10-6-4 in around each plant in such a way as to avoid direct contact between the stems and the fertilizer or use compost tea or one of the soluble plant foods.

Perennials: A perennial bed will require an even supply of nutrients throughout the growing season. Since different plants grow and flower at different times, a fertilizer source that is able to release nutrients slowly would be most suitable. Incorporating well composted organic matter (humus) into the bed before planting and around individual plants annually will provide for most plants' nutritional requirements. If additional nutrients are required at specific times, then compost tea or a water soluble plant fertilizer such as 5-10-5 can be used.

ANNUALS

Annual flowers complete their life cycle in one growing season, during which time they grow, flower, and produce seed. Although some varieties will self-sow, or naturally re-seed themselves, the parents of each seed are unknown and certain characteristics will be lost. Such is the case with many annuals that are hybrids. Self-seeders such as alyssum, petunia and viola will scatter seed freely in perhaps undesirable areas.

Perennial or Annual?

Some perennials, plants that live from year to year, are not typically winter hardy in our area and must be set out every year. They are classified and sold as annuals in Ontario. Begonias, geraniums, and snapdragons are examples.

Plant breeders have produced many new and improved varieties. Annuals are easy to grow, produce instant colour, and most important, they bloom for most of the growing season. The main disadvantage of annuals is that you must sow them from seed or set out transplants every year, thus involving some effort and expense.

Annuals offer you a chance to experiment with colour, height, texture, and form. If you make a mistake, it's only for one growing season. Use them for filling in spaces until you install permanent plants or after an earlier perennial or bulb is already gone. They extend perennial beds and fill planters, window boxes, and hanging baskets.

BIENNIALS

Biennials complete their life cycle in two growing seasons. During the first growing season they produce leaves, usually in rosettes. In the second growing season, after a cold period, they produce blooms and die. Popular biennials are sweet William, some foxgloves, and forget-me-nots.

For the flower gardener, biennials present the obvious disadvantage of producing only foliage the first year and no blooms. For this reason, new varieties have been developed that produce early bloom. Biennial seeds can be sown in midsummer to produce plants that develop in the fall, forcing the plant to bloom the next year. Cultural practices are basically the same as for annuals except the plants grow in the garden for two years. Biennials can also be incorporated into a perennial garden by planting them every year.

PERENNIALS

Perennials are plants that live year after year. This means the tops of the plants die back to the ground each fall, and every spring new plant tops arise from the crown or roots which persisted through the winter. Perennials are said to be hardy, because they live through the winter.

The most obvious advantage to growing perennials is that they do not have to be set out each year, although some must be replaced or divided every few years. Another advantage is that, with careful planning, a perennial flower bed will change colours as one type of plant finishes and another variety begins to bloom. Deadheading is not always necessary to keep them blooming, since perennials have a limited blooming period. However, they do require pruning and maintenance to keep them attractive.

Their relatively short bloom period is a disadvantage to the long-season gardener, but combining them and using annuals will give a continuous show.

Selecting Plants

Select plants with a purpose, such as edging plants, accents for evergreens, masses of colour, rock garden specimens, etc. Then you can choose perennials by considering their characteristics and deciding which plants best meet your requirements.

For a good display from a limited number of plants in limited space, select known varieties. Observe the flowering times of perennials in your neighborhood. That way you will be able to choose plants that will flower together and plants that will be showy when little else is in bloom. To obtain details on particular plants or groups of plants consult local Master Gardeners, plant societies, specialty books, nursery operators, and local botanical gardens.

Select a variety of plants for texture, spread, flower form, and height. Grow your own plants or purchase them from your local nursery. Choose perennial plants that are compact and dark green. Avoid buying plants with thin, pale yellow stems and leaves or any signs of disease or insects.

Fall Care

In the fall, after the foliage of perennials has died down, cut and remove any diseased leaves, stems, or spent flowers 5 cm above the crown. These materials often harbor insects and disease causing organisms that can re-infect plants next year. Apply winter mulch after the soil has frozen. Foliage and seed heads that were healthy can be left over winter. These stems will help to trap snow on the garden and provide winter food for birds.

Fall is a good time to plan the transplanting and separating of your perennials to give them more space. Increasing air movement between plants is an important method of preventing disease problems. If you are concerned about excessive bare space, plan to fill in with annuals for the first few years.

PROPAGATING PERENNIALS

Sexual Propagation

Seed propagation has several advantages over vegetative division. Diseases are less likely to be carried over with seed. Less common varieties are more often available as seed. Seed of species plants will generally come true to type, whereas seed of cultivars may not.

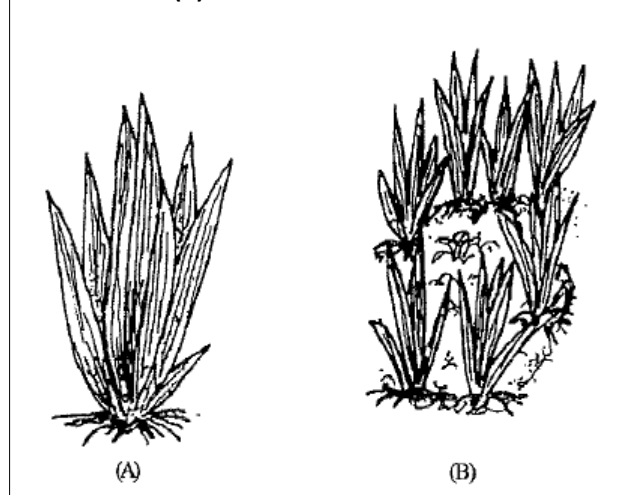
Start perennials from seed either in mid-to-late summer, the same time as Mother Nature would start them, or sow them indoors in the early spring. (See **Chapter 7 "Propagation"**.)

Division

Many perennials left in the same place for more than three years are likely to be overcrowded, with dead unsightly centers. The center of the clump will grow poorly, if at all, and the flowers will be sparse. The clump will have a "doughnut" appearance. These perennials need to be divided.

In Ontario, divide spring and summer bloomers after they bloom, either in late summer or fall as the foliage dies down. Fall-blooming herbaceous perennials are usually divided in the spring when the foliage is 5 to 8 cm tall, giving the plants an entire growing season to recover.

Figure 11-B: (A) A NORMAL PLANT
(B) OVERGROWN “DOUGHNUT” PLANT



To divide mature clumps of perennials:

- Water well prior to digging to help maintain the soil ball and keep the roots damp.
- Keep only vigorous side shoots from the outer part of the clump. Discard the center of the clump.
- Divide the plant into clumps of three to five shoots each. Be careful not to over divide; too small a clump will not give much colour the first year after replanting.
- Divide perennials just before a new season of growth, or in the early fall so they can become established before the ground freezes.
- Don't replant all of the divisions in the same space that contained the original plant. Give some to friends, plant them elsewhere in the yard, or compost them.

Cuttings

Many plants can be propagated from either tip or root cuttings. Generally, tip cuttings are easier to propagate than root cuttings.

Select new growth for cuttings. Make tip cuttings 8 to 15 cm long. Treat the base of the cutting with a root stimulant. Leave all foliage on the cutting except the part that will be below the soil line. Insert one cutting in a pot filled with damp sand. Place pots of tip cuttings in a lightly shaded place. Cover with a sheet of clear plastic, or place pots in a plastic bag. Check regularly to make sure the cuttings do not dry out.

Figure 11-C: DIVIDING A PLANT WITH A FORK OR SPADE



When cuttings do not pull easily out of the soil, they have begun to root. Make holes in the plastic sheet to increase air circulation. This will harden the cuttings. Every few days make new holes, or enlarge the holes.

Make root cuttings of such plants as phlox, baby's breath, and Oriental poppy. Dig the plants in spring. Select pencil-size roots; cut them into 10 cm sections. Prepare a tray of pots as for seeds, except the soil mix should be 2 parts sand, 1 part soil, and 1 part peat moss. Put each root piece in a peat pot. Water thoroughly.

BULBS

Bulb is a term loosely used to include corms, tubers, tuberous roots, and rhizomes as well as true bulbs. They are broadly grouped into spring flowering (January-May) and summer flowering (June-September).

Spring bulbs provide early colour before most annuals and perennials bloom. Popular spring bulbs include crocus, tulips, narcissus, daffodils, and jonquils. Selecting spring bulbs of quality is very important because the flower bud has already developed before the bulb is offered for sale. Size is important. Look for plump, firm bulbs. Choose your bulbs on the basis of colour and flower size for specific purposes; for example, small ones create a natural look and large ones stand out as specimen plants. Keep bulbs cool (15°-18°C) until planting time, usually in October.

Summer flowering bulbs include amaryllis, tuberous begonia, caladium, calla lily, dahlia, gladiolus, lily, and spider lily. As with spring bulbs, select summer flowering bulbs that are large, firm and plump.

Before investing considerable time and money, be aware that many of these bulbs are not cold hardy. They will have to be dug and properly stored in a frost-free location over the winter.

Figure 11-D: Bulbs can be propagated by separating and replanting them, or by removing bulblets and setting them out in a transplant bed.



CULTURE AND MAINTENANCE OF BULBS

Site Selection and Preparation

- Most bulbs need full sunshine, so select a planting site that will provide at least 5 to 6 hours of direct sunlight a day. Bulbs left in the ground year after year should have 8 to 10 hours of daily sunlight for good flowering.
- Adequate drainage is an important consideration, as most bulb plants will not tolerate poor drainage and rot easily if overwatered or planted in wet areas.
- Function must also be kept in mind. If bulbs are being used to naturalize an area, toss the bulbs and plant them where they fall to create a scattered effect.
- Prepare your bulb bed as you would for perennial plants.
- For individual planting holes, loosen the soil below the depth at which the bulb is to be planted. Add fertilizer and a good source of phosphorous. Cover with a layer of soil (bulbs should not contact fertilizers directly). Set bulb upright in planting hole and cover with amended soil.

Time of Planting

Hardy, spring flowering bulbs are planted in late summer or early fall. Hardy, fall flowering bulbs such as colchicum are planted in August. Tender, summer flowering bulbs are planted in the spring after danger of frost. Lilies are best planted in fall.

Depth of Planting

It is best to check correct planting depth for each bulb with a successful local grower or other good local source. Catalogs and reference books are general sources of information but may not consider soil type or condition. Generally, plant bulbs two and one half to three times the diameter of the bulb in depth. If you plant bulbs too shallowly, you may encourage frost heaving and lose the bulbs. In colder areas it is wise to plant bulbs deeply. Planting bulbs deeply also thwarts the efforts of many squirrels.

Watering

Normal rainfall usually provides enough moisture for bulbs. But during dry weather, water plants at weekly intervals, soaking the ground thoroughly. Don't neglect your bulbs after blooming.

Mulching

Mulch your bulb bed according to the recommendations given on page 11-4. Remove mulch as soon as danger of severe freezing has passed in early spring. If mulch is left on the ground after growth starts, new shoots may be pale green or colourless and new stems and foliage may be bent or broken.

Fertilizing

After plants bloom, fertilize them lightly with 5-10-10 fertilizer. Avoid high-nitrogen fertilizer. Be sure to keep fertilizer off the leaves and away from stems, as it will burn them. In addition to 5-10-10 fertilizer, you can use bonemeal as an extra source of phosphorus. Avoid organic fertilizers in wet hot summers. They retard blooming and promote disease, especially among gladiolus.

Staking

Staking bulbs is sometimes necessary. See the guidelines on page 11-5. Some bulb flowers will face in only one direction. Use the stake to orient the face to the front of the bed.

Deadheading

When flowers fade, cut them off to prevent seed formation. Development of seed pods takes stored food from the bulbs. Deadheading may also promote longer bloom periods. Avoid removing any foliage, however.

Moving

Bulb foliage is very important. Do not cut the leaves after flowering until they start to wither to allow the green leaves to produce food for next year's growth. If insects or disease have infected the bulb foliage, wait until the leaves yellow and then remove and destroy them.

If bulbs have become crowded or need to be moved to another site, move only after the foliage has faded. Bulbs dug and moved before foliage fades become weakened.

Divide bulbs carefully by digging up the entire clump. Separate the bulbs and replant them in other locations.

Digging and Storing

Many summer flowering bulbs are tender, and must be dug and stored, usually when the leaves on the plants turn yellow. Use a spading fork to lift the bulbs from the ground. Wash off any soil that clings to the bulbs, except those that are stored in pots or with the soil around them. Spread the washed bulbs in a shaded place to dry. When dry, store them away from sunlight in a cool, dry basement, cellar, garage, or shed at 15° to 18°C. Avoid temperatures below 10°C or above 20°C. Be sure that air circulates around stored bulbs.

Never store bulbs more than two or three layers deep as they generate heat and cause decay. Leave the soil on achimenes, begonia, canna, caladium, and dahlia bulbs. Store these bulbs in clumps on a slightly moistened layer of peat moss or sawdust in a cool place. Rinse clean and separate them just before planting.

Botanically Speaking

Bulb: a short, flattened stem bearing fleshy, food storage leaves. Examples: Lily, narcissus, and tulip.

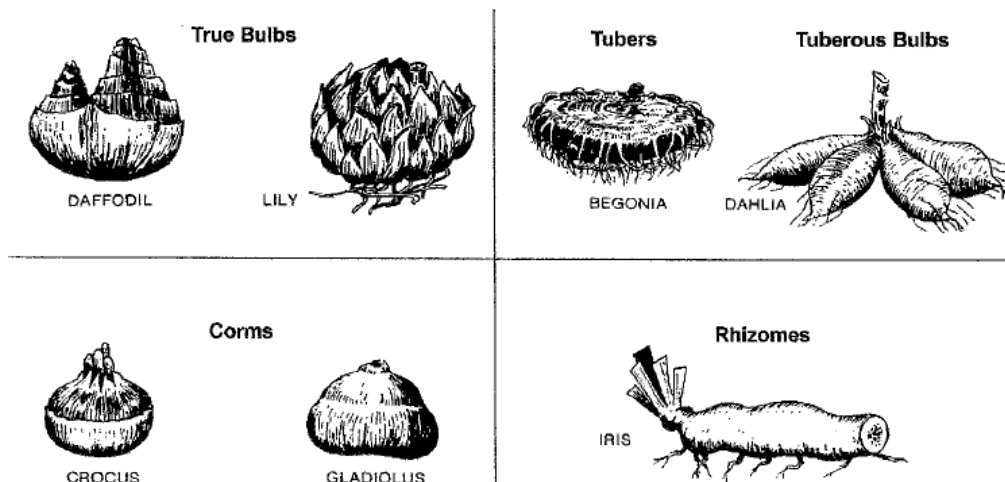
Corm: a solid, vertical, underground stem with a bud on top and covered with dry, leaf bases. Examples: crocus, gladiolus.

Tuber: a thickened piece of underground stem with 'eyes' or buds on top and roots below. Examples: tuberous begonia, ranunculus, anemone.

Tuberous root: a swollen root used for food storage. Example: dahlia.

Rhizome: thickened, underground stems that grow horizontally at or below the soil surface. Example: canna.

Figure 11-E: TYPES OF BULBS



Source: *Flowering Bulbs for Canadian Gardens, Publication 264*. 1988. Ontario Ministry of Agriculture and Food.

PERENNIALS FOR SPECIAL ENVIRONMENTS

ORNAMENTAL GRASSES

The popularity of ornamental grasses has increased rapidly over the last decade and many new and hardy varieties have been introduced. Ornamental grasses can be used in the landscape as large or small specimens, as groundcovers, as edgings, or in containers. There are grasses or grass-like plants for almost every type and size of garden, from a dramatic large specimen at pond-side to a dwarf accent in a formal rock garden. Some ornamental grasses are grown for their striking foliage that can be brightly coloured, striped or banded. Other ornamental grasses are grown for their showy flower spikes or seed heads. Many are chosen for their interesting form.

WARM AND COOL SEASON GRASSES

Grasses are often referred to as either warm or cool season grasses. Understanding the differences between the two groups will help you choose an appropriate species for your garden. Cool season grasses grow actively when temperatures are cool (15°C). They begin to grow in early spring and go dormant during the hottest months of the summer. These grasses do best in areas with cooler summers and little humidity. Warm season grasses grow actively when temperatures are above 25°C and often don't show signs of growth until early summer. These grasses bloom and set seed in late summer or autumn and are often the taller grasses.

PERENNIALS FOR SHADE

Ajuga spp. (Bugleweed)
Anemone japonica (Japanese Anemone)
Asperula spp. (Woodruff)
Convallaria majalis (Lily-of-the-Valley)
Dicentra spectabilis (Bleeding-Heart)
Dodecatheon meadia (Shooting Star)
Helleborus niger (Christmas Rose)
Heuchera sanguinea (Coral Bells)
Hosta spp. (Plantain Lily)
Lilium martagon (Martagon Lily)
Mertensia virginica (Virginia Bluebells)
Phlox divaricata (Wild Blue Phlox)
Primula spp. (Primrose)
Trillium grandiflorum (Trillium)
Trollius europaeus (Common Globeflower)

PERENNIALS FOR SEMISHADE

Aconitum spp. (Monkshood)
Anchusa azurea (Bugloss)
Aquilegia spp. (Columbine)
Astilbe spp. (Astilbe)
Campanula spp. (Bellflower)
Chelone lyonii (Pink Turtlehead)
Cimicifuga racemosa (Cohosh, Bugbane)
Digitalis purpurea (Foxglove)
Doronicum plantagineum (Leopard's bane)
Epimedium spp. (Barrenwort)
Hemerocallis spp. (Daylily)
Lobelia cardinalis (Cardinal flower)
Lysimachia clethroides (Gooseneck loosestrife)
Monarda didyma (Bee-balm)
Physostegia virginiana (False Dragonhead)
Polemonium caeruleum (Jacob's ladder)
Primula spp. (Primula)
Pulmonaria spp. (Lungwort)
Pyrethrum (Painted Daisy)
Saxifraga (Saxifrage)
Silene caroliniana (Wildpink)
Thalictrum spp. (Meadow Rue)
Tradescantia virginiana (Spiderwort)
Viola spp. (Violets)

PERENNIALS FOR WET SOILS

Boltonia asteroides (White Boltonia)*
Caltha palustris (Marsh Marigold)*
Eupatorium purpureum (Joe-pye-weed)
Hibiscus moscheutos (Swamp Rose-Mallow)*
Iris versicolor (Blue Flag)*
Iris kaempferi (Japanese Iris)*
Iris siberica (Siberian Iris)
Lobelia cardinalis (Cardinal Flower)
Miscanthus sinensis (Eulalia or maiden grass)
Monarda didyma (Bee balm)
Myosotis scorpioides (True Forget-me-not)
Onoclea sensibilis (Sensitive Fern)
Osmunda cinnamomea (Cinnamon Fern)*
Osmunda regalis (Royal Fern)*
Primula spp. (Primula)
Saxifraga pennsylvanica (Pennsylvania or Swamp Saxifrage)

* May be grown in water.

PERENNIALS THAT MAY BE GROWN IN WATER

Caltha palustris (Marsh Marigold)
Iris versicolor (Blue flag)
Osmunda regalis (Royal Fern)

PERENNIALS FOR POOR SOIL

Achillea millefolium (Milfoil or Yarrow)
Ajuga genevensis (Geneva Bugle)
Artemisia spp. (Wormwood, Artemisia)
Aurinia saxatilis (Goldentuft)
Cerastium tomentosum (Snow-in-summer)
Gypsophila paniculata (Baby's breath)
Helianthemum nummularium (Rock or Sun Rose)
Iberis sempervirens (Evergreen Candytuft)
Phlox subulata (Moss Phlox)
Potentilla spp. (Cinquefoil)
Sedum stoloniferum (Running Sedum)
Sempervivum spp. (Hen and Chickens)
Verbascum thapsus (Mullein)
Veronica rupestris (Creeping Speedwell)
Viola cucullata (Marsh Blue Violet)

PERENNIALS REQUIRING WELL DRAINED SOIL

Arabis alpina (Alpine Rockcress)
Aubrieta deltoidea (Purple Rockcress)
Baptisia australis (False Indigo)
Coreopsis grandiflora (Tickseed)
Dianthus barbatus (Sweet William)
Digitalis purpurea (Foxglove)
Echinops ritro (Globe Thistle)
Eryngium maritimum (Sea-holly)
Globularia trichosantha (Globe Daisy)
Helianthus maximiliani (Maximilian Sunflower)
Iberis sempervirens (Candytuft)
Iris germanica (German Iris)
Linum perenne (Blue flax)
Nepeta spp. (Catmints)
Papaver nudicaule (Iceland Poppy)
Penstemon spp. (Beardtongue)
Perovskia spp. (Russian Sage)
Salvia spp. (Sage, Salvia)

PERENNIALS FOR DRY, SANDY SOIL

Achillea ptarmica (Sneezewort)
Anthemis tinctoria (Golden Marguerite)
Aster novae-angliae (New England Aster)

Armeria spp. (Thrift)
Artemisia spp. (Artemisia, Wormwood)
Coreopsis grandiflora (Tickseed)
Dianthus plumarius (Grass Pink)
Echinops ritro (Globe Thistle)
Eryngium spp. (Sea Holly)
Helianthus spp. (Sunflower)
Lavendula spp. (Lavender)
Limonium latifolium (Statice)
Linum spp. (Flax)
Papaver nudicaule (Iceland Poppy)
Rudbeckia laciniata (Coneflower)
Sedum spp. (Stonecrop)
Sempervivum spp. (Hens and Chickens)
Thymus spp. (Thyme)
Yucca filamentosa (Common Yucca)

PERENNIALS FOR LATE SUMMER BLOOM

Aconitum spp. (Monkshood)
Aster spp. (Asters)
Boltonia asteroides (Boltonia)
Chelone spp. (Turtlehead)
Echinacea purpurea (Purple Coneflower)
Helenium autumnale (Helen's flower)
Heliopsis spp. (False sunflower)
Hosta spp. (Hosta)
Liatris spicata (Gayfeather)
Phlox paniculata (Summer phlox)
Ratibida spp. (Grey Coneflower)
Sedum spectabile (Autumn Joy sedum)

FRAGRANT PERENNIALS

Agastache anisata (Anise hyssop)
Anthemis tinctoria (Golden Marguerite)
Arabis caucasica (Rock cress)
Bellis perennis (English daisy)
Calamintha spp. (Calamint)
Centranthus ruber (Red valerian)
Dianthus spp. (Pinks, carnations)
Galium odoratum (Sweet woodruff)
Hesperis matronalis (Dame's rocket)
Lavandula spp. (Lavender)
Lilium spp. (Lily)
Nepeta spp. (Catmints)
Paeonia spp. (Peony)
Primula spp. (Primula)
Valeriana officinalis (Valerian)
Viola spp. (Violet)

ANNUALS FOR SPECIAL ENVIRONMENTS

TENDER ANNUALS

Ageratum	Morning glory
Amaranth	Nasturtium
Balsam	Nicotiana
Begonia	Petunia
Celosia	Salvia
Coleus	Verbena
Impatiens	Vinca
Marigold	Zinnia

HEAT-RESISTANT ANNUALS

Ageratum	Larkspur
Castor Bean	Marigold
Celosia	Morning glory
Cleome	Nicotiana
Cornflower	Nierembergia
Cosmos	Phlox drummondii
Dusty Miller	Pinks
Four o'clock	Portulaca
Gaillardia	Salvia
Gazania	Scabiosa
Geranium	Shasta daisy
Globe Amaranth	Sunflower
Gloriosa	Verbena
Helichrysum	Zinnia
Heliotrope	

EXTREMELY HEAT-RESISTANT ANNUALS

Four o'clock	Sunflower
Morning Glory	Zinnia

ANNUALS FOR PARTIAL SHADE

Alyssum	Lobelia
Aster	Myosotis
Balsam	Nasturtium
Begonia	Nicotiana
Browallia	Pansy
Calendula	Petunia
Coleus	Snapdragon
Cornflower	Torenia
Impatiens	Wallflower

ANNUALS THAT TOLERATE HEAT, DROUGHT, AND SANDY SOILS

Alyssum	Phlox
Cleome	Portulaca
Daisy	Salvia
Gaillardia	Sunflower
Gloriosa	Verbena
Marigold	Zinnia
Petunia	

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CHAPTER 12: WOODY ORNAMENTALS

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WOODY ORNAMENTALS

INTRODUCTION

Woody ornamental plants are key components in a well-designed landscape. This large body of plants falls into four groups: trees, shrubs, vines, and groundcovers. Trees are woody plants that produce one main trunk and a more or less distinct and elevated head with a height of 4.5 m or more. Shrubs are woody plants that grow 4.5 m or less. They produce shoots or stems from the base and do not form a single trunk. Vines are climbing or crawling on woody or semi-woody plants with no self-supporting, upright stems. Groundcovers are very low plants which supplant turf, particularly where mowing or growing grasses is difficult.

This chapter describes how to select plants based on their desired uses, environmental factors influencing plant growth, and procedures for planting and caring for woody plants.

PURCHASING PLANTS

Woody ornamentals are usually sold as transplants. Transplants can be classified into three groups according to the way they are dug and shipped: bare-rooted plants, balled and burlapped plants (B&B), and container-grown plants.

Bare-Rooted

Bare-rooted plants have had the soil washed or shaken from their roots after digging. Nearly all are deciduous trees or shrubs that are dormant. Most mail order plants are of this class because plants in soil are too heavy to ship economically. Many tap-rooted plants, such as nut trees and some fruit and shade trees, are handled this way because they are not amenable to balling and burlapping.

Bare-rooted plants are also those available in nurseries in early spring with their roots wrapped in damp sphagnum and packaged in cardboard or plastic containers. These need special attention because their roots are tightly bound in unnatural positions in order to package them. Discard the sphagnum packing, and be sure to spread the roots out to a natural position before they are planted. Plants in the bare-rooted class are planted while dormant. Never let the roots dry out.

This is perhaps the single most important reason for failure in planting bare-rooted plants. Keep roots moist - wrapped in plastic or wet paper until you are ready to plant. Roots can be soaked in water for up to six hours before planting. Bare-rooted plants may need root-pruning at planting time to repair damaged roots as well as stem-pruning to correct broken stems.

Balled and Burlapped (B&B)

B&B plants are likely to have been grown in nursery rows for some time and to have been root-pruned so the root system within the ball is compact and fibrous. Such plants re-establish themselves rapidly.

Plants in this class are planted almost any time the ground can be worked. If put out in summer, however; pay special attention to their water needs.

When selecting a balled and burlapped plant, be sure the ball is sound and hasn't been broken. Avoid plants that feel loose in the soil ball or have been lifted by the trunk. Be sure the soil ball does not dry out.

Container-Grown

Plants grown in the container in which they are sold are becoming increasingly popular in the nursery trade. Their appearance often misleads gardeners into thinking that all they have to do is set the plants into the ground and forget about them. But, in fact, these plants need the same careful planting and maintenance as others do.

This class of plants may have what can be called a container habit. Their roots are contained in a limited space and coiled around one another tightly in the container.

To correct the problem, first remove the plant from the container. Separate the roots gently and, if necessary, by slicing shallowly into the root ball in several places. Gently pull the roots apart, spreading them out. This will prevent girdling roots and encourage new lateral root growth.

When selecting plants, look for a good natural shape, free of thin spots or broken limbs. Make sure the root ball is solid. Avoid container-grown plants with visible roots circling on the surface or coming out of the drainage holes. Plants with damaged bark should be passed over.

Container-grown plants can be planted any time the ground can be worked. Proper watering is critical.

Table 12-1: NURSERY TREE AND SHRUB SELECTION CHECKLIST

LOOK FOR:	AVOID:
Species or varieties well adapted to soil, water, light, heat, wind, and other prevailing conditions where they will be planted.	Species or varieties poorly adapted to local environmental conditions. Check your hardiness zone.
Plants that at maturity will fit into the space provided for roots and branches.	Plants that at maturity will be too large for the available space. Do your research.
Pest-resistant species or varieties.	Species or varieties prone to pest problems.
Roots, bark and crown areas free of rot, galls, wounds, and insects.	Injured, distorted, diseased roots, or crown areas.
Roots that are not kinked or circling the trunk.	Encircled or kinked roots around trunk.
Roots that aren't a solid mass or are too small compared to aboveground plant parts.	Trees that cannot stand without being staked
Good overall plant appearance, color, leaf size, and vigor. Smaller sized plants are more likely to survive transplanting.	Discolored, undersized, distorted foliage or branches.
A tree trunk that has not been headed back or topped and is well-shaped.	Trees that lack a single, dominant leader, or have been topped.

*Adapted from: University of California, 1994. **Pests of Landscape Trees and Shrubs**. Publication 3359. University of California Division of Agriculture and Natural Resources.*

PLANTING TIPS FOR TREES

INTRODUCTION

Trees are the most significant plants in the landscape. They help to create the feeling of spatial enclosure that forms the basic framework upon which all other landscape design elements are built. They meet several needs in the urban, suburban and rural landscape. Trees provide shade, beauty, screening, and habitat for wildlife. They can also soften the architectural features of a building. High quality species of trees will also increase the value of the home property. Trees do their jobs well and will do so for a long time. That is why careful selection, placement and planting are very important. It takes ten years or longer to attain reasonably sized trees. Don't get discouraged and be patient. Given the proper care, small trees will grow well and reward you.

Tree Selection Tips

- Select quality tree species with strong wood, minimal surface rooting problems, low susceptibility to disease or insect pests and tolerance of the weather and soil conditions of the site. Always buy trees from a reliable nursery. A high quality tree will show no bark damage, insect or disease problems, or signs of being root bound.

- Some species have characteristics that are undesirable in certain situations. Many of these are listed on pages 12-15 and 12-16.
- Select the correct size tree for your landscape. There are many types of trees that range in height from 8 m to over 25 m. Some have a spreading habit of growth, while others grow more upright. A little research before buying a tree will assure you that your selection will not outgrow its site. For many species there are dwarf cultivars available that are ideally suited to smaller yards and spaces.
- The trunk and branching pattern of a shade tree are also very important. Avoid trees with trunks that divide into multiple leaders or with branches that originate at sharp angles from the trunk. These are potential problems as they are prone to breaking when the tree becomes large. Some exceptions are flowering cherries, clump-form birch and Japanese maples.

SITE SELECTION

Good soil drainage to a depth of at least 1.5 m is needed for ornamental trees and shrubs in a landscape planting. Plants on poorly drained soil may exhibit one or more symptoms of poor growth. If the site is low, install drainage tile to remove excess water before plants are set out. The tile must have an outlet at a lower level so the water can move out freely.

If using tile is impractical, or a suitable outlet for the water cannot be arranged, the grade may be elevated by using fill to provide better runoff and drainage conditions.

Most trees and shrubs tolerate a rather wide range of soil pH. A pH range of 6.0 to 7.0 is suitable for most landscape plants. They usually will make satisfactory growth without special treatment to raise or lower pH.

Plants such as andromeda, azalea, blueberry, holly, laurel, pieris and rhododendron are exceptions to the above rule. They grow best on an acid soil with a pH of 5.0 to 5.5. On soils with a pH of 6.0 or higher, these acid-loving plants may grow poorly and become quite yellow. You should have the soil tested to determine the pH level. If the pH is too high, it can be lowered by using sulfur, iron sulfate, or aluminum sulfate (see Chapter 3). Aluminum sulfate is the least desirable for long-term use because of potential aluminum toxicity. After several months, test the soil again to determine the effectiveness of treatment. You may need to repeat the application every year or two to maintain the desired pH level.

When to Plant Trees

Most nursery grown trees can be successfully planted any time of year. Early spring and early fall are the preferred times to plant. Many deciduous species can be successfully planted when dormant in the fall. Weather conditions are conducive to good root growth and rapid establishment at these times. Exceptions to fall planting are oak, dogwood, sourgum, tulip tree, pine, magnolia, beech, yellowwood, mountain ash, hemlock and larch.

Planting Procedure

1. Prepare the site by loosening the soil in a wide area (i.e., two times wider than the actual plant hole). Do not dig much deeper than the root ball or the tree might sink into the ground too deeply as the soil and tree settle. The sides of the planting hole should slope outwards when planting in heavy soil.
2. Do not add soil amendments such as compost or peat moss directly into the planting hole. In clay soils, drainage problems are created when these materials are not incorporated with existing soil, causing water to be drawn into the hole. This water remains in the hole for an extended period and rots the roots. A better method is to incorporate organic matter into the soil removed from the hole and backfill with the amended soil. Improving the soil surrounding the tree with coarse organic matter such as leaf mould or chopped leaves is also beneficial.

In sandy soils, a similar procedure should be followed to ensure that adequate moisture is retained in the planting hole.

3. In heavy clay soils, plant the tree with the top of the root ball slightly higher than the existing soil line. Eight to ten percent of the root ball above the line may be needed in some soils. Grade the soil out gradually from the root ball to keep it secure and to prevent the root ball from drying out.
4. When space allows, plant shade trees in mass plantings. This creates a natural setting that is attractive and makes it possible to have more trees in your yard. Trees grown in "island" plantings tend to be healthier than those planted singly.
5. Fertilization of a newly planted tree is usually helpful. Ideally, the soil should be tested before planting so that the recommended fertilizer can be worked into the soil before planting. Use a fertilizer with an analysis low in nitrogen and high in phosphorus and potassium (i.e., 5-10-10). The phosphorus and potassium will promote root growth. Fertilizer should not be applied if a dormant tree is planted in late fall. Wait until the plant has been growing for one season before fertilizing again.
6. If balled and burlapped, remove the cords and cut the burlap loose from the root ball. The cords used today on balled and burlapped roots are usually made of plastic. As the tree grows it will girdle the trunk. Some burlap is treated to retard rotting, and some root ball wraps are plastic or synthetic burlap. These should always be removed.

Care After Planting

1. Do not stake a newly planted tree. Research has shown that the natural movement of the trunk by the wind actually stimulates root growth and increases trunk caliper more quickly than is the case with staked trees. If the tree has an adequate-sized root ball and is properly planted, the tree will not fall over or lean. Occasionally, with very windy conditions and soft soil, staking may be needed for the first season. Allow enough slack in the guy wire for some trunk movement. Use a rubber hose over the wire to prevent bark damage.
2. Do not "head back" a tree after planting. It is not necessary to "balance" top growth with roots. The tree needs the top growth to generate root growth. The carbohydrates stored in the branches are used during root growth.

Nursery trees should already be properly pruned and usually need no further pruning when planted. Fruit trees are an exception.

3. To wrap or not to wrap your tree? Trunk wrap is often used for the first season after planting to help reduce sun scald on the bark. Some trees seem to be very prone to sun scald after being planted in a new location if the original southern orientation of the trunk has been changed. If possible, ensure that the original southern orientation of the tree is maintained by marking the north side of the trunk before the tree leaves the nursery or is dug. Winter wraps are used not only to prevent sunscald, but also to deter rodents and deer. These guards tend to be quite rigid and should be placed carefully and checked annually to prevent damage to the tree. Some arborists feel trunk wrapping is helpful, while others believe it makes no difference.
4. Research has shown that an effective way to maximize growth of trees is with a large mulched area instead of grass under the tree. This will reduce competition for nutrients and moisture between young trees and grass. Mulch new trees as far out as the spread of the branches. Large trees also benefit from a mulched area at least 4.5 m beyond the trunk or as far as the spread of the branches. This may not be practical unless the trees are in a mass planting. The mulch layer should not exceed 9 cm in thickness.
5. Keep trees properly watered. 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 gives the soil time to absorb water and prevents creating muddy conditions during planting. Once a tree or shrub has been planted, shape the soil around the stem to create a shallow depression the diameter of the root ball. Fill the depression with water. This permits water to go straight to the root zone rather than run off the surface. Thorough soaking during planting eliminates air pockets around roots. It is important when planting (particularly container-grown material) to avoid covering the top of the root ball with more than 1 to 2 cm of fine soil. Otherwise, water may be diverted sideways through the native soil and not soak down into the root ball, where it is needed. Newly planted trees should be watered when the soil below the mulch and in the root ball feels dry. Be careful not to over-water. Many people have inadvertently drowned newly planted trees by watering them too often.

Figure 12-A: Healthy roots are vital to plant survival. Woody plants have several different types of roots and about 90% of roots grow in the upper 1 m of soil. Up to about 70% of roots are in the top 30 cm, and because roots need air, even more of a tree's roots are near the surface if soils are compacted or water-logged. Conversely, drought-adapted species and trees in deep or well-drained soil have more of their roots growing deeper below ground than shown here. Roots typically extend beyond the tree canopy drip line.

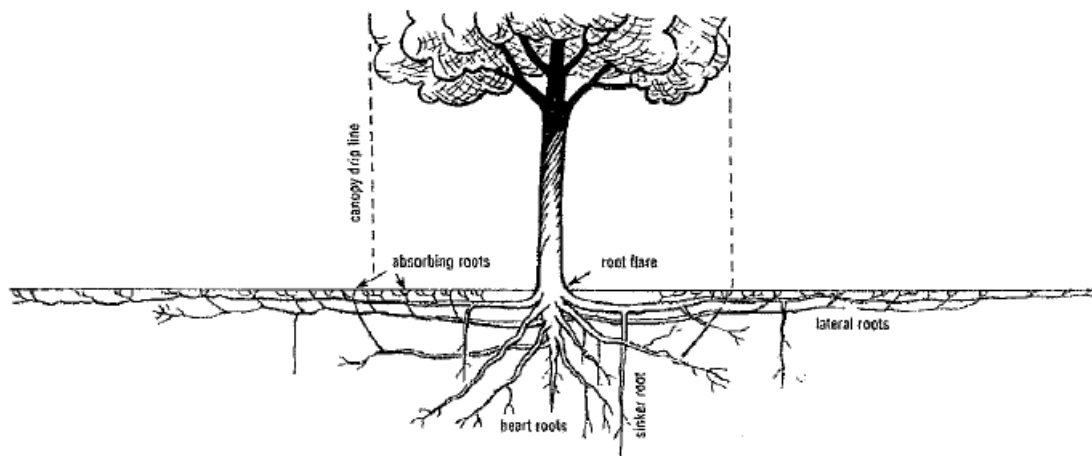
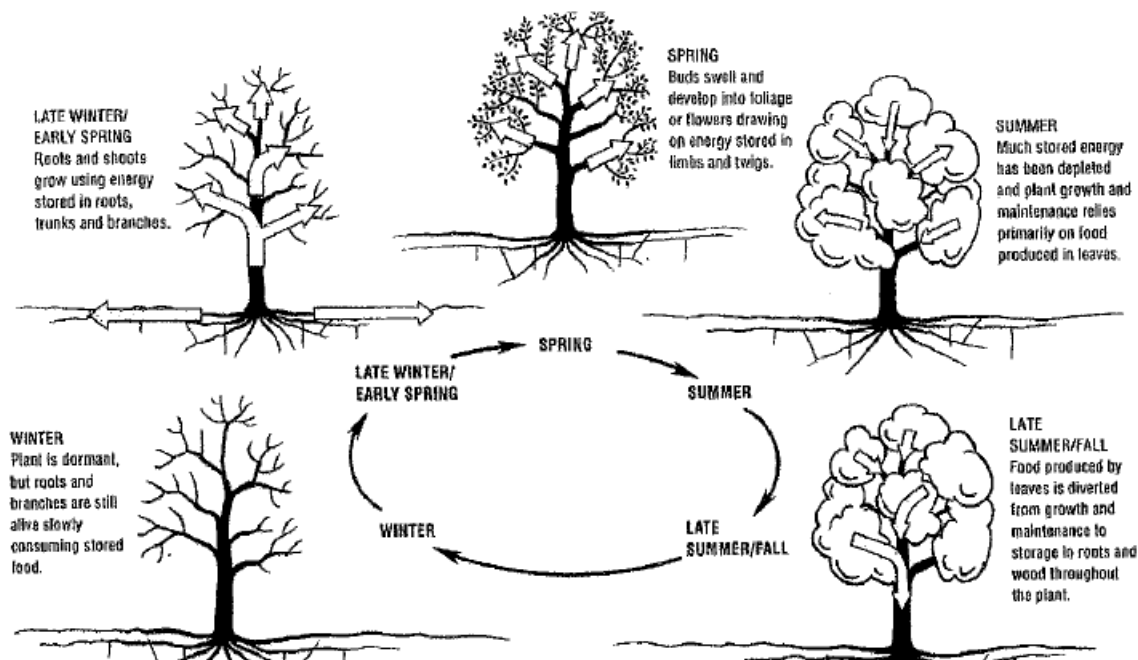


Figure 12-B: The seasonal growth cycle of a typical deciduous, perennial plant. Wide arrows indicate the direction of major energy flow in the form of carbohydrates.



Source for Figures 12-A and 12-B. Flint, M.L. 1994. *Pest of Landscape Trees and Shrubs*. Publication 3359. Division of Agriculture and Natural Resources. University of California.

CARING FOR TREES AND SHRUBS

PRUNING AND SUPPORTING NEWLY INSTALLED PLANTS

For all newly planted woody plants, it is usually best to avoid heavy pruning at planting if you can ensure that the plants will be well watered during their first year or two in the ground. Remember that your tree will not resume a normal growth rate until the original root system size is re-established. Pruning also reduces the leaf surface area that produces photosynthates, essential for root growth and the final establishment of the tree. Pruning may also force a proliferation of water sprouts in the inner canopy.

Some initial light pruning, however, may be needed immediately after planting. Container-grown and balled and burlapped plants require only the removal of all broken and damaged branches. Some minor cosmetic pruning might also be in order at this time to improve the overall appearance.

- Remove all sucker growth coming from the base of the tree. If the plant is grafted, this growth could weaken the tree.
- If the tree has multiple leaders, remove all but one.
- Other interfering branches should either be removed or be headed back, to slow their development. If headed back, they should be removed in a few years once the tree is established.

All support should be removed from a small tree within one year after planting. The tree should have become established in this period of time. It has been reported that growth is actually reduced if the supports are left in place for longer periods of time.

FERTILIZING ORNAMENTAL TREES & SHRUBS

Ornamental trees and shrubs planted in fertile, well drained soil should not require significant annual fertilization. **Trees and shrubs that are growing well don't require extra nutrients.** They receive some fertilization when the lawn is fertilized. If you have mature ornamentals that are not doing well, fertilization may be helpful but only after the problem causing poor growth has been corrected.

Poorly growing plants will exhibit any or all of these symptoms:

- Light green or yellow leaves.
- Leaves with dead spots.
- Leaves smaller than normal.
- Fewer leaves and/or flowers than normal.
- Less than 10 cm of new twig growth per year on mature standard trees.
- Dying back of branches at the tips.
- Wilting of foliage.

These symptoms may be caused by inadequate soil aeration, moisture, or nutrients; by adverse climatic conditions; by incorrect pH; or by disease. Ornamentals transplanted or disturbed by construction within the previous five or ten years may be in shock or the soil may be severely compacted. You should attempt to determine the specific cause in each particular situation and apply corrective measures. Do not assume that an application of fertilizer will quickly remedy any problem encountered (see **Diagnostic Keys, Chapter 18**).

A feeding program must be coupled with proper cultural practices. For example, neglecting necessary insect or disease control and failure to remove dead wood from a large shade tree will negate the positive effects of fertilization.

OVER-FERTILIZATION

A moderate rate of growth and good green color is all that is desired of woody plants. Over-fertilized trees may exhibit the following problems:

- Excessive vigor, which is evident by lush green leaves and long shoot growth. Such plants are more susceptible to injury and insect damage, are more likely to be broken during wind and sleet storms, and usually have a shorter life than those making moderate growth.
- Weak, brittle wood that breaks in storms.
- Excessive growth, especially on shrubs. They may outgrow the location in which they are planted and require extra care and pruning.
- Root damage or root burn. Burn is a term describing visual symptoms of dehydration due to over-application of fertilizer.

Symptoms resemble those of drought damage.

Plants are injured by lack of water even though sufficient water may be present in the soil.

Fertilization in late spring and early summer is more likely to burn roots, especially during a dry season.

Proper tree and shrub fertilization is an investment in a more attractive landscape planting.

Fertilizing Trees

How much and how often to fertilize shade trees depends on the size, species, and growth rate desired. Established trees benefit from fertilization once every 3 to 4 years at a rate of 0.5 to 1 kg per 2.5 cm of trunk diameter. For trees larger than 15 cm diameter (measured at chest height) the rate should be increased to 1 to 2 kg. A fertilizer with a 5-4-3 or 5-3-2 ratio is appropriate.

The best period of the year to fertilize trees is early spring, before active top growth occurs. Fertilizer is absorbed by the roots when soil temperatures are above 5°C. Avoid fertilizing trees and shrubs in summer and early fall since this interferes with the plant's ability to prepare for winter dormancy (harden off).

Did You Know?

80% to 90% of nutrient-absorbing roots of most trees grow in the upper 25 to 30 cm of soil and the roots extend in a wide area from the trunk.

- Research studies to date have shown the greatest plant responses are to additions of nitrogen. A commonly used complete fertilizer for this purpose is 10-6-4.
- Fertilizers with a slow release form of nitrogen are recommended. The application rate is based on the approximate area of root zone of the tree. Start by measuring the area of the tree's root zone. The amount of fertilizer is based on the actual nitrogen. The recommended rate of nitrogen is no more than 0.5 kg of actual nitrogen per 100 m². For example:

A 230 m² area would require 11.5 kg of 10-6-4 fertilizer.

- The most practical way to fertilize large trees is to broadcast the required amount of granular fertilizer on the surface of the soil under the canopy and 2.5 to 3 m out from the dripline and allow water to transport the nutrients to the roots.

- Fertilizing in late fall reduces the chances of injury to the lawn.
- Granular or liquid fertilizers may be injected into holes no deeper than 20 to 25 cm deep. These holes should be made in a regular pattern at 50 to 75 cm intervals, starting with the drip line for single trees and within 1 to 1.5 m from the trunk for groups of trees. Fertilizing should extend at least to a radius equal to the height of the tree.
- To use granular fertilizers, auger 2.5 to 4 cm diameter holes into the soil at 50 to 75 cm intervals. After all of the holes have been drilled, divide the calculated amount of fertilizer by the number of holes and place the proper amount in each hole with a can or funnel. Scrape the augured soil back into the hole after fertilizing.
- Holes for fertilization should be made with a soil auger. This method is preferred over using a pipe or a bar because as the hole is made larger by wiggling the bar, the wall of the hole become less porous. This may delay the movement of the fertilizer into the surrounding soil.
- Compressed fertilizer "spikes" are also available for tree fertilization. These are driven into the soil with a heavy hammer and can only be used effectively when the soil is moist. However, they are costly and can burn roots and injure lawns, particularly in dry soils.

Liquid injectable fertilizer is also available. It is frequently used commercially. Special injecting needles that connect to the garden hose and prepackaged water-soluble fertilizers are available to the home gardener. When using these, the tip of the Injection needle should be inserted 20 to 25 cm into the soil at 50 cm intervals, in the root zone of the tree.

Fertilizing Acid-Loving Plants

Rhododendrons, azaleas, mountain laurel, pin oak, pieris, and leucothoes require an acid soil. The first step is to plant them in soils that are naturally acidic, with an approximate pH of 4.5 to 6.0. Incorporate liberal quantities of peat, pine bark, or other acidifying organic matter into the soil as it is being prepared for planting.

Do not use a compost material that has had limestone added. Limestone should never be used for these acid-loving plants unless a soil test indicates the need for it.

One yearly application in early spring of a complete fertilizer, such as a 10-6-4, is sufficient. Apply this at the rate of 0.5 kg of fertilizer per 10 m².

If the soil is well supplied with phosphorus and potassium; only nitrogen is necessary, such as ammonium sulfate (21-0-0) or ureaform (38-0-0) at the rate of 200 g per 10 m².

Trade-named fertilizers prepared for acid loving plants often include some material to maintain an acid soil. Such products should be used only at the rates that are recommended and then only when necessary. Repeated applications without checking the soil pH can actually make the soil too acidic and adversely affect micronutrient availability.

Fertilizing Evergreen and Deciduous Shrubs

The best practice in growing evergreens and deciduous shrubs is to start with soil in good condition; a soil with open tilth and adequate organic matter. Then only a light application of fertilizer is needed every few years to maintain the shrubs in a healthy condition. Apply the fertilizer in early spring. Broadcast it uniformly on the soil under the plant and cultivate it lightly into the soil. An application of 1 to 1.5 kg of a 5-10-5 fertilizer per 10m² should be sufficient. The lower rate of nitrogen fertilizer is used around foundation plantings to reduce excessive growth in soils with a low level of fertility. Plants that have not been fertilized for several years may have the rate increased to 1.5 to 2 kg per 10 m² the first year it is applied.

CHLOROSIS

Iron deficiency (chlorosis) appears as a yellowing of the new leaves at the ends of the branches, with the mature leaves remaining dark green. The veins in the chlorotic leaves may be green. This deficiency can be temporarily corrected with one or two applications of iron sulfate sprayed on the foliage. If necessary, a second application may be made in 10 to 14 days. For longer-lasting control, apply 0.5 to 1 kg of iron sulfate per 10 m² of area under the plants and water in thoroughly. Iron chelate is another material that will correct iron deficiency. Rates of application of iron chelate vary and package instructions should be followed. If the chlorosis persists, have the soil tested, requesting the special test for manganese (Mn).

Poor soil drainage, over-watering, over-mulching, planting too deeply, magnesium deficiency, root nematodes, or any condition that causes root injury will also produce chlorosis symptoms. Soils, either alkaline or near the neutral point, generally have an insufficient amount of iron available to plants for proper growth.

Such an iron deficiency condition sometimes develops near building foundations, where plaster, cement, and other construction debris have been discarded and covered with soil.

In very sandy soils, magnesium deficiency can also be a serious problem with acid-loving plants. The symptoms resemble chlorosis, with pale, yellow-green foliage and short, unhealthy-looking new growth. Soil testing is the only accurate method to determine this deficiency, providing samples are taken from the upper 7.5 cm of soil, within the drip line of the plants. The deficiency can easily be corrected by applying 115 g of magnesium sulfate (Epsom salts) per 10 m² and irrigating thoroughly.

MULCHING PLANTS

For year-round benefits of mulching, apply a 5 cm layer of mulch around recently planted trees. This mulch will conserve moisture and help suppress the growth of weeds and grass. A circle of mulch 1 to 1.5 m in diameter should be maintained around shade trees. All mulches should be tapered away from the trunk.

In some cases, mice may tunnel into 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 place the mulch 15 cm from the base. A circle of crushed stone or coarse, sharp cinders 15 cm wide around the base may also be helpful.

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

Softwood or Hardwood: Softwood (pine bark) mulches are preferable because they are slower to decompose. Hardwood mulches contain high manganese levels which may produce toxicity symptoms, especially in plants growing in low pH soils.

Bark: A 5 to 8 cm layer of one of several types of bark provides good weed control. Bark is slow to decompose and will stay in place. 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 very attractive mulch and is especially recommended around trees and shrubs. When used over black plastic around perennials, bark provides effective weed control for long periods of time. Be sure there are holes in the plastic to allow water to penetrate.

Pine needles: Baled pine needles are also found in garden centres for use as mulch. They make excellent mulch for acid-loving trees and shrubbery.

Grass clippings: A 5 cm layer of grass clippings provides good weed control. Build up the layer gradually, using dry grass partially incorporated into the soil, to prevent a solid mat from forming. Clippings decompose rapidly and provide an extra dose of nitrogen to growing plants, and make fine humus. Avoid crabgrass and grass full of seed heads. Do not use clippings from lawns that have been treated that season with herbicides or a fertilizer-herbicide combination ("weed and feed" types).

Leaves: A 5 to 8 cm layer of leaves provides good weed control. Leaves decompose fairly quickly but are easily blown unless shredded or partially decomposed. Leaves are usually easy to obtain, attractive as mulch, and improve the soil once decomposed. They are highly recommended as mulch.

Gravel and stone: A 2.5 cm layer of rock provides fair weed control. These materials make good mulch for permanent plantings, around foundation plants and in alpine gardens. They are not recommended for acid loving plants, since alkaline elements within the rocks may dissolve and leach into the soil. Use a landscape fabric under gravel and stone to prevent them from settling into the soil.

Black plastic: One layer of black plastic provides excellent weed control. It is broken down slowly by sunlight and must be replaced every 2-3 years. Black plastic mulch increases soil temperature by about 5°C in the spring. It may cause soil temperatures to rise excessively in mid-summer, though, "cooking" the roots of plants. Use a good foliage cover or organic mulch to prevent direct absorption of sunlight. Check periodically to see that soil remains moist beneath the plastic and cut holes in it where necessary.

Paper: Using two to four layers of newspaper provides good weed control. Newspaper decomposes within a season and is readily available and cheap. Cover with leaf or bark mulch to hold paper in place. It is excellent for use in pathways. The printers ink used in newspapers no longer contains lead.

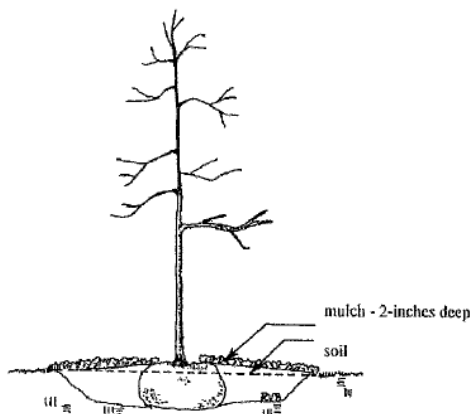
Landscape fabrics: These are synthetic, cloth-like materials that are spread over the soil surface to discourage annual weed growth in soil under plants. They come in two forms: woven and spun-bound. The woven types look like burlap or similar coarse fabric, or they may have the consistency of fine screen.

The spun-bound types have a more fibrous texture and are probably more effective on sloping ground because they are thicker, and their texture tends to hold rough, coarse-textured mulches in place. Generally, the thicker and more tightly woven fabrics are most effective at suppressing weeds. Neither type is intended to be used on the soil surface without a top coating of another material like bark or stone. **It is important not to allow annual weeds to germinate and penetrate downward through any of the landscape fabrics.** Growing conditions for roots are ideal under the fabric, and it is very difficult to pull established weeds out of this situation.

Vertical Mulching

The growth of trees in heavy clay or silty soil can often be improved by vertical mulching. This is done by auguring holes 5 to 8 cm in diameter, 30 cm deep and 1 to 1.5 m apart, in a pattern and area similar to that used for fertilizing. The holes are filled to the surface with compost or finely ground pine bark. Vertical mulching allows greater airflow and water into the soil, which encourages better root distribution and growth.

Figure 12-C: PROPER MULCHING TECHNIQUES FOR WOODY ORNAMENTALS



WATERING PLANTS

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 root rot, in which case the plant wilts because it is oxygen starved, and cannot take up moisture. As a rule, plants can withstand moderate drought more easily than excessive moisture. For this reason, it is important to water thoroughly yet allow the soil to become fairly dry between waterings.

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. This can encourage the growth of fungus or mildew, making plants unsightly and jeopardizing their health.

Drought Stress

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 does not harm plants. Over a prolonged period, however, it will cause permanent damage. Sometimes a plant wilts 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 late summer or early fall it is not uncommon to experience a sustained period of wilting, particularly of broadleaved evergreens such as rhododendrons. The latest research has shown late summer drought to be the cause of leaf damage typically attributed to winter desiccation. When the leaves hang down and no rain is predicted, it is advisable to provide prolonged, deep watering to keep the leaves rigid. To wet the soil at least 15 cm deep requires 2 to 5 cm of surface water (250 to 500 L water per 10 m²).

Well-established groups of woody plants should be watered every 10 days during prolonged dry spells. Since root systems of established plants are rather widespread and deep, it is vital that enough moisture be put down to reach them. If a sprinkler is set up to water a group of plants, a coffee can, should be placed in range of the sprinkler. When 2.5 cm of water accumulates in the can, 2.5 cm of water has been distributed in the soil; enough to penetrate 15 cm of soil.

Container-grown landscape plants may be susceptible to drought stress once they are transplanted into the landscape. The organic mix in which 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.

Available moisture in the container mix can be depleted in about two days in the absence of irrigation. For this reason, nurseries water at least every other day. This routine should be followed after transplanting until the root system establishes itself (approximately three to four weeks).

Practice effective watering:

- Know your soil. Observe how quickly soil dries out after a rain or watering. Clay soil drains slowly, porous sandy soil quickly. Incorporating organic matter into the soil will increase drainage in clay soil and moisture retention in sandy soil.
- Learn the cultural requirements of your plants. It is particularly important to supply relatively high soil moisture 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 5°C. If the soil is dry, the plants may become desiccated, turn brown, and die.
- Water shrubs several times during the late fall, if the soil moisture supply is low.
- Mulch plantings to reduce the frequency of watering during dry spells. Mulches keep soils cool and reduce water loss through evaporation.

One of the most effective watering methods is trickle irrigation. When combined with a layer of mulch, this method allows plants to use nearly all of the added water. A trickle system discharges small quantities of water on a regular basis directly to the root zone under a tree, shrub, or row of garden vegetables or flowers. Very little water is lost to the air through evaporation. The application rate can also be controlled to meet the needs of the crop and the drainage capacity of the soil.

When there is an extended period without rain during the summer, new plants should be deeply watered once a week. By allowing the soil surface to dry out somewhat between waterings, roots grow deeper into areas where soil moisture is highest. The roots of plants watered frequently, but lightly, are close to the surface, making the plants more vulnerable to wilting. They will not become well established and will have little drought tolerance. This can occur with automatic overhead sprinkler systems that are designed to go on for a short period of time each night and only moisten the surface. The practice also encourages foliar diseases in mid-summer.

Over or under-watering can severely stress a plant. If this occurs, the plant becomes more susceptible to disease and insect attacks (see **Tables 12-2 and 12-3**).

Table 12-2: COMMON PROBLEMS ASSOCIATED WITH UNDER-WATERING WOODY LANDSCAPE PLANTS

Damage Symptoms	Problem
Leaves drop prematurely	abiotic disorder
Leaves spotted	abiotic disorder
Leaves bleached/stippled	mites - insects that suck plant juices
Shoot or branch dieback	abiotic disorder Botryosphaeria canker wood-boring insects
Bark cracking	abiotic disorder
Bark or branch cankers	abiotic disorder Botryosphaeria canker cypress canker Cytospora canker
Bark weeping	abiotic disorder wood-boring insects Botryosphaeria canker bacteria
Bark with holes	wood-boring insects
Bark with sawdust	wood-boring insects

Table 12-2: COMMON PROBLEMS ASSOCIATED WITH UNDER-WATERING WOODY LANDSCAPE PLANTS

Damage Symptoms	Problem
Leaves drop prematurely	anthracnose diseases
Leaves spotted/dicoloured	fungal and bacterial diseases root and crown diseases vascular wilt diseases abiotic disorder
Fruit spotted/dicoloured	fungal diseases
Branch cankers	anthracnose diseases
Branches die back	root and crown diseases abiotic disorder

Source: University of California, 1994. *Pests of Landscape Trees and Shrubs*. Publication 3359, University of California, Division of Agriculture and Natural Resources.

WINTERIZING TREES AND SHRUBS

It is often necessary to give extra attention to plants in the fall to help them overwinter and start spring in peak condition. Understanding certain principles and cultural practices can help you prevent winter damage.

Causes of Winter Damage

Winter damage can be divided into three categories: desiccation, freezing, and breakage.

Desiccation, or drying out, is a significant cause of damage, particularly on evergreens. This occurs when water is leaving the plant faster than it is being taken in. Several environmental factors can influence desiccation. The needles and leaves of evergreens continue to transpire and give off moisture throughout the winter. When the soil in the root zone is frozen, water is lost from plant tissues and the plant may become desiccated. If the fall has been particularly dry, there may be insufficient ground moisture to supply the roots with adequate water.

Water loss is greatest during periods of strong winds and sunny, mild weather. The sun's heat can cause stomates on the lower sides of the leaves to open, thus increasing transpiration. Small, shallow-rooted plants are often injured when alternate freezing and thawing of the soil heaves the plants from firm contact with the soil and exposes the roots to drying winds.

Injury from desiccation is commonly seen as discolored, "burned" evergreen needles or leaves. It can be particularly serious if the sun's rays reflect off of a white-sided house or there is extended snow cover.

Freezing injury can take several forms. New growth stimulated in early fall by late summer fertilization or pruning may not have had time to harden off before extremely cold weather. Ice crystals rupture cell walls, showing up as dead branch tips and branches. A sharp temperature change between day and night may freeze the water within the trunk of a tree, causing it to explode or split open in a symptom called frost cracking. If not severe, these cracks seem to close when warm weather arrives, but the wood fibers inside may not grow together. This is sometimes called southwest injury because it is commonly found on the southwest side of shade trees where warm, afternoon sun creates extremes in day and night temperatures.

The sun can also prematurely stimulate the opening of flowers or leaf buds, killing them in freezing night temperatures. Bud injury due to the cold temperatures of winter can also occur in the dormant stage of more tender trees and shrubs. Flowering shrubs may lose their flower buds although their leaf buds usually come through. Root injury may occur if container-grown or balled and burlapped stock has not been planted when extremely cold weather arrives. Lethal root temperatures begin at -5°C for some species if they are not dormant.

Breakage of branches is usually related to snow and ice. Two causes of damage by snow and ice are weight and careless snow removal. High winds compound the damage done when ice is on the plant. Damage may cause misshapen plants or produce broken branches and split trunks. When removing snow from plants be gentle and do not beat the plant. An upward movement through the plant with a broom or similar object will dislodge snow and allow it to filter through the branches and foliage.

DAMAGE CONTROL

PREVENTING WINTER DAMAGE

Much of the disappointment and frustration of winter-damaged plants can be avoided by planning ahead.

Select hardy plants: Grow plant materials that are native or are known to be winter hardy in your area.

Select appropriate site: When planting broadleaved evergreens known to be easily injured, such as some varieties of rhododendron, azalea, daphne, and holly, choose a location on the north, northeast, or eastern side of a building or other barrier where plants are protected from prevailing winds and intense winter sun. These exposures will also delay spring growth, thus preventing injury to new growth of flowers from late spring frost.

Avoid poorly drained soil: Avoid low spots that create frost pockets and sites that are likely to experience rapid fluctuations in temperature. Since heavy snow and ice can cause much damage to branches and trunks, it is important that plants be placed away from house eaves and other snow or ice-collecting areas where snow or ice are likely to fall onto the plants.

Follow recommended cultural practices: Plants that are diseased or deficient in nutrients are more susceptible to winter injury than strong, healthy plants.

Fertilize in the fall: Fertilizing after plants are dormant but before soil temperature drops below 7°C may be of value in preventing winter damage. Avoid late summer or early fall fertilization while plants are still active. This stimulates late fall growth that is easily killed by the cold.

Prune properly: Proper pruning at an appropriate time throughout the year is effective in reducing damage by ice and snow. Particularly important is the removal of any weak, narrow-angled, V-shaped crotches. Avoid late summer pruning, which stimulates new, tender growth and reduces the supply of nutrients available to the plant through the winter.

Water properly: Watering can be a critical factor in winterizing. If autumn rains have been insufficient, give plants a deep soaking that will supply water to the entire root system before the ground freezes. This practice is especially important for evergreens. Mulching is an important control for erosion and water loss. A 5 cm layer of mulch such as bark, pine needles, or wood chips will reduce water loss and help maintain uniform soil moisture around roots.

Mulching also reduces alternate freezing and thawing of the soil, which heaves some shallow-rooted plants and can cause significant winter damage.

Protect against damage: Special precautions can be taken to protect plants during the winter. Small evergreens can best be protected by using windbreaks made of burlap, canvas, or a similar material. Windbreaks help reduce the force of wind and also shade the plants. They can be created by attaching materials to a frame around a plant. A complete wrapping of burlap is sometimes used. Black plastic should be avoided for wrapping plants. During the day heat builds up inside and actually increases the extreme fluctuation between day and night temperatures. Heat buildup may speed growth of buds in the spring, making them more susceptible to a late frost.

Certainly these various boxes, shields, and wrappings add nothing to the aesthetics of your winter landscape. If your ornamentals require these annual protection measures, it would be wise to move them to a more protected location or replace them with hardier specimens.

Anti-desiccant compounds are readily available to homeowners. However, research has shown that some of these compounds degrade rapidly and are of little value unless repeat applications are made throughout the winter months.

Frost Protection

Protection against an early fall or late spring frost, can be given to a particularly valuable specimen by providing it with a fine, gentle, continuous spray of water. Satisfactory protection can be obtained in many cases, even when the temperature drops as low as -7°C. When the air temperature drops below freezing, the water sprayed onto the plant begins to form ice. During the process of freezing, water gives off heat and enough heat is absorbed by the plants to prevent them from freezing. As long as water is applied continuously, the plant remains above its freezing point. Application of water must begin when the temperature at plant level reaches 1°C and must be constant throughout the period when the air temperature is below freezing and continued until all ice has melted off the plant. Stationary or rotary sprinklers will give satisfactory results. This technique is also useful when late spring frosts threaten flowering trees or shrubs. Bark splitting, especially dangerous on newly planted trees, can be prevented by wrapping trunks with burlap strips or commercial tree wrap.

If Winter Injury Occurs

At winter's end examine plants carefully. Remove only those branches that are broken or so brown that they are obviously dead. Do not remove branches if the outer bark reveals a green layer underneath when scraped. Wait until late spring before pruning because even dead-looking plants may still be alive. The extent of winter damage can best be determined after new growth starts in the spring. At that time, prune all dead twigs or branches back to within 0.5 cm above a live bud, or to the nearest live branch.

If discoloration on narrow evergreen needles is not too severe, they may regain their green color or new foliage may be produced on the undamaged stem. Broadleaved evergreens showing leaf damage will usually produce new leaves, if branches and vegetative leaf buds have not been severely injured. Damaged leaves may drop or be removed. Prune to remove badly damaged or broken branches to shape plant and stimulate new growth.

Replant small plants with root systems partially heaved out of the ground as soon as the soil thaws. An application of fertilizer to the soil around winter-damaged plants, accompanied by adequate watering, will usually induce new growth to compensate for winter injuries.

Special care should be given to plants injured by winter's cold. The dry months of June, July, and August can be particularly damaging. The plants are weak and often unable to survive the added stress of drought. Be sure to water adequately.

STORM-DAMAGED TREES

Treating storm-damaged trees requires wise decisions and prompt action, if maximum repair is to be achieved. Repairs come in two stages: first aid for immediate attention and follow-up work to be distributed over a period of several months to several years.

In deciding what action to take, you must consider the following factors:

Is the tree damaged beyond practical repair? If over 30%- 50% of the main branches or trunk is severely split, broken, or mutilated, extensive repair efforts are questionable.

Desirability of species: Some species are more susceptible to storm damage than others because of branching patterns, growth habits or strength of wood.

Some less desirable species are: Bradford pear, black locust, Siberian (Chinese) elm, Manitoba maple, mulberry, true poplars, silver leaf maple, cedar. More desirable trees are: oak species, most maples, sweet gum, pine species, magnolia, hollies, hackberry, beech.

Location: If too close to power lines, buildings, or other structures, the tree may need to be removed.

Soundness: Extremely old trees of low vigor might not be able to recover.

Special value: Rarity of species or variety; sentimental or historical value.

Purpose of tree: Does it have a true landscaping purpose or value?

If you decide to repair trees, take the following first-aid steps:

- Remove only the branches necessary for immediate repair. Removing too much wood in one season can create problems such as sunscald, weak branching habits, and soft growth e.g., water sprouts or suckers.
- Re-attach bark to the inner wood with galvanized nails if healing seems possible and the bark or wood has not dried out. Reshape torn tissue areas to vertically elongated shapes to encourage healing. Support split branches with adequate guys or braces. Avoid leaving stubs of branches; make branch removal cuts at side branches if possible.
- Observe safety precautions regarding falling branches; use ladders; avoid contact with power lines, etc.
- Promptly remove from the premises all debris such as broken branches and other litter to help eliminate breeding grounds for insects and diseases.
- Do not apply wound dressings.

Follow up work should include:

- Checking the progress of growth unions of reattached bark areas.
- Establishing a tree fertilizer program. Most older trees need fertilizer to increase vigor and reduce susceptibility to breakage.
- Gradually pruning and reshaping trees for balance and general appearance over a period of three to five years.
- Controlling conditions such as suckers or water sprouts and insect and disease damage.
- Replacing trees, if necessary. Carefully select for durability, general adaptation, and size for the area.

CONSTRUCTION DAMAGE

Trees can be severely marred or even killed by certain construction practices, some of which are unavoidable. If you are aware of these situations before they occur, damage to trees may be kept to a minimum.

- Site a new home carefully. Make use of existing trees and avoid excessive grading.
- Protect desirable trees by using fencing and clearly marking them.
- Consult a landscape professional to review your plans and assess your property before any clearing begins.

Once an area is disturbed look for the following problems:

- **Poor grading around trunks:** If tree roots have been exposed, a 5 to 10 cm layer of fertile loam may be applied over them. If more than 10 cm of soil has been piled around the base, attempt to reduce it by using gravel or tree wells, if necessary. Otherwise, the tree may die from lack of oxygen to the roots.
- **Compaction by heavy equipment:** Soil immediately around trees may be seriously compacted as trucks and equipment passes by. There are few mechanical corrections for this problem, although vertical mulching and core aeration can help.
- **Damage to bark and limbs:** Broken tree limbs should be clearly cut at the branch "collar" on the trunk (see **Chapter 8** for details). If bark has been ripped, carefully remove ragged edges with a sharp knife, or re-attach with galvanized nails.
- **Root damage from trenching:** Any excavating may damage roots of nearby trees. If this cannot be avoided, thin out the tree to reduce water demands. Flush-prune exposed roots.

Regardless of the type of construction damage incurred, most trees will benefit from fertilization and added irrigation. Continue these practices, as recommended, until the tree recovers or it is evident the tree has lost vigor and requires removal.

MOWER AND LINE TRIMMER WOUNDS

Injury and infection started by lawn mower wounds can often be a most serious threat to tree health.

Most arborists and tree pathologists have been aware of the lawn mower problem for some time.

Extensive research has been conducted on the importance of wounds in tree health care. This research has led to significant changes in pruning, cabling, bracing, injection, and cavity treatment

Lawn mowers cause the most severe injury during periods when tree bark is most likely to slip — in early spring during leaf emergence, and in early fall during leaf drop. If the bark slips, a large wound is produced from even minor injuries. Such wounds should be repaired with galvanized nails.

Most tree injuries occur when mower operators attempt to trim close to tree trunks with a power mower. This can be prevented by removing a circle of turf surrounding the trunk and replacing it with mulch. Hand trimming can also be used. Care must also be used to avoid harming trees with the filament line of weed trimming machines. They can do a great deal of damage to bark, particularly on young trees.

The usual site of injury is the root buttress, since it flares out from the trunk and gets in the path of the mower. However, injury is common anywhere from the roots to a metre above the ground. Although large wounds are most serious, repeated small wounds can also add up to trouble.

Basal damage to all plants can be avoided by keeping a layer of mulch 1 m wide around the stem or trunk to eliminate the need for close trimming of unwanted grass. Groundcovers can also be used to protect tree trunks.

PROBLEM TREES

When selecting a tree to plant in the yard, you want to know exactly what you are getting. Many homeowners plant a sapling, enjoy it for a few years, and then discover some serious disadvantage when the tree reaches an effective height. The following trees have certain disadvantages that you should be aware of before planting them in your landscape.

***Acer negundo* (Box Elder, Manitoba Maple):** This tree has weak wood. It is also short-lived and susceptible to box elder bugs. Strong, invasive roots.

***Acer saccharinum* (Silver Maple):** One of the worst trees because of its brittle wood and tendency to become hollow and hazardous. Its shallow surface roots can ruin sidewalks and driveways as well as preventing turfgrass growth underneath. Roots can penetrate drains, weeping tiles and foundations. Also susceptible to insects. Banned in some localities.

***Betula papyrifera* (White Birch):** Authorities say this tree isn't likely to do well where the mean July temperature is above 21°C. Once weakened, the tree is likely to be killed by the bronze birch borer. Tree is pretty but short-lived. Susceptible to storm and ice damage.

***Betula pendula* (European White Birch):** Susceptible to insects and much environmental stress.

***Catalpa species*:** All catalpas have messy flowers and seed pods.

***Ginkgo biloba* (Ginkgo):** Female ginkgo trees bear fruit that has a very offensive odour. Purchase only male trees.

***Juglans nigra* (Black Walnut):** Tree roots produce a toxin that is harmful to certain other plants. Anthracnose, a late spring blight, may defoliate it during August and September. A large tree with valuable wood.

***Laburnum anagyroides* (Golden Chain Tree):** Subject to much environmental stress.

***Malus species* (Crabapple):** Most older varieties are defoliated by scab diseases every year. Fruits of some cultivars can be messy. Select disease resistant cultivars.

***Morus species* (Mulberry):** Mulberries have messy fruit. Subject to witches broom.

***Paulownia tomentosa* (Empress Tree):** Its pretty flowers become thousands of seeds that sprout everywhere. Its wood brings high prices in certain markets.

***Platanus occidentalis* (Sycamore):** Leaves and seeds are messy; exfoliates bark; tree has brittle wood and surface roots. Attacked by anthracnose.

***Populus species* (Lombardy Poplar, White or Silver Poplar, Hybrid Poplars, Cottonwood):** These trees have brittle wood and surface root systems. Their main problem is their susceptibility to canker diseases that disfigure and usually kill them. Some also have messy flowers or send up suckers from their roots. The Lombardy poplar is very short-lived.

***Prunus serotina* (Black Cherry):** Has objectionable fruit; is susceptible to insects and attracts many birds. Is a large native tree.

***Robinia pseudoacacia* (Black Locust):** Good for fence posts and firewood, but not for landscaping. It has brittle wood and is susceptible to cankers and locust borers. Leaf miners render it unattractive by summer. The tree frequently sends up numerous root suckers in lawns.

***Salix species* (Willows):** These trees have very brittle wood and are susceptible to canker diseases and storm damage. Their roots will clog sewer and drain pipes. Some are attractive on large lots.

***Sorbus species* (Mountain-ash):** Likes cool climates. Subject to damage from sawflies, borers, scale, and fire blight.

***Ulmus americana* (American Elm):** Until Dutch elm disease can be controlled, this long-time favorite should not be planted.

***Ulmus pumila* (Siberian Elm):** Its brittle wood will result in severe damage in ice storms. Its seeds and suckering habit make it a pest. Very short-lived. The Chinese Elm (*Ulmus parvifolia*) is often confused with the Siberian Elm but is far superior.

The following trees will give you trouble if they are not planted correctly. Many are slightly out of their preferred habitat and will not tolerate much abuse.

***Abies species* (Fir):** These generally large trees need deep, fertile, well-drained soils and a cool, moist climate.

***Acer saccharum* (Sugar Maple):** Needs to be planted in deep, moist, well-drained soil. Requires considerable space.

***Picea abies* (Norway Spruce):** Subject to environmental stress. Large tree.

***Pinus strobus* (White Pine):** A very large tree that won't tolerate overcrowding. It also dislikes disturbed soil suffers from air pollution and salt damage. Does not like extreme heat or poor drainage.

***Tsuga canadensis* (Hemlock):** Once established, hemlock does pretty well. It requires rich soil and shelter from wind and sun to get off to a good start.

It is recommended that all characteristics of a tree be carefully evaluated before it is planted. Size, hardiness, disease susceptibility and growth habits are all important features.

CHARACTERISTICS OF SPECIFIC WOODY ORNAMENTALS

Where several species of a plant are indicated, the zone listing refers to the range of lower zone limits for the various species.

TREES RESISTANT TO GYPSY MOTH

Species rarely fed upon:

Botanical Name	Zone	Common Name
<i>Cornus florida</i>	6a	Flowering Dogwood
<i>Fraxinus</i> spp.	2-3	Ash
<i>Gleditsia triacanthos</i>	4	Honey Locust
<i>Juglans nigra</i>	3	Black Walnut
<i>Juniperus virginiana</i>	2-3	Eastern Red Cedar
<i>Liriodendron tulipifera</i>	5b	Tulip Tree
<i>Platanus occidentalis</i>	5b	Sycamore
<i>Robinia pseudoacacia</i>	4	Black Locust
<i>Thuja occidentalis</i>	2b	White Cedar

Species fed upon when other foliage is gone:

Botanical Name	Zone	Common Name
<i>Acer platanoides</i>	5	Norway Maple
<i>Acer rubrum</i>	3	Red Maple
<i>Carpinus caroliniana</i>	3b	Hornbeam, Musclewood
<i>Carya</i> spp.	5	Hickory
<i>Fagus grandifolia</i>	4	American Beech
<i>Nyssa sylvatica</i>	5b	Black Gum, Tupelo
<i>Sassafras albidum</i>	6	Sassafras

PLANTS TO DISCOURAGE CHILDREN AND PETS (MOSTLY THORNY)

Botanical Name	Zone	Common Name
<i>Chaenomeles</i> spp.	5b	Flowering Quince
<i>Crataegus</i> spp.	2-6	Hawthorn
<i>Hippophae rhamnoides</i>	2b	Sea Buckhorn
<i>Ilex</i> spp.	2-6	Holly (American English, Winterberry)
<i>Juniperus virginiana</i>	2-3	Eastern Red Cedar
<i>Mahonia</i> spp.	5	Mahonia, Oregon Grape
<i>Pyracantha</i> spp.	6	Pyracantha or Firethorn
<i>Rosa</i> spp.	2-6	Rose
<i>Yucca</i> spp.	4-6	Yucca

PLANTS TOLERANT OF DRY, POOR SOIL

Get the plants listed here off to a good start by preparing the soil they are to be planted in and by watering until they are established.

Botanical Name	Zone	Common Name
<i>Abies concolor</i>	4	Silver Fir
<i>Acer ginnala</i>	2b	Amur Maple
<i>Acer negundo</i>	2	Manitoba Maple, Box elder
<i>Ailanthus altissima</i>	6	Tree of Heaven
<i>Amelanchier alnifolia</i>	2b	Saskatoon Berry
<i>Amorpha fruticosa</i>	2b	False Indigo
<i>Aralia spinosa</i>	4b	Devil's Walking Stick
<i>Arctostaphylos uva-ursi</i>	2	Bearberry
<i>Caragana arborescens</i>	2b	Peashrub, Caragana
<i>Catalpa speciosa</i>	5	Northern Catalpa
<i>Celastrus scandens</i>	3	American Bittersweet
<i>Celtis occidentalis</i>	2b	Hackberry
<i>Chaenomeles speciosa</i>	5b	Flowering Quince
<i>Cladrastis lutea</i>	4b	Yellowwood
<i>Colutea arborescens</i>	5	Bladder Senna
<i>Comptonia peregrina</i>	2	Sweetfern
<i>Cornus florida</i>	6	Flowering Dogwood
<i>Cornus kousa</i>	6a	Kousa Dogwood
<i>Cornus mas</i>	4	Cornelian Cherry
<i>Cornus racemosa</i>	2b	Grey Dogwood
<i>Corylus</i> spp.	4-5	Filbert, Hazelnut
<i>Cotinus coggygria</i>	5	Smokebush
<i>Cotoneaster</i> spp.	3	Cotoneaster
<i>Crataegus</i> spp.	2-6	Hawthorn
<i>Cytisus</i> spp.	5b	Broom
<i>Daphne cneorum</i>	2b	Rose Daphne
<i>Daphne mezereum</i>	4	February Daphne
<i>Diervilla sessifolia</i>	4	Bush Honeysuckle
<i>Elaeagnus angustifolia</i>	2	Russian Olive
<i>Elaeagnus commutata</i>	2	Silverberry
<i>Elaeagnus umbellatus</i>	5	Autumn Olive
<i>Fraxinus pennsylvanica</i>	2b	Green Ash
<i>Genista</i> spp.	5	Woadwaxen
<i>Ginkgo biloba</i>	3	Ginkgo
<i>Gleditsia triacanthos</i>	4	Honey Locust
<i>Hippophae rhamnoides</i>	2b	Sea Buckthorn
<i>Hypericum</i> spp.	3-6	St. John's Wort
<i>Juniperus</i> spp.	2-5	Juniper

Botanical Name	Zone	Common Name
<i>Koelreuteria paniculata</i>	5b	Golden Rain Tree
<i>Kolkwitzia amabilis</i>	5	Beautybush
<i>Maclura pomifera</i>	5b	Osage-orange
<i>Microbiota decussata</i>	3	Russian Arborvitae
<i>Myrica pennsylvanica</i>	2	Bayberry
<i>Ostrya virginiana</i>	3	Ironwood
<i>Parthenocissus quinquefolia</i>	2b	Virginia Creeper
<i>Paxistima canbyi</i>	2b-3	Paxistima
<i>Pinus banksiana</i>	1	Jack Pine
<i>Pinus mugo</i>	2b	Mugo Pine
<i>Pinus resinosa</i>	2b	Red Pine
<i>Pinus thumbergiana</i>	4b	Japanese Black Pine
<i>Platanus x acerifolia</i>	5b	London Plane
<i>Potentilla</i> spp.	1-3	Cinquefoil
<i>Prinsepia sinensis</i>	2b	Cherry Prinsepia
<i>Prunus padus</i> var: <i>commutata</i>	3	Mayday Tree
<i>Prunus tenella</i>	2-3	Russian Almond
<i>Prunus tomentosa</i>	2-3	Nanking Cherry
<i>Prunus virginiana</i>	2	Chokecherry
<i>Prunus x cistena</i>	3	Purple Sand Cherry
<i>Pyracantha coccinea</i>	6	Firethorn
<i>Quercus macrocarpa</i>	2	Burr Oak
<i>Rhodotypos scandens</i>	4	Jetbead
<i>Rhus aromatica</i>	3	Fragrant Sumac
<i>Rhus typhina</i>	3	Staghorn Sumac
<i>Robinia pseudoacacia</i>	4	Black Locust
<i>Rosa rugosa</i>	2	Rugose Rose
<i>Sassafras albidum</i>	5	Sassafras
<i>Shepherdia argentea</i>	1	Buffalo Berry
<i>Sophora japonica</i>	5b	Japanese Pagoda Tree
<i>Sorbaria sorbifolia</i>	2-3	Ural False Spirea
<i>Stephanandra incisa</i>	4-5	Cutleaf Stephanandra
<i>Symphoricarpos</i> spp.	2b-3	Coralberry, Snowberry
<i>Syringa</i> spp.	2-3	Lilac
<i>Tamarix ramosissima</i>	4	Tamarix
<i>Thuja occidentalis</i>	2b	Eastern White Cedar
<i>Vaccinium</i> spp.	1b-4	Blueberry, Cranberry
<i>Viburnum lantata</i>	2b	Wayfaring Tree
<i>Yucca</i> spp.	4-6	Yucca, Adam's Needle

PLANTS TOLERANT OF SHADE

The degree of shade tolerance varies from plant to plant. Most prefer some sun, especially those grown for their flowers. Those plants suitable for full shade are indicated by an "*" next to the zone designation.

Botanical Name	Zone	Common Name
<i>Acanthopanax sieboldianus</i>	*3-4	Five-leaved Aralia
<i>Acer palmatum</i>	6	Japanese Maple
<i>Acer pennsylvanicum</i>	*2b	Stripped Maple, Moosewood
<i>Alnus glutinosa</i>	4	Common Alder
<i>Amelanchier</i> spp.	*2-5	Serviceberry
<i>Arctostaphylos uva-ursi</i>	2	Bearberry
<i>Aronia</i> spp.	4	Chokeberry
<i>Buxus hybrids</i>	5-6	Boxwood
<i>Calluna vulgaris</i>	4b-6	Heather
<i>Calycanthus florida</i>	5	Carolina Allspice
<i>Carpinus caroliniana</i>	*3b	Hornbeam, Muscledwood
<i>Catalpa speciosa</i>	5	Northern Catalpa
<i>Celastrus scandens</i>	3	Bittersweet
<i>Clethra alnifolia</i>	4b	Summersweet
<i>Cornus alba</i>	*2	Tatarian Dogwood
<i>Cornus alternifolia</i>	2	Red Osier Dogwood
<i>Cotoneaster dammeri</i>	4	Bearberry Cotoneaster
<i>Deutzia gracilis</i>	*4-5	Slender Deutzia
<i>Epigaea repens</i>	2	Trailing Arbutus
<i>Erica</i> spp.	4b-6	Heath
<i>Euonymus fortunei</i>	*4-5	Winter Creeper
<i>Fothergilla major</i>	*5	Large Fothergilla
<i>Gaultheria procumbens</i>	*4	Wintergreen
<i>Hamamelis vernalis</i>	5b	Vernal Witch Hazel
<i>Hamamelis virginiana</i>	4b	Common Witch Hazel
<i>Hedera helix</i>	*5b	English Ivy
<i>Hippophae rhamnoides</i>	2b	Sea Buckthorn
<i>Hydrangea anomala</i> spp. <i>petiolaris</i>	5	Climbing Hydrangea
<i>Hydrangea quercifolia</i>	5b	Oak-leaved Hydrangea
<i>Ilex verticillata</i>	3b	Winterberry
<i>Itea virginica</i>	6	Sweetspire
<i>Kalmia latifolia</i>	*5b	Mountain Laurel
<i>Kerria japonica</i>	*5	Japanese Kerria
<i>Laburnum x watereri</i>	6	Goldenchain Tree
<i>Leucothoe fontanesia</i>	*6	Fountain Leucothoe
<i>Lindera benzoin</i>	5b	Spicebush

Botanical Name	Zone	Common Name
<i>Magnolia stellata</i>	5	Star Magnolia
<i>Magnolia x soulangiana</i>	5	Saucer Magnolia
<i>Mahonia aquifolium</i>	4-5	Oregon Grape
<i>Microbiota decussata</i>	3	Russian Arborvitae
<i>Myrica pennsylvanica</i>	2	Bayberry
<i>Ostrya virginiana</i>	*3	Ironwood
<i>Parthenocissus quinquefolia</i>	*2b	Virginia Creeper
<i>Parthenocissus tricuspidata</i>	*4-5	Boston Ivy
<i>Paxistima canbyi</i>	*2b-3	Paxistima
<i>Physocarpus opulifolia</i>	*4	Ninebark
<i>Pieris japonica</i>	5b	Japanese Pieris
<i>Polygonum aubertii</i>	4-5	Silverlace Vine
<i>Ptelea trifoliata</i>	*4	Hoptree
<i>Rhamnus frangula</i>	3b	Alder Buckthorn
<i>Rhododendron</i> spp.	1-6	Rhododendron, Azalea
<i>Rhodotypos scandens</i>	*4	Jetbead
<i>Rhus aromatica</i>	3	Fragrant Sumac
<i>Ribes alpinum</i>	*2	Alpine Current
<i>Sorbaria sorbifolia</i>	2-3	Ural False Spirea
<i>Staphylea trifolia</i>	*4	Bladdernut
<i>Styrax japonicas</i>	6	Snowbell
<i>Symphoricarpos</i> spp.	*2b-3	Coralberry, Snowberry
<i>Taxus</i> spp.	*4-6	Yew
<i>Thuja occidentalis</i>	6	False Arborvitae
<i>Tsuga canadensis</i>	3	Hemlock
<i>Viburnum acerifolia</i>	*3-4	Maple-leaved Viburnum
<i>Viburnum carlesii</i>	5b	Korean Spice Viburnum
<i>Viburnum dentatum</i>	4	Arrowwood
<i>Viburnum lantana</i>	2b	Wayfaring Tree
<i>Viburnum lentago</i>	*2	Nannyberry

PLANTS TOLERANT OF WET OR MOIST CONDITIONS

Very few woody plants can survive prolonged periods submerged under water. The following plants are able to withstand periodic flooding or consistently damp conditions.

Botanical Name	Zone	Common Name
<i>Abies balsamea</i>	3	Balsam Fir
<i>Alnus glutinosa</i>	4	Common Alder
<i>Aronia melanocarpa</i>	4	Black Chokeberry

Botanical Name	Zone	Common Name
<i>Betula melanocarpa</i>	4	Black Chokeberry
<i>Betula alleghaniensis</i>	3b	Yellow Birch
<i>Betula nigra</i>	3	River Birch
<i>Calycanthus floridus</i>	5	Carolina Allspice
<i>Celtis occidentalis</i>	2b	Hackberry
<i>Cephalanthus occidentalis</i>	5	Buttonbush
<i>Chamecyparis nootkatensis</i>	4b	False Cypress
<i>Chionanthus virginicus</i>	4-5	Fringetree
<i>Clethra alnifolia</i>	4b	Summersweet
<i>Cornus racemosa</i>	2b	Gray Dogwood
<i>Cornus stolonifera</i>	2	Red Osier Dogwood
<i>Dirca palustris</i>	4	Leatherwood
<i>Enkianthus campanulatus</i>	5b	Enkianthus
<i>Fraxinus americana</i>	3b	White Ash
<i>Fraxinus excelsior</i>	5a	European Ash
<i>Fraxinus nigra</i>	2b	Black Ash
<i>Fraxinus pennsylvanica</i>	3b	Green Ash
<i>Gaultheria procumbens</i>	4	Wintergreen
<i>Gymnocladus dioica</i>	5	Kentucky Coffee Tree
<i>Hamamelis vernalis</i>	5b	Vernal Witch Hazel
<i>Hamamelis virginiana</i>	4b	Common Witch Hazel
<i>Hypericum kalmianum</i>	3	Kalm St. John's Wort
<i>Ilex verticillata</i>	3b	Winterberry
<i>Itea virginica</i>	6	Sweetspire
<i>Kalmia latifolia</i>	5b	Mountain Laurel
<i>Larix laricina</i>	1	Eastern Larch
<i>Lindera benzoin</i>	5b	Spicebush
<i>Nyssa sylvatica</i>	5b	Tupelo, Black Gum
<i>Picea glauca</i>	1	White Spruce
<i>Pieris japonica</i>	5b	Japanese Pieris
<i>Ptelea trifoliata</i>	4	Hoptree
<i>Quercus bicolor</i>	4b	Swamp White Oak
<i>Quercus palustris</i>	4	Pin Oak
<i>Salix</i> spp.	1-5	Willow
<i>Sambucus canadensis</i>	3	American Elder
<i>Sciadopitys verticillata</i>	6	Japanese Umbrella Pine
<i>Stephanandra incisa</i> 'Crispa'	5	Cut-leaved Stephanandra
<i>Taxodium distichum</i>	5	Bald Cypress
<i>Thuja occidentalis</i>	2b	Eastern White Cedar
<i>Thuja occidentalis</i>	6	False Arborvitae
<i>Tsuga canadensis</i>	3	Hemlock

WOODY PLANTS FOR FALL COLOUR

Botanical Name	Zone	Common Name
<i>Acer ginnala</i>	3	Amur Maple
<i>Acer griseum</i>	6	Paperbark Maple
<i>Acer palmatum</i>	6	Japanese Maple
<i>Acer pennsylvanicum</i>	2b	Moosewood
<i>Acer rubrum</i>	3	Red Maple
<i>Acer saccharum</i>	4	Sugar Maple
<i>Acer tataricum</i>	1b	Tatarian Maple
<i>Actinidia arguta</i>	4	Tara vine, Hardy Kiwi
<i>Amelanchier</i> spp.	2b-5	Serviceberry
<i>Aralia spinosa</i>	4b	Devil's Walking Stick
<i>Arctostaphylos uva-ursi</i>	2	Bearberry
<i>Aronia</i> spp.	4	Chokeberry
<i>Betula</i> spp.	2-3b	Birch
<i>Calycanthus floridus</i>	5	Carolina Allspice
<i>Carya ovate</i>	5	Shagbark Hickory
<i>Celastrus scandens</i>	3	Bittersweet
<i>Celtis occidentalis</i>	2b	Hackberry
<i>Cercidiphyllum japonicum</i>	4	Katsura Tree
<i>Cercis canadensis</i>	5b	Redbud
<i>Chionanthus virginicus</i>	4-5	Fringetree
<i>Cladrastis lutea</i>	4b	Yellowwood
<i>Clethra alnifolia</i>	4b	Summersweet
<i>Cornus alternifolia</i>	3b	Alternate-leaved Dogwood
<i>Cornus florida</i>	6a	Flowering Dogwood
<i>Cornus kousa</i>	6	Kousa Dogwood
<i>Cornus mas</i>	4	Cornelian Cherry
<i>Cornus stolonifera</i>	2	Red Osier Dogwood
<i>Cotinus coggygria</i>	5	Smokebush
<i>Crataegus crus-gali</i>	2b	Cockspur Hawthorn
<i>Crataegus phaenophyrum</i>	5	Washington Hawthorn
<i>Crataegus nitida</i>	5	Glossy Hawthorn
<i>Dirca palustris</i>	4	Leatherwood
<i>Enkianthus campanulatus</i>	5b	Enkianthus
<i>Euonymus alatus</i>	3	Winged Euonymus
<i>Euonymus europaeus</i>	4	Spindle Tree
<i>Fagus</i> spp.	4-6	Beech
<i>Fothergilla major</i>	5	Fothergilla
<i>Fraxinus americana</i>	3b	White Ash
<i>Fraxinus nigra</i>	2b	Black Ash

Botanical Name	Zone	Common Name
<i>Fraxinus pennsylvanica</i>	2b	Green Ash
<i>Ginkgo biloba</i>	3	Ginkgo
<i>Gleditsia triacanthos</i>	4	Honey Locust
<i>Halesia caroliniana</i>	5	Silverbell
<i>Hamamelis</i> spp.	4b-6	Witch Hazel
<i>Hydrangea quercuefolia</i>	5b	Oak-leaved Hydrangea
<i>Itea virginica</i>	6	Sweetspire
<i>Koelreuteria paniculata</i>	5b	Golden Rain Tree
<i>Larix</i> spp.	1-2b	Larch
<i>Lindera benzoin</i>	5b	Spicebush
<i>Liquidambar styraciflua</i>	6	Sweet Gum
<i>Liriodendron tulipifera</i>	5b	Tulip Tree
<i>Magnolia stellata</i>	5	Star Magnolia
<i>Mahonia aquifolium</i>	5	Oregon Grape
<i>Metasequoia glyptostroboides</i>	5	Dawn Redwood
<i>Nyssa sylvatica</i>	5b	Tupelo, Black Gum
<i>Ostrya virginiana</i>	3	Ironwood
<i>Oxydendrum arboreum</i>	6	Sourwood
<i>Parrotia persica</i>	6	Persian Parrotia
<i>Parthenocissus quinquefolia</i>	2b	Virginia Creeper
<i>Parthenocissus tricuspidata</i>	4-5	Boston Ivy
<i>Phellodendron amurense</i>	3	Amur Corktree
<i>Populus tremuloides</i>	1	Trembling Aspen
<i>Prunus pennsylvanica</i>	2	Pin Cherry
<i>Prunus sargentii</i>	5b	Sargent's Cherry
<i>Prunus serrulata</i>	6	Japanese Flowering Cherry
<i>Prunus tomentosa</i>	2	Nanking Cherry
<i>Prunus virginiana</i>	2	Chokeberry
<i>Pyracantha coccinea</i>	6	Firethorn
<i>Pyrus calleryana</i>	5b	Callery Pear
<i>Pyrus ussuriensis</i>	2b	Ussurian Pear
<i>Quercus coccinea</i>	4	Scarlet Oak
<i>Quercus palustris</i>	4	Pin Oak
<i>Quercus rubra</i>	3	Red Oak
<i>Rhus aromatica</i>	3	Fragrant Sumac
<i>Rhus typhina</i>	3	Staghorn Sumac
<i>Rosa rugosa</i>	2	Rugose Rose
<i>Sassafras albidum</i>	5	Sassafras

Botanical Name	Zone	Common Name
<i>Sorbus alnifolia</i>	4	Korean Mountain Ash
<i>Spirea x bumalda</i>	3	Bumalda Spirea
<i>Styrax japonicus</i>	6	Snowbell
<i>Symphoricarpos orbiculatus</i>	2b	Coralberry
<i>Syringa patula</i>	4	Korean Lilac
<i>Vaccinium corymbosum</i>	3-4	Highbush Blueberry
<i>Viburnum acerifolia</i>	4	Maple-leaved Viburnum
<i>Viburnum carlesii</i>	5b	Korean Spice Viburnum
<i>Viburnum dentatum</i>	4	Arrowwood
<i>Viburnum dilatatum</i>	4	Linden Viburnum
<i>Viburnum lentago</i>	2	Nannyberry
<i>Viburnum x carlcephalum</i>	6	Fragrant Snowball
<i>Zelkova serrata</i>	6	Japanese Zelkova

WOODY PLANTS WITH ATTRACTIVE FALL FRUIT

Botanical Name	Zone	Common Name
<i>Acer ginnala</i>	2b	Amur Maple
<i>Acer tataricum</i>	1b	Tatarian Maple
<i>Ampelopsis brevipedunculata</i>	4	Porcelain Vine
<i>Arctostaphylos uva-ursi</i>	2	Bearberry
<i>Aronia spp.</i>	4	Chokeberry
<i>Catalpa speciosa</i>	5	Northern Catalpa
<i>Celastrus scandens</i>	3	Bittersweet
<i>Chaenomeles speciosa</i>	5b	Flowering Quince
<i>Colutea arborescens</i>	5	Bladder Senna
<i>Cotoneaster spp.</i>	3	Cotoneaster
<i>Crataegus spp.</i>	2b-6	Hawthorn
<i>Elaeagnus angustifolia</i>	2	Russian Olive
<i>Elaeagnus commutata</i>	2	Silverberry
<i>Elaeagnus umbellata</i>	5	Autumn Olive
<i>Euonymus alatus</i>	3	Winged Euonymus
<i>Euonymus europaeus</i>	4	Spindle Tree
<i>Euonymus fortunei</i>	4-5	Winter Creeper
<i>Gymnocladus dioica</i>	5	Kentucky Coffee Tree
<i>Halesia caroliniana</i>	5	Silverbell
<i>Hippophae rhamnoides</i>	2b	Sea Buckthorn
<i>Ilex spp.</i>	2b-6	Holly
<i>Lindera benzoin</i>	5b	Spicebush
<i>Lonicera spp.</i>	2-6	Honeysuckle

Botanical Name	Zone	Common Name
<i>Mahonia aquifolium</i>	5	Oregon Grape
<i>Malus spp.</i>	2b-5	Crab Apple
<i>Myrica pennsylvanica</i>	2	Bayberry
<i>Ostrya virginiana</i>	3	Ironwood
<i>Oxydendrum arboreum</i>	6	Sourwood
<i>Parthenocissus quinquefolia</i>	2b	Virginia Creeper
<i>Parthenocissus tricuspidata</i>	4-5	Boston Ivy
<i>Phellodendron amurense</i>	3	Amur Corktree
<i>Ptelea trifoliata</i>	4	Hoptree
<i>Pyracantha coccinea</i>	6	Firethorn
<i>Rhus aromatica</i>	3	Fragrant Sumac
<i>Rhus typhina</i>	3	Staghorn Sumac
<i>Rosa spp.</i>	1-6	Rose
<i>Sambucus spp.</i>	3	Elderberry
<i>Shepherdia argentea</i>	1	Buffalo Berry
<i>Sophora japonica</i>	5b	Japanese Pagoda Tree
<i>Sorbus spp.</i>	3-5	Mountain Ash
<i>Staphlea trifolia</i>	4	Bladdernut
<i>Symphoricarpos spp.</i>	2-3	Coralberry, Snowberry
<i>Taxus spp.</i>	4-6	Yew
<i>Viburnum spp.</i>	2-6	Viburnum

SALT TOLERANT WOODY PLANTS

Botanical Name	Zone	Common Name
<i>Acer platanoides</i>	5	Norway Maple
<i>Ailanthus altissima</i>	6	Tree of Heaven
<i>Arctostaphylos uva-ursi</i>	2	Bearberry
<i>Caragana arborescens</i>	2b	Peashrub, Caragana
<i>Carya ovata</i>	5	Shagbark Hickory
<i>Clethra alnifolia</i>	4b	Summersweet
<i>Cytisus spp.</i>	5b	Broom
<i>Elaeagnus angustifolia</i>	2	Russian Olive
<i>Euonymus alatus</i>	3	Winged Euonymus
<i>Fraxinus americana</i>	3b	White Ash
<i>Hippophae rhamnoides</i>	2b	Sea Buckthorn
<i>Juniperus spp.</i>	2-5	Juniper
<i>Lonicera spp.</i>	2-6	Honeysuckle
<i>Myrica pennsylvanica</i>	2	Bayberry
<i>Parthenocissus quinquefolia</i>	2b	Virginia Creeper
<i>Picea pungens</i>	2	Colorado Spruce

Botanical Name	Zone	Common Name
<i>Pinus flexilis</i>	2b	Limber Pine
<i>Pinus mugo</i>	2b	Mountain Pine
<i>Pinus nigra</i>	4	Austrian Pine
<i>Pinus parviflora</i>	5b	Japanese White Pine
<i>Pinus thunbergiana</i>	4b	Japanese Black Pine
<i>Populus deltoids</i>	3	Cottonwood
<i>Prunus virginiana</i>	2	Chokecherry
<i>Quercus rubra</i>	3	Red Oak
<i>Rhus typhina</i>	3	Staghorn Sumac
<i>Robinia pseudoacacia</i>	4	Black Locust
<i>Syringa</i> spp.	2-3	Lilac
<i>Tamarix ramosissima</i>	4	Tamarix

PLANTS RARELY DAMAGED BY DEER

Botanical Name	Zone	Common Name
<i>Buddleja davidii</i>	5b	Butterfly Bush
<i>Cotoneaster</i> spp.	3	Cotoneaster
<i>Elaeagnus angustifolia</i>	2	Russian Olive
<i>Forsythia</i> spp.	5-6	Forsythia
<i>Ilex opaca</i>	5	American Holly
<i>Juniperus</i> spp.	2-5	Juniper
<i>Leucothoe fontanesiana</i>	6	Fountain Leucothoe
<i>Picea</i> spp.	1-3	Spruce
<i>Syringa vulgaris</i>	2	Common Lilac

Resistance of Woody Ornamental Plants to Deer Damage

1. Deer are selective feeders. They forage on plants or plant parts with considerable discrimination. Generally, deer avoid plants that are thorny, fuzzy or have a strong scent.
2. Landscaping based on knowledge of deer feeding preferences can provide an alternative to the use of expensive chemical repellents and unsightly physical barriers.
3. Whether or not a particular plant species or variety will be eaten depends on the deer's previous experience, nutritional needs, plant palatability, seasonal factors, weather conditions, and the availability of alternative foods. Deer are creatures of habit, and prior movement patterns or foraging experience can foretell where damage will occur. Deer are known to feed selectively on fertilized plantings and managed croplands. New plantings added to an existing landscape already severely damaged by deer will likely suffer from browsing.
4. In general, the most damage takes place when winter snow cover or extreme cold has reduced food availability. Rather than face starvation, deer will browse even the most resistant plants during the periods of food shortage. No plant species will be avoided by deer under all conditions.

WOODY LANDSCAPE PLANTS FOR ATTRACTING BIRDS

In order to attract birds, an area must satisfy four basic needs: food, water, cover, and nesting sites. Proper selection and planting of trees and shrubs can create an environment which will provide three of these requirements. A mixture of densely-branched deciduous as well as evergreen trees will afford year-round cover. Selection of plants with a wide overlap of flowering and fruiting times can provide a year-round food supply.

The following list includes those trees, shrubs, and vines which provide food sources most likely to attract birds to the garden (see **Chapter 9** for more detailed information).

Botanical Name	Zone	Common Name
<i>Acer rubrum</i>	3	Red Maple
<i>Amelanchier</i> spp.	2b-4b	Serviceberry
<i>Celastrus scandens</i>	3	Bittersweet
<i>Celtis occidentalis</i>	2b	Hackberry
<i>Cornus</i> spp.	2-6	Dogwood
<i>Crataegus</i> spp.	2b-6	Hawthorn
<i>Elaeagnus angustifolia</i>	2	Russian Olive
<i>Elaeagnus umbellata</i>	5	Autumn Olive
<i>Ilex opaca</i>	5	American Holly
<i>Ilex verticillata</i>	3b	Winterberry
<i>Juniperus virginiana</i>	2-3	Easter Red Cedar
<i>Lonicera</i> spp.	2-6	Honeysuckle
<i>Malus</i> spp.	2b-5	Crab Apple
<i>Myrica pennsylvanica</i>	2	Bayberry
<i>Nyssa sylvatica</i>	5b	Black Gum, Tupelo
<i>Parthenocissus quinquefolia</i>	2b	Virginia Creeper
<i>Parthenocissus tricuspidata</i>	4-5	Boston Ivy
<i>Prunus serotina</i>	5	Black Cherry
<i>Prunus virginiana</i>	2	Chokecherry
<i>Pyracantha coccinea</i>	6	Firethorn
<i>Quercus</i> spp.	2-5	Oak
<i>Rhamnus</i> spp.	3b	Buckthorn
<i>Rhus aromatica</i>	3	Fragrant Sumac
<i>Rhus typhina</i>	3	Staghorn Sumac
<i>Ribes</i> spp.	1-4	Currant
<i>Rosa</i> spp.	1-6	Rose
<i>Sambucus</i> spp.	3	Elderberry
<i>Sorbus</i> spp.	3-5	Mountain Ash

Botanical Name	Zone	Common Name
<i>Symphoricarpos</i> spp.	2-3	Coralberry, Snowberry
<i>Vaccinium</i> spp.	1-4	Blueberry, Cranberry
<i>Viburnum</i> spp.	2-6	Viburnum

TREES FOR URBAN CONDITIONS

Botanical Name	Zone	Common Name
<i>Acer campestre</i>	4	Hedge Maple
<i>Acer platanoides</i>	5	Norway Maple
<i>Acer rubrum</i>	3	Red Maple
<i>Carpinus betulus</i>	4	European Hornbeam
<i>Cornus mas</i>	4	Cornelian Cherry
<i>Crataegus crusgalli</i>	2b	Cockspur Hawthorn
<i>Crataegus phaenopyrum</i>	5	Washington Hawthorn
<i>Crataegus punctata</i>	5	Dotted Hawthorn
<i>Crataegus viridis</i>	5	Green Hawthorn
<i>Fraxinus americana</i>	3b	White Ash
<i>Fraxinus pennsylvanica</i>	2b	Green Ash
<i>Ginkgo biloba</i>	3	Ginkgo
<i>Gleditsia triacanthos</i>	4	Honey Locust
<i>Koelreuteria paniculata</i>	5b	Golden Rain Tree
<i>Malus</i> spp.	2b-5	Crab Apple
<i>Prunus virginiana</i> 'Shubert'	2	Shubert Cherry
<i>Quercus bicolor</i>	4b	Swamp White Oak
<i>Quercus coccinea</i>	4	Scarlet Oak
<i>Quercus macrocarpa</i>	2	Bur Oak
<i>Quercus rubra</i>	3	Red Oak
<i>Sophora japonica</i>	5b	Japanese Pagoda Tree
<i>Tilia cordata</i>	3	Littleleaf Linden

Adapted from: P.C. Kozel, M.J. Jasen and G.P. Hettel. 1978. Ten year study shows which trees do best in the city. *Ohio Report*. 63(1): Pages 6-9.

VINES IN THE LANDSCAPE

Like shrubs, trees, and ground-covers, vines can be an important element in any garden. Each species and variety possesses distinctive characteristics that make it well adapted to certain locations in the landscape plan.

Selecting Plants

Vines can be useful in a variety of locations. Some are valued for the shade they provide when trained over an arbor. Others add interest to a planting when used against the wall of a building or to frame a doorway. Vines can be useful in forming a cascade of bloom on rough, steep banks while holding the soil in place.

They offer diverse visual qualities and are valued for the rich texture of their foliage, their decorative habit of growth, the fragrance of their blooms, and the beauty of their flowers. Some are valued for the graceful tracery of their simple stems or for the beauty of their leaf patterns. For the home gardener, vines offer a rich source of material for creating interesting, exciting, and beautiful plantings.

Vines can be divided into three groups based on their method of climbing:

- Some, like Boston ivy (*Parthenocissus tricuspidata*), climb by clinging with small root-like holdfasts to the wall as a means of support. Sometimes these are modified tendrils with small circular discs at the tips. Others, like English ivy (*Hedera helix*), have small rootlets along the stem that firmly attach the vine to either brick or wood.
- Another group, which includes clematis and grape, climb by attaching and winding tendrils or leaf-like appendages, which act as tendrils, around the object on which they are growing.
- A third group, including bittersweet (*Celastrus scandens*) and wisteria (*Wisteria floribunda*), climb by twining. All vines do not twine in the same direction, yet the method of climbing is not haphazard. The plants of each species invariably twine in one direction, so it is important to start the winding of young vines around their support in the correct direction. For example, bittersweet twines by climbing from left to right; Hall's honeysuckle (*Lonicera japonica* 'Halliana') twines by climbing from right to left. Observe how each vine climbs; then provide the proper means of support for the vines you have selected.

When choosing a vine, consider the following questions:

- Is the climbing habit appropriate for the support or site? Rootlets can damage brick and wisteria vines can crush small supports.
- Does it prefer sun or shade?
- Is it being planted primarily for bloom or its foliage?
- Will it be a permanent planting? If so, select perennial vines hardy for your area.
- Will the vine drop undesirable fruit or other plant material on or near the site?
- Will stinging or other nuisance insects be attracted to the vine?
- Does it exhibit rampant growth that will require frequent pruning to control?

Culture

- Like most other plants, vines occasionally require some maintenance. Pruning is sometimes necessary to remove old wood, to keep the plant within bounds, or even to guide future growth. Check references for detailed instructions about pruning, blooming or fruiting vines (see **Chapter 8**).
- Insects and diseases can cause damage to vines. Become an observant gardener to minimize problems. At the first sign of a problem, determine the cause; monitor the situation and select a control measure if necessary (see **Chapter 18**).
- It is not advisable to plant clinging-type vines on or near wooden surfaces. They can easily attach to the wood and pose major maintenance problems.

Table 12-4: SOME VINES TO CONSIDER

Botanical Name	Climbs By	Foliage	Hardiness Zone	Common Name
<i>Actinidia arguta</i>	Tw.	D	4	Tara Vine, Hardy Kiwi 'Issai' is self-fertile
<i>Actinidia kolomikta</i>	Tw.	D	4	Kolomikta, Hardy Kiwi
<i>Ampelopsis brevipedunculata</i>	Tend.	D	4	Porcelain Vine
<i>Aristolochia macrophylla</i>	Tw.	D	5	Dutchman's Pipe
<i>Campsis radicans</i>	Cl.	D	4-7	Trumpet Creeper
<i>Celastrus scandens</i>	Tw.	D	3	Bittersweet
<i>Clematis</i> spp.	Leaf Stalks	D	1b-5	Clematis
<i>Euonymus fortunei</i>	Cl.	Ev.	5	Winter Creeper
<i>Hedera helix</i>	Cl.	Ev.	5-7	Ivy
<i>Hydrangea anomala petiolaris</i>	Cl.	D	5	Climbing Hydrangea
<i>Lonicera</i> spp.	Tw.	D	2-6	Honeysuckle
<i>Parthenocissus quinquefolia</i>	Tend.	D	2b	Virginia Creeper
<i>Parthenocissus tricuspidata</i>	Tend.	D	5	Boston Ivy
<i>Polygonum aubertii</i>	Tw.	D	5	Silverlace Vine
<i>Wisteria floribunda</i>	Tw.	D	4-6	Wisteria
Key: Cl. = Climbs by clinging Ev. = Evergreen foliage, but perennial Tend. = Climbs with tendrils Tw. = Climbs by twining D. = Deciduous foliage, but perennial				

GROUNDCOVERS

Generally speaking, groundcovers include any materials that cover the ground surface. By this definition, grass, various types of paving, shrubs, and even trees could be called groundcovers. However, we are referring to groundcovers as low (up to 45 cm), mat-forming, or trailing plants. Grasses or other plants that tolerate walking or mowing are not included. Most groundcovers are not intended to be walked on and are severely damaged by pedestrian traffic.

When groundcovers 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:

- Control erosion on slopes.
- Obstruct traffic without impeding view.
- Conserve soil moisture and, during periods of extreme heat, lower temperatures in the soil.
- Reduce lawn maintenance.

- Fill narrow, oddly shaped areas where mowing and edging might be difficult.
- Provide vegetative growth where grass is difficult to maintain.
- Produce interesting patterns with variation in height, texture, and color.
- Reduce weeding of bare soil.

In practice, the groundcovers most frequently used are plants that are easily propagated, vigorous, and hardy.

Selecting Plants

Selecting a groundcover depends on where it is to be used. Is the area flat or sloping? Is it in sun? Partial or deep shade? Also consider the soil at the site. Some groundcovers prefer a moist soil rich in organic matter; others adapt to dry, sandy situations. Consider color, texture, height, and habit as well, since some groundcovers tend to grow rampantly. A well-prepared planting bed is essential for establishing plants.

Culture

Significant maintenance is required for the first one to three years or until the groundcover becomes established. Cultivation is necessary to control weeds and other plant invaders. Fertilize in spring to encourage fast, vigorous growth and to achieve good cover. Irrigate in times of dryness. Occasional attacks by pests or diseases may occur. Remain observant and begin control measures when warranted (see **Chapter 18**). When maintenance considerations are ignored, progress in achieving a good groundcover planting will be disappointing.

Wherever paving, lawn, or cultivated beds are not appropriate or desirable, groundcovers can be successfully used. Newly cut banks and any slopes greater than 12% are best treated with groundcover plantings. Around buildings, groundcovers are superior to paving or structural controls. They will perform extremely well and help reduce heat, glare, noise and dust.

Table 12-5: A SELECTION OF WOODY GROUNDCOVERS

Botanical Name	Zone	Common Name
<i>Arctostaphylos uva-ursi</i>	2	Bearberry
<i>Cotoneaster dammeri</i>	4	Bearberry Cotoneaster
<i>Daphne cneorum</i>	5	Rose Daphne
<i>Euonymus fortunei</i>	5	Winter Creeper
<i>Juniperus</i> spp.	2-5	Junipers
<i>Microbiota decussata</i>	3	Russian Arborvitae
<i>Mitchella repens</i>	3	Partridgeberry
<i>Pachysandra</i> spp.	3	Pachysandra
<i>Rhus aromatica</i>	3	Fragrant Sumac
<i>Teucrium chamaedrys</i>	6	Germander
<i>Vinca minor</i>	3	Periwinkle

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Various weeping forms of *Picea*, *Salix*, *Larix*, *Pinus* *Abies*, *Tsuga*, *Malus* and *Prunus* can be used as a groundcover if not grafted on a standard.

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CHAPTER 13: THE VEGETABLE GARDEN

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THE VEGETABLE GARDEN

INTRODUCTION

Vegetable plants are the pampered "princes and princesses" of the garden. They are mostly tender, shallow rooted and short-lived. They compete poorly against weeds for food and drink and must be pushed to maturity to ensure high yields, succulence and good eating quality. Many vegetables are easily grown in Ontario, but consistent success only comes when careful attention is paid to all plant needs.

This chapter will first explore the basics of vegetable gardening, followed by a brief discussion of individual crops. The emphasis will be on sustainable and intensive gardening practices that can help you achieve the greatest yields, in the smallest space with the least amount of labour and purchased inputs (fertilizers, pesticides, etc.).

GARDEN PLANNING TIPS

Intensive vegetable gardening requires planning and timeliness. List the crops you plan to grow on paper and draw a map showing the spacing and location of crops. Develop spring, summer and fall maps if you plan to practice succession gardening (growing 2-3 crops in each bed or garden area). Below are listed some important planning considerations:

- Place tall crops on the north and west sides of the garden so they won't shade lower-growing plants.
- Group plants by their "days to maturity". For example, plant spring crops together and re-plant the area after harvest.
- Place perennial crops to the side of the garden where they will not be disturbed.
- Vegetable plant roots mine the soil for nutrients at varying depths (see **Figure 13-A**). They also have different fertilizer needs. Rotating crop location can help even out nutrient removal from the soil. Rotation is only marginally helpful in lessening insect and disease pressure when the vegetable garden is small.
- Avoid planting vegetables near trees and shrubs. They compete for water and nutrients, and may cause excessive shading. Buildings and other structures may also shade sun-loving vegetable plants.
- The daily sunlight requirement of garden crops can be generalized as follows:
 - **6-8 hours (prefer 8-10 hours):** "warm-season" crops-tomato, pepper, eggplant, squash, bean
 - **6 hours:** root crops - carrots, potato, turnip
 - **4-5 hours:** leafy greens-spinach, lettuce
- Avoid sites next to buildings with lead paint. Soil lead may be present in toxic amounts (see **Chapter 3 "Soils and Fertilizers"**).

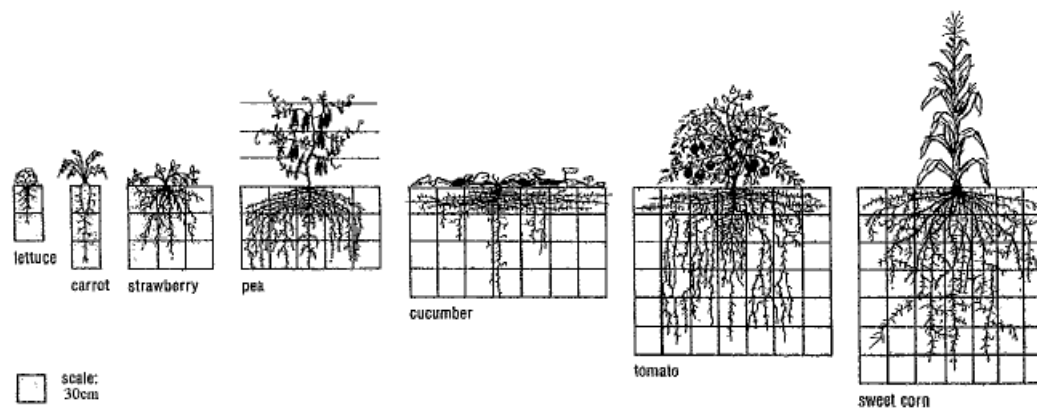
Never plant your vegetable garden near a black walnut or a butternut. The roots of these trees exude a chemical, juglone, which is toxic to tomato, potato, pea and asparagus plants, and which will reduce yields in other crops.

SOIL PREPARATION AND FERTILITY

For best results, vegetable garden soil should be deep, friable (crumbly), well drained, and high in organic matter. You can usually enhance germination and seedling vigour and increase overall garden productivity by following these recommendations:

- Keep it weed-free.
- Increase the effective rooting depth of the soil: raised beds, adding organic matter and loosening subsoil.
- Check soil fertility and pH by having your soil analyzed at least once every three years. Most garden crops will do well with a soil pH of 6.2-6.8. Avoid working soils when excessively wet. This can destroy soil structure, which may take years to rebuild. Do not "over-till" or pulverize your soil.
- Incorporate organic matter and lime (if needed) in the fall to allow time for decomposition and pH adjustment. Fall tillage also helps to disrupt overwintering insect pests.
- Composted or well-rotted animal manures (not dog or cat) are highly recommended for vegetable plants.
- All vegetable plants benefit from continuous availability of nutrients. Slow-release fertilizers are helpful. The yields and size of vegetable plant fruits can be increased by periodic fertilizing, especially after the first fruits form.

Figure 13-A: COMPARATIVE ROOTING DEPTHS OF COMMON GARDEN VEGETABLES



SEEDS AND TRANSPLANTS

PLANTING SEED

You can sow many seeds directly in the garden:

- Select varieties that have good disease resistance and are grown successfully by gardeners in your area.
- A good rule of thumb is to sow your seeds 2-3 times deeper than their width.
- Seeds may be sown more deeply in light, sandy soils. Plant less deeply in heavier, clay soils.
- With cloddy or crusty soils, it may be helpful to apply a narrow band of sand, fine compost, or vermiculite over the row after seeds are planted. This will hold soil moisture and reduce crusting, making it easier for seedlings to push through the soil surface.
- Always firm the soil over your seeds to hasten germination.
- Soil temperature has a major affect on the speed of seed germination. In the spring, soil is often cold and large seeds (i.e., corn, beans) may rot before they can sprout.
- Corn and beans are often planted in single rows while cucurbit crops are sometimes planted 4-6 seeds to a "hill".
- Crops such as spinach, beans, peas, beets, lettuce, and carrots are often sown in wide rows or beds instead of in long single rows. Sow seed evenly over the area, and then rake in gently.

What's a Hybrid?

Hybrid varieties result from the intentional crossing of two distinct, open-pollinated varieties. The first generation offspring (F1) have unique and desirable qualities-disease resistance, compact growth habit, etc. Seed saved from hybrid varieties will not "come true"; it will either be sterile or express a range of parental characteristics. Open-pollinated varieties do "come true" from seed, if two similar parents are used.

SAVING SEED

Saving your own vegetable seed makes your garden more sustainable and self-sufficient and saves you money. You can also help maintain an heirloom variety that is not available commercially, thus perpetuating a broad genetic base of plant materials. Breeders search for old varieties when attempting to improve commercial plants. They often have pest-resistance, cold-hardiness or other desirable traits. Heirloom, endangered and unusual varieties can be swapped through seed saving exchanges.

Keep these considerations in mind when saving seed:

- Second generations of hybrid varieties are not likely to be the same as the parent plant. Use only open pollinated (or "species") varieties for home seed saving.
- Mark your seed storage containers (glass is best) clearly with permanent ink, indicating the variety and date saved. Viability increases when seeds are stored in a cool dry, dark location.
- When properly stored, most vegetable seeds will remain viable for at least 3-5 years.

Mystery Squash

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

- Save seed from common self-pollinated annual plants such as lettuce, beans, and peas. Tomatoes and peppers are largely self-fertile, but some crossing may occur if different varieties are planted in close proximity.
- To save beans and peas, allow seed pods to turn brown on the plant. Harvest pods, dry for 1-2 weeks, shell, and then store.
- To save tomato seeds, pick fruit from desirable plants when ripe. Cut fruit and squeeze out pulp into a container. Add a little water and then let ferment 2-4 days at room temperature, stirring occasionally. The fungus that grows on the mixture will kill some seed-borne diseases. When seeds settle out, pour off pulp, spread seeds thinly and dry thoroughly.
- To test for germination, sprout 20 seeds between moist paper towels; if germination is less than 50%, either discard the seed or plant enough extra to give the desirable number of plants.

USING TRANSPLANTS

Using transplants is essential for successful vegetable gardening. Warm-season crops must be sown indoors to allow for a sufficient harvest period. Cool-season crops need an early start indoors to mature prior to summer heat.

TIPS FOR BUYING AND PLANTING

- Transplants should be stocky, disease-free, not overly mature and with good colour.
- Inspect the root system; roots should be white and fibrous but should not encircle the container bottom.
- Be prepared to "hold" plants in a protected location if transplanting must be delayed.
- Transplant on a cloudy day, in late afternoon, to prevent wilting. Water your plants several hours before transplanting.

Grow Your Own

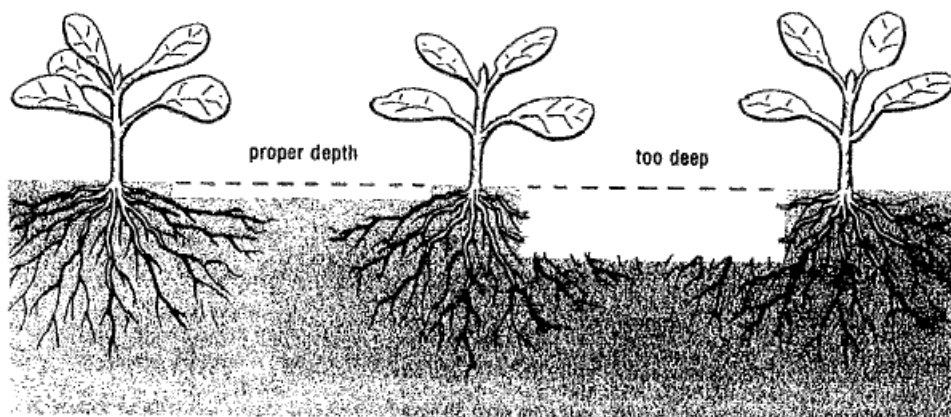
For a larger choice of varieties and the control of plant production from seed to harvest, you may choose to start your own transplants. For successful transplants follow these tips:

- Use a soilless growing medium (containing peat, sand, perlite and vermiculite).
- Cover seedling trays with clear plastic and set them on top of your refrigerator. Once seedlings emerge remove plastic and place trays under lights.
- Grow plants under "shop lights" with warm and cool white fluorescent tubes. Use a timer to keep lights on for 14-16 hours each day.
- To prevent legginess, keep light no more than 2.5-5 cm from plants.
- After emergence, feed seedlings every 2 weeks with a weak liquid fertilizer; e.g., fish emulsion or dilute 10-52-10.
- Grow transplants at 21°-24°C during the day and 15°-18°C at night.
- A plastic tent helps raise the humidity level and prevent heat loss.
- Bottom watering is recommended. **Be careful not to over water.**
- Transplant seedlings to larger containers after "true" leaves appear. Don't crowd plants; use deep containers and give tomato, pepper and egg plant 65-130 cm² of space per plant.
- **The "key" is growing your plants quickly without interruption.**

Don't allow them to dry out completely at any time. Handle plants carefully; avoid disturbing the roots or bruising the stems.

- Plant peat pots directly in the garden, first removing the pot bottom and rim. 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 the exposed surface. Sides of the pot should be slit.
- Dig a hole large enough to hold the roots of the plants. Tomatoes will develop roots all along the stems. If they are very tall you can lay the stems horizontally in a trench leaving only two or three sets of leaves above-ground.
- Press soil firmly around the roots of transplants. Water in your plants with a weak, liquid fertilizer or starter solution (high in phosphorous). Fish emulsion or dilute manure tea may also be used.
- For a few days after transplanting, protect the plants from wind and sun by covering with jugs, baskets, or flower pots. Water the plants once or twice during the next week if there is insufficient rain.

Figure 13-B: Deep cultivation destroys necessary roots. Shallow cultivation is preferable.



IRRIGATING AND MULCHING

WATERING

Vegetable plants are 75%-90% water. Succulence, eating quality, plant growth and productivity are all improved when sufficient soil moisture is available.

- Vegetable plants need 2.5 cm of water per week for optimal growth (250 litres per 10 m²). Adjust according to soil texture.
- Keep a rain gauge near the garden and then supplement rainfall with irrigation water if needed.
- Avoid shallow, frequent watering (except for fast growing salad greens) - it encourages shallow rooting which makes plants more susceptible to drought damage.
- When hand-watering, wet the soil around the plant base. Overhead watering may encourage plant diseases but it also helps to cool plants and provide moisture for beneficial insects, spiders and other animals. Soaker hoses and drip systems are highly recommended. They minimize water use and deliver water slowly and directly to the root system. Cover soaker hoses and drip tubing with an organic mulch.
- Water in the morning when possible. Disease problems are more likely to get started on cool leaf surfaces such as would occur overnight.
- Adding organic matter increases a soil's water-holding capacity; mulches will help conserve this available moisture.

In general, water is most needed during the first few weeks of development, immediately after transplanting, and during development of edible plant parts.

MULCHING

Weeds are "plants out of place". They compete with garden plants for water and nutrients and may serve as alternate hosts for insect and disease pests. Furthermore, many first-time vegetable gardeners become discouraged when weeds take over their garden. Controlling weed growth is critical for success in the vegetable garden. However, weedy plants can also be beneficial:

- They provide shelter, pollen and nectar for beneficial insects such as bees and parasitic wasps.
- They're a good source of nitrogen for the compost pile if removed before flowering. Many have long roots that bring elements from the subsoil into their aboveground parts; when you incorporate weeds into your garden soil these elements are made available to growing plants.

Goodies from the Wild

Dandelions, purslane, chickweed, cress, mustards, and lamb's quarters can be problem weeds or edible and nutritious greens. Be sure to properly identify plants before eating them.

There are several ways to rid the garden of most problem plants:

- Mulch, mulch, mulch! After your soil has warmed, lay down 5 to 15 cm of grass clippings, finished compost, newspaper covered with straw or shredded leaves to smother weeds. Hand-pull the vigorous weeds that grow through the mulch layer.

- Remove weeds when they are young and tender. Mature weeds extract large quantities of moisture and nutrients from the soil.
- Mow around your garden to prevent the spread of weeds.
- Cultivate when the soil is somewhat moist, but not wet. Working wet soil may ruin the soil structure, especially of heavy soils.
- Shade the soil with closely-spaced plants so that the foliage of adjacent plants touches and forms a closed canopy at maturity.
- Try setting spring transplants directly into winter-killed or closely-mowed cover crops, like oats and hairy vetch.

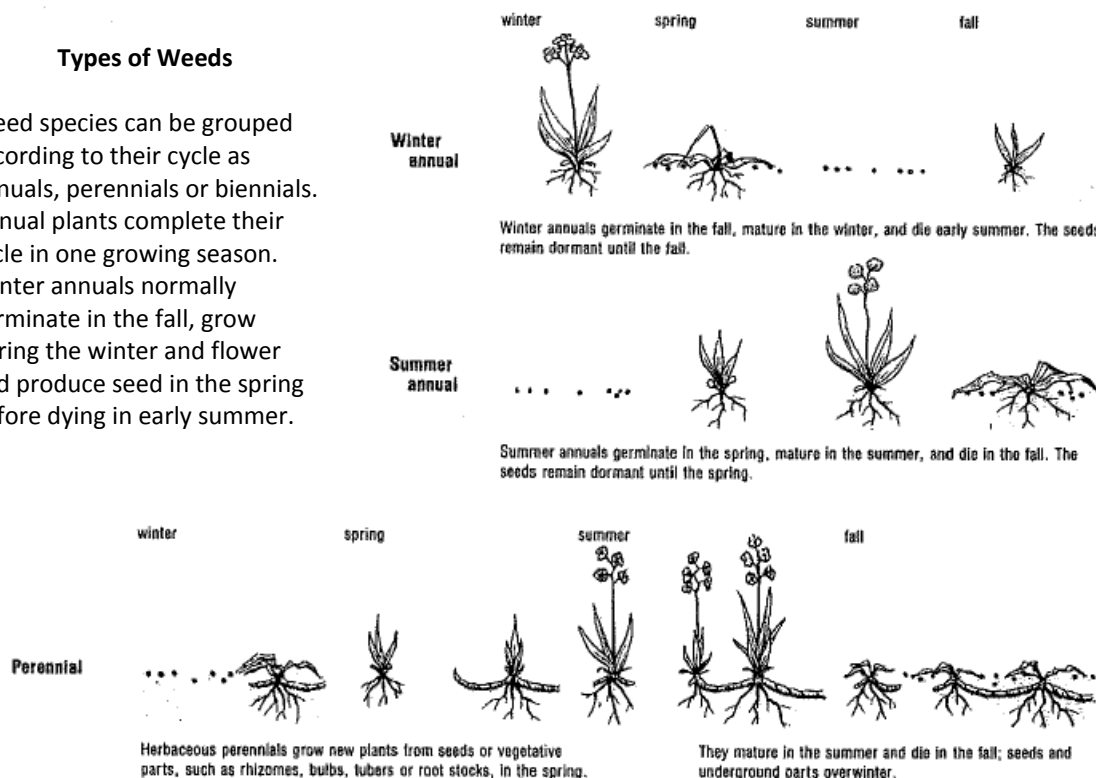
Floating Row Covers

Floating row cover is a spun-bound polyester material used by gardeners to (1) exclude insect pests, (2) provide plants with slight frost protection, and (3) create a more favorable micro-climate for spring crops (increased humidity and temperature). The light, gauzy materials allow light and water to penetrate and can be used to cover individual plants or entire beds. Provide enough slack so that plants can grow to maturity and secure the edges with soil, rocks or boards to prevent wind whipping and pest invasions. Ultralight covers can be used all season long for serious pests (e.g., flea beetles on eggplant). Be sure to remove row covers from cross-pollinated crops (cucurbits) during the bloom period.

Figure 13-C: LIFE CYCLES OF WINTER ANNUAL, SUMMER ANNUAL, AND PERENNIAL WEEDS

Types of Weeds

Weed species can be grouped according to their cycle as annuals, perennials or biennials. Annual plants complete their cycle in one growing season. Winter annuals normally germinate in the fall, grow during the winter and flower and produce seed in the spring before dying in early summer.



INTENSIVE GARDENING METHODS

Intensive vegetable gardening has been practiced by our ancestors around the world for thousands of years. The objective is to harvest the most produce possible from a given space. An intensive garden reduces wasted space to a minimum. Intensive methods are not just for those with limited garden space. Rather, an intensive garden allows you to concentrate your efforts to create an ideal plant environment, resulting in higher yields with less labour.

Intensive gardening methods are demanding, however:

- There is typically less weeding to do because of fewer pathways and closely spaced plants, but the necessary weeding is usually done by hand or with hand tools. High yield garden areas are achieved by continual planting and harvesting through the growing season. You should be prepared to sow seed, grow and care for young seedlings and set out and protect transplants over a 5-9 month period.
- It requires a thorough knowledge of vegetable plants, including days to maturity, nutrient needs, shade tolerance, growth habit and preferred growing season. To maximize yields one also needs to develop and follow a garden plan for each growing bed.

THE RAISED BED

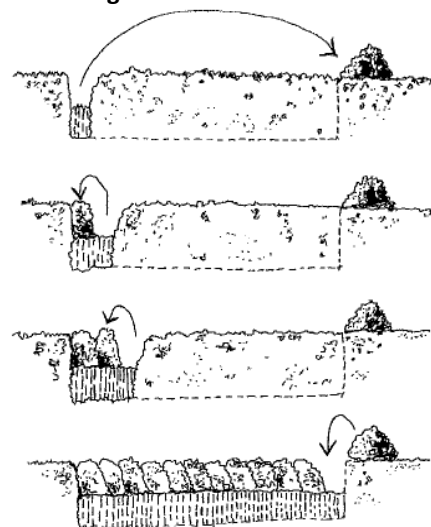
The raised bed or growing bed is the basic unit of an intensive garden. Raised beds have the following advantages:

1. Minimize soil compaction, because you never walk in the planting area.
2. Well-drained; increased water-holding capacity and oxygen availability.
3. Easier to plant, weed, and maintain.
4. Greater yields due to high fertility and increased root growth.
5. Allow earlier and later planting as they warm up earlier in the spring and hold the heat later in the fall.
6. Space-saving; increased yields per garden area.
7. Improved seed germination and seedling establishment.
8. Reduced fertilizer use because walkways are permanent.
9. Less tilling required; tillers and other gas-powered tools may be unnecessary.

An intensive garden may be divided into rectangular beds, intersected by narrow paths. Beds are generally 20 to 30 cm high, 1 m wide and as long as desired. You work from either side of the bed, thus avoiding soil compaction caused by walking on the garden. Paths are 45 cm or wider between beds, with a wider central path of 1 m the length of the garden to allow room for a wheelbarrow and garden tools.

Figure 13-D: DOUBLE-DIGGING A GARDEN BED

The top 20 to 30 cm is removed with a spade. The underlying sub soil is then loosened to a depth of 20 to 30 cm with a garden fork.



Soil preparation is the key to successful intensive gardening. To grow in close proximity, plants must have abundant nutrients and water. Providing them with extra synthetic fertilizers and irrigation water will accomplish this, but there is no substitute for deep, fertile soil high in organic matter. High organic matter content (at least 20% for best results) enables your garden to support heavy, intensive crop production.

DOUBLE DIGGING

You can effectively double the rooting depth of your garden by loosening the subsoil or "double-digging" the bed (see **Figure 13-D**). Start by removing the top 20 to 30 cm of soil from one end of a bed. Next, insert a spade or spading fork 20 to 30 cm into the exposed subsoil and move the handle back and forth. Do this every 15 to 20 cm in the bed. Loosening the subsoil will break up compacted layers, improve drainage and aeration and allow for deeper root penetration.

Unless your soil is in excellent condition, mix the topsoil with a generous amount of compost or manure, and return the mixture to the bed. It should be somewhat fluffy and several inches higher than ground level. To raise the bed 20 to 25 cm, take topsoil from the neighboring pathways and mix it in as well.

SPACING

Raised beds are a form of wide-bed gardening, a technique by which seeds and transplants are planted in several rows or broadcasted in a single, 45 cm wide strip. The goal is to space plants at equal distances from each other on all sides, so that leaves will touch at maturity. This saves space, reduces moisture loss from surrounding soil and retards weed seed germination. However, plants should not be crowded to the point at which disease problems arise or competition causes stunting.

VERTICAL GARDENING

Pole beans, some peas, tomatoes and most cucumbers can be grown vertically with the necessary support. Eggplant, sweet corn, pepper and some cucurbit plants can likewise be supported to prevent lodging and limit vine sprawl. Some plants entwine themselves onto the support, while others may need to be tied.

- Plant shade-tolerant crops near vertically-supported crops.
- Plants grown vertically take up much less space than plants on the ground, and the yield per square foot of garden space is much greater.

- Vertically-grown plants are more exposed to the sun and air and dry out faster. Water them more frequently than if they are allowed to sprawl.
- Fertilize vertical plantings more frequently than plants you allow to sprawl on the ground.

INTERPLANTING

Growing two or more types of vegetable plants in the same space at the same time is known as interplanting. Consider the following factors for each plant:

1. Length of the plant's growth period.
2. Its growth pattern (tall, short, below or above ground).
3. Possible negative effects on other plants (such as the allelopathic effects of sunflowers and Jerusalem artichokes on nearby plants).
4. Preferred season.
5. 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).
- Mixing plants within a row.
- Distributing various species throughout the bed.

Some interplanting suggestions: Seed long-season (carrots) and short-season (radishes) plants at the same time. Harvest the radishes before they begin to crowd the carrots. Another example is the planting of smaller plants close to larger plants, like 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. Interplant heavy feeders, such as cabbage family crops, with less gluttonous plants.

SUCCESSION AND RELAY PLANTING

Succession planting is an excellent tool for maximizing food production. To obtain a succession of crops, plant something new in spots vacated by spent plants. Planting 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, followed by more cool-season plants, or a winter cover crop.

Relaying is 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 early are likely to get a slower start due to 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 corn extra time to get started. Another way to achieve the same result is to plant various varieties of the same vegetable all at once; for example, you can plant an early-, a mid-, and a late-season corn at the same time to have a lengthy harvest.

Keep Those Transplants Coming!

Starting seeds indoors or in a protected outdoor area is an important aspect of intensive gardening. To get the most from each bed, have a new crop ready to take the place of the crop being removed. You'll gain several weeks if you have 15 to 20 cm tall transplants ready to go into vacated areas. Don't forget to recondition the soil for the new plants.

PREPARING SOIL FOR WINTER

- Pull up all dead and unproductive plants and place this residue on top of the soil to be tilled under, or in the compost heap.
- Remove diseased or insect-infested plant material from the garden that may shelter overwintering stages of disease and insect pests. If this plant material is left in the garden, an inoculum of diseases and insects will reproduce the next spring and add to your pest problems.
- Add shredded leaves or compost to the garden.
- Compost contains nutritious, decomposed plant material and beneficial organisms, and is an excellent soil builder. By spreading compost and other wastes on the soil and plowing them in, you are adding nutrients to the soil for next year's crop.

COVER CROPS

Cover crops decrease soil erosion during the winter, add organic material when it is incorporated in the spring, improve soil tilth and porosity, and add valuable nutrients. You should plant winter cover crops as early as August 1, but no later than October 10. They should make some growth before hard frost kills them. Where you have fall crops growing, sow cover crop seed between rows a month or less before expected harvest. Your cover crop will get a good start but will not interfere with vegetable plant growth.

Some cover crops suitable for winter use are listed in **Table 13-2**. Mixtures of legumes and non-legumes are also effective.

Prepare the soil for cover crop seed by tilling under or removing plant wastes and mulch from the summer. The seed must directly contact soil to germinate. Broadcast the seed, preferably before a rain, and rake it evenly into the soil. Spring planting may be delayed somewhat by the practice of cover cropping, since time must be allowed for the green manure to break down. If you have crops that need to be planted very early, you may prefer to leave a section of the garden bare or with stubble mulch.

CONTAINER GARDENING

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 with 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. Dwarf or miniature varieties often mature and bear fruit early, but most do not produce as well overall as standard varieties. Select varieties specifically bred for container culture, which are not necessarily miniature or dwarf and may produce as well as standard types.

The amount of sunlight that your container garden spot receives may determine which crops can be grown. Root crops and leafy crops can tolerate partial shade, but vegetables grown for their fruits need at least 6 hours of full, direct sunlight, and perform better with 8-10 hours.

CONTAINERS

Clay, wood, plastic, and metal are some suitable materials. Containers for vegetable plants must (1) be of adequate size to support fully grown plants, (2) hold soil without spilling, (3) have adequate drainage, and (4) have held only non-toxic materials. Consider using barrels, flower pots, cut-off milk and bleach jugs, recycled Styrofoam coolers, window boxes, baskets lined with plastic (with drainage holes punched in it), or even pieces of drainage pipe or cinder block. 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.

Be sure there are holes in the bottom for drainage so that plant roots do not stand in water.

Table 13-1: INFORMATION FOR GROWING VEGETABLES IN CONTAINERS

Vegetable*	Light Requirements**	Minimum Container Size (L)	Distance Between Plants in Containers (cm)	Days from Seed to Harvest	Comments
Beans, bush	FS	7	5-7.5	45-60	Several plantings, 2 week intervals
Beets	FS/PS	2	5-7.5	50-60	Thin plants when
Carrots	FS/PS	1	5-7.5	65-80	Several plantings, 2 week intervals
Cabbage	FS/PS	20	30-45	65-120	Requires fertile soil
Chard, Swiss	FS/PS	2	10-15	30-40	Harvest leaves
Cucumbers	FS	20	35-45	70-80	Require hot weather; vining types need support
Eggplant	FS	20	1 plant per container	75-100	Requires support
Kale	FS/PS	20	25	55-65	Harvest leaves
Lettuce, leaf	PS	2	10-15	30-35	Harvest leaves
Mustard greens	PS	2	10-12	35-40	Several plantings, 2-week intervals
Onions, green	FS/PS	2	5-7.5	70-100	Require lots of moisture
Peppers, bell	FS	7	1 plant per container	110-120	Require support
Squash, summer	FS	20	1 plant per container	50-60	Plant only bush type
Tomatoes	FS	20	1 plant per container	55-100	Stake and prune or cage
Tomatoes, cherry	FS	4	1 plant per container	55-100	Helps to stake and prune
Turnips	FS/PS	10	5-7.5	30-60	Harvest leaves and roots
* Consult seed catalogues for varieties adapted to container culture. ** FS = Full sun; FS/PS = Full sun; tolerates partial shade; PS = Partial Shade					

Table 13-2: COVER CROPS

Type	Legume Non-Legume	Amount to Sow per 10 m ² (g)	When to Sow **	When to Turn Under	Effects	Notes
Alfalfa	L	14 g	Spring, Late summer	Fall Spring	Fixes 170-280 kg/N/ha/yr; deep roots break up hard soil, bring trace elements to surface	Loam, fairly fertile soil; needs warm temps for germination. Lime if pH is low. Hardy and drought tolerant.
Barley*	N	113 g	Fall Spring	Spring	Adds organic matter, improves soil aggregation	Prefers medium-rich loam soil. Lime if pH is low. Not as hardy as rye. Tolerates drought.
Buckwheat	N	71 g	Spring Summer	Fall	Add organic matter; improves soil aggregation; high in potassium	Must leave part of garden in cover crop during season. Grows quickly. Not hardy.
Oats*	N	113 g	Spring Fall	Summer Spring	Adds organic matter; improves soil aggregation	Needs adequate manganese. Not hardy; tolerate low pH.
Rye, winter	N	95 g	Fall	Spring	Adds organic matter; improves solid aggregation.	Very hardy. Can plant until late September.
Vetch, hairy	L	70 g	Early Fall	Spring	Fixes 90-110 kg/N/ha/yr	Inoculate with appropriate <i>Rhizobium</i> spp.; slow to establish. Fairly hardy. Till under before it seeds; can become a weed.
Winter wheat*	N	113 g	Fall	Spring	Adds organic matter; improves soil aggregation	Same as barley. Can be planted later than other cover crops.
*Will winter kill in most years leaving “mat” of dead vegetation which can be incorporated in the spring. ** Sow fall cover crops from August 15 – October 1, depending on location and cover crop.						

PLANTING MEDIUM

You will need a fairly lightweight potting mix. Soilless mixes (containing peat moss, perlite and vermiculite) are generally too lightweight. If the container is also lightweight, a strong wind can blow plants over. Also, soilless mixes are sterile and contain few nutrients, so if you add chemical fertilizers, few trace elements will be available for good plant growth. Add soil or compost if you wish to use a sterile mix. Good results have been achieved with a 1:1:1 mix of garden soil, soil-less mix and composted yard waste or manure.

WATERING

Pay particular attention to watering container plants.

Because the volume of soil is relatively small, containers can dry out very quickly, especially on a concrete patio in full sun. Daily or twice-daily watering may be necessary. Apply water until it runs out the drainage holes. 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 rot if kept too wet.

Water clay pots and other porous containers more frequently, as they allow additional evaporation from the sides of the pots. 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, consider putting containers on pallets or other structures that will allow air movement beneath the pots and prevent direct contact with the cement.

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. Consider installing an automatic trickle irrigation system if you plan to be away for extended periods of time.

FERTILIZING

Fertilize plants with a water-soluble fertilizer at the recommended rate every 2-3 weeks. An occasional application of fish emulsion or compost will add trace elements to the soil. Do not add more than the recommended rate of any fertilizer, since this may cause fertilizer burn and kill your plants. Container plants do not have the buffer of large volumes of soil and humus to protect them from over-fertilizing or over-liming.

CULTURE NOTES: SELECTED VEGETABLE CROPS

Notes on the culture of individual plants are presented as a summary of information on the culture, nutritional value, harvest, and storage of specific vegetable crops. These references are not intended to be comprehensive; you may need to consult other materials for more detailed information. The following key will help explain the various terms used under each crop.

ENVIRONMENTAL PREFERENCES

Light

- Sunny - requires direct light at least 6 hours/day; prefers 10 hours/day.
- Tolerates partial shade - does well with fewer than 8 hours of sunshine/day, but probably needs at least 5 hours/day.
- Prefers shade - more than 6 hours of direct sunlight may be harmful.
- Prefers filtered light - probably needs at least 3-4 hours of light/day.

Fertility

Results of soil tests can be used to determine the basic fertility level of your soil.

Acidity or Alkalinity of Soil

7.0 is neutral, below 7.0 is acidic, above 7.0 is alkaline.

Temperature

Approximate ranges of daily mean temperatures that are preferred for optimum growth.

Moisture

Amount of rainfall or supplemental water needed for optimum growth; more for sandy soils, less for clay. Average is roughly 2.5 cm of water per week (250 litres/10m²). Moist is roughly 2.5 to 5 cm of water per week; soil should be well-drained.

CULTURE

Planting

Specific information needed to get plants started, such as when to seed, whether to start plants indoors, best transplant time, etc.

Spacing

Optimum distances between plants (first number) and rows (second number).

Hardiness

- Very hardy perennial - can withstand winter extremes in most parts of Ontario with only slight protection.
- Hardy perennial - can withstand normal winters with protection in colder areas.
- Hardy annual - can withstand frosts in spring and fall; may need protection from heavy frosts or freezing.
- Half-hardy annual - can withstand light frosts, but not heavy frosts or freezing.
- Tender annual - frost will damage plant tissue).
- Very tender annual - frost will destroy tissues; needs warm weather to grow.

Fertilizer Needs

Low, medium, or heavy feeder. (This refers to relative levels of required nutrient uptake from the soil. The information can be used to group similar types of plants, so that fertilizers may be applied to sections of the garden according to plant needs.)

CULTURAL PRACTICES

General growing information. Includes proven methods for increasing production and/or decreasing pest problems. May include unique growing suggestions.

HARVESTING AND STORAGE

Approximate Yields

These figures vary according to variety, local environmental conditions, planting designs, and cultural practices.

Storage

Optimum storage conditions; gives temperature ranges and percent of relative humidity (RH).

ASPARAGUS

ENVIRONMENTAL, PREFERENCES

Light: Sunny

pH: 6.0-6.7

Temperature: Cool (15°-18°C)

Moisture: Average; a flush of spears often follows a soaking rain.

CULTURE

Planting: One-year crowns, early spring.

Spacing: 45 cm x 1.2-1.5 m; or in wide beds of three rows with plants 35 cm apart in all directions.

Hardiness: Hardy perennial; should be mulched in autumn.

Fertilizer needs: Medium-heavy feeder, high phosphorus and potassium and organic matter at planting; annual nitrogen in late winter or very early spring; may side-dress after harvest; benefits from yearly top-dressing of compost.

CULTURAL PRACTICES

Asparagus is a perennial vegetable that lives from 15 years or longer. It is one of the most valuable of the early vegetables and is well adapted to freezer storage. During the harvest period (traditionally spring, see "harvesting" section below for summer harvest instructions), the spears develop daily from underground crowns.

Asparagus does well where winters are cool and the soil occasionally freezes at least a few centimetres deep; it is considered very hardy.

Planting

- Select all-male hybrid varieties. They are more productive and disease-resistant than older varieties.
- Start asparagus either from seed or from one- to two- year-old crowns. Crowns are usually shipped and set out in early spring.
- Starting plants from seed requires an extra year before harvest. They are slow to germinate and should be transplanted in June.
- Look for roots that are full, slightly moist, and have colour. Roots that are dry brown or soggy black indicate poor storage and will probably not give good results.
- Check crowns for signs of viable buds. Inspect plants for signs of insects or disease.
- 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, store them in a cool place or else heel them in a trench of moist soil in a shaded location. Pack soil firmly against roots to eliminate any air pockets.

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 manure, compost, leaf mold, or a combination of several of these materials. In heavy soils, double-digging is recommended.

Double-digging is ideal for the trench method of planting asparagus since a 30 cm deep trench is usually dug anyway. The trench is dug 30 to 45 cm wide, with 1.2 to 1.5 m 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 5 cm of the mixture in the bottom of the trench or bed. Set the plants 30 to 35 cm apart, mounding the soil slightly under each plant so that the crown is slightly above the roots. Remove any rotted roots before planting.

Spread the roots out over the mound of soil and cover the crown with 5 to 10 cm soil. Firm well. As the plants grow, continue to pull soil over the crowns until the trench is filled.

Harvesting

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. For asparagus started from seed, 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.

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 weeds rather than hoe if possible.

Harvest spears daily during the 8- to 10-week harvest period. The 15 to 20 cm spears 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. 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 (after 8-10 weeks), allow the spears to grow. Asparagus has attractive, fern-like foliage that makes a nice garden border. Asparagus can also be easily integrated into the perennial border. Some gardeners prefer to support the growing foliage with stakes and strings to keep them tidy. In high-wind areas, it is a good idea to plant the rows parallel to the prevailing winds so that the plants support each other to some extent. There are several ways to extend the harvest period:

- Plant at different depths (7.5, 10-15, 15-20, 20-25 cm). The shallow plantings will come up first and can be harvested while the deeper plantings are just fanning. This method will result in a slightly longer harvest, but the planting may be less vigorous.
- Remove mulch from half of the asparagus bed. Leave the mulch on the other half. The exposed soils will warm up more quickly, and the crowns will sprout earlier. This process may be speeded up even further using black plastic, but be careful not to encourage growth too early, as heavy frost can make spears inedible.

Remove mulch from the second bed when spears begin to appear.

- Plant double the amount of asparagus needed for your household. Harvest half of the plants as you normally would in spring and early summer and allow the ferns to grow in the other half of the asparagus planting. Then, cut the ferns in the unharvested plot in late July. The crowns will send up new spears, which can be harvested till late in the season. Keep plants well watered. Light mulch will aid in spear emergence. When using this method, harvest the spring bed only in spring and the fall bed only in fall! Otherwise you risk weakening the crowns.

Winter Care

In all asparagus plantings, cut the foliage down to 5 cm stubs after frost when the foliage yellows, before the red berries fall off. A 10-15 cm mulch of compost, manure, leaves, or other material added at this time will help control weeds and add organic matter and nutrients.

HARVESTING AND STORAGE

Days to maturity: 2-3 years

Harvest: third-year spears; snap off just under soil surface when 15 to 20 cm tall, before tips begin to separate; use or refrigerate immediately.

Approximate yields: (per 3 m row) 1.2-2 kg/year.

Storage: process or refrigerate immediately in plastic bag.

BEANS

ENVIRONMENTAL PREFERENCES

Light: Sunny

Fertility: Medium-rich pH: 5.8-7.0

Temperature: Warm (18°-27°C) except Fava beans - cool (15°-21°C).

Moisture: Average

CULTURE

Planting: Seed after danger of frost is past.

Pre-germinating seed before planting in cool, spring soil may help prevent soil rot and seed corn maggot problems. Inoculating seeds with nitrogen-fixing bacteria may increase yields on land newly planted in beans.

Days to maturity:

- snap beans 50-60
- pole beans 60-110
- bush limas 65-75
- pole limas 85-110

Spacing:

- bush snap 5 x 60-75 cm
- bush limas 5 x 45-75 cm
- pole beans 5 x 60-90 cm

Hardiness: Tender annual, except Fava (semi-hardy annual).

Fertilizer needs: medium feeders. Since beans are legumes they will fix nitrogen once a good root system is established; inoculation will speed the process. Excess nitrogen will delay flowering, so side-dress only after heavy bloom and set of pods, using 45 ml of 10-10-10 (or equivalent) per 3 m of row.

CULTURAL PRACTICES

Types

Bush Beans or snap beans are popular because of their early maturity and bush growth habit. Varieties include standard green, yellow wax, and purple-pod types. Flat-pod (Roman) green snap beans are somewhat different in flavour and texture than the round-pod ones, and are preferred by many gardeners. These are available in both bush and pole types.

Half-Runner Beans are a snap bean with a growth habit between that of bush and pole beans. Though they have runners about 1 m long, half-runners are generally grown like bush beans. Trellising, however, may increase production of these heavy yielders.

Pole Beans generally produce higher yields over a longer period in less space than bush types. Pole beans are natural climbers but will not interweave themselves through horizontal wires. A tripod support can be made with three wooden poles or large branches that are lashed together at the top. Five to six seeds are planted in a circle 15 to 20 cm from each pole.

Many types of homemade trellises work well as long as they provide the needed support. Trellises should be 1.8 to 2.5 m tall and sturdy enough to withstand strong winds and rain.

Scarlet Runner Beans are a type of pole bean that grows rapidly, producing beautiful red flowers that are attractive to hummingbirds along with delicious beans. They 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 kilograms are produced per plant. The lush 1.8 to 4.5 m vines can be used to cover arbors, trellises, or fences. Scarlet runner bean grows best in cooler weather. Prolonged, high temperatures will reduce yield and pod quality. Keep maturing beans picked off to prolong the life of the vines.

Lima Beans are available in bush or pole types. Bush limas mature about 10-15 days earlier than pole limas but the pole limas are more productive over a longer period. Soil temperature must be 18°C for 5 days in order for the beans to germinate well. Because the large seeds store considerable amounts of carbohydrates, limas are quite susceptible to soil fungi and bacteria.

Asparagus Beans or "yard-long" beans are related to the black-eyed pea and have a similar flavour, but the entire pod may be 45 to 60 cm long. Asparagus beans need warm temperatures and a long growing season to grow well.

Fava Beans or broad beans are quite hardy. In cool climates they are often substituted for limas. Favas are sown early in spring, and do not grow well in warm weather. Some people of Mediterranean origin have a genetic trait that causes a strong allergic reaction to fava beans.

Succession Planting

For a continuous harvest, snap beans can be planted every 2-3 weeks from the frost-free date through August 1. Snap beans should be kept picked to keep plants producing heavily. Seed planted in cold soils germinates slowly and is susceptible to rotting. Also, seedling growth may be slow in cool temperatures. For early spring plantings, try pre-germinating your seed or starting seed indoors in peat pots, being careful not to damage the roots and shoots when transplanting. Soil should be kept moist, but not soaking wet, until the seedlings emerge. Prevent crusting of heavy clay soils, and conserve moisture, by spreading 0.5 cm of sand, sawdust, or light mulch over the seeded row.

Cold, wet spells and excessively hot and dry periods can cause lima flowers to drop, reducing yields. Baby limas or butter beans are less susceptible to blossom drop problems.

HARVESTING

Harvest: Snap beans -full sized pods, small beans or larger beans as long as pods are still tender; pods break easily with a snap when ready; seed should not cause pods to bulge.

Lima/dry beans - Seeds will be full sized and pods will be bright green. End of pod will be spongy. For dry beans (of all types) pods should remain on bush until dry and brown.

Approximate yields (per 3 m row): snap beans, 1.5 to 2 kg; lima beans, 1.5 to 2.5 kg.

BEETS AND SWISS CHARD

ENVIRONMENTAL PREFERENCES

Light: Full sun, will tolerate light shade.

Fertility: High; needs high amounts of organic matter: boron, a micronutrient, may be deficient in sandy soils and cause development of black spots in the roots which will, in turn, affect yields.

pH: 6.0 to 6.8, will tolerate alkaline soils but are sensitive to excessive acidity.

Temperature: Cool, 15°-18°C. Prolonged temperatures (30-60 days) below 10°C will cause bolting.

Moisture: Average - regular moisture will give even, uniform growth.

CULTURE

Planting: Direct seed into garden in early spring and throughout summer, if desired.

Days to maturity: 50-70

Hardiness: Hardy biennial. Treat as annual. Fertilizer

Needs: Heavy feeder: apply a pre-plant fertilizer before seeding. In areas with boron deficiency, apply 90 to 100 ml of borax/100 m² of garden area.

CULTURAL PRACTICES

Beets come in a variety of colours, including red, golden, white, and striped. Cylindrically shaped beets, such as 'Cylindra' and 'Formanova' yield many uniform slices per root.

Beet seed is actually a fruit or seed ball with several embryos. Unless you buy seed designated as monogerm seed - one embryo per fruit - you will need to thin the planting when plants are 5 cm in height. Sow beets several weeks before the last spring frost, throughout the summer and up until 6 weeks before the first killing frost in the fall. Seed germination temperature range is 7°-30°C. Plant in wide rows or beds, space seeds 5 cm apart in all directions, and cover with 1.5 cm of fine soil or 2.5 cm of sandy soil. Thinnings can be used in salads. Final spacing should be 8 cm in all directions. The final thinning can be delayed until small beets are large enough for table use.

Use row covers for an earlier crop and to keep spinach leaf miners from laying eggs on the leaves of beets, chard and spinach.

Swiss chard is the ancestor to table beets. It is similar except it lacks a swollen storage root. Like beets, the seed is really a fruit containing several embryos which will need to be thinned. Swiss chard leaves grow vigorously throughout the season. It can be rejuvenated by cutting plants 5 cm above the crown. New succulent leaves will shoot up and soon be ready for harvest.

HARVESTING AND STORAGE

Harvest: when beet roots are 2.5 to 7.5 cm in diameter. Cut chard leaves when they are mature, leaving crown to re-grow.

Approximate Yields: Beets: 1-2 kg/3m of row, depending on size of harvest.

Storage: 0°C at 95% RH is ideal. Store in the refrigerator in a vented plastic bag.

BROCCOLI

ENVIRONMENTAL PREFERENCES

Light: Sunny Fertility: Rich

pH: 6.0-7.0

Temperature: Cool (15°-18°C)

Moisture: Keep moist, not waterlogged.

CULTURE

Planting: Start seeds indoors for early spring transplants. Seed in beds or flats for fall transplants or direct seed into garden.

Days to maturity: 55-65 from transplanting (less for fall crop).

Spacing: 55-60 x 60-75 cm

Hardiness: Hardy biennial. Treat as annual.

Fertilizer needs: Heavy feeder: use starter fertilizer when transplanting; side-dress three weeks later and when central head has been cut (100 g of 10-10-10 per 3 m row).

CULTURAL PRACTICES

Types

There are three types of broccoli: heading, Romanesco and sprouting. The heading type, which is closely related to cauliflower, forms a large central head. The heads of broccoli are really flower buds that must be harvested before the flowers open or show yellow. Mature heads measure 7.5 to 15 cm across. Smaller, lateral heads develop throughout the summer after the central head is cut. The spiraling heads of Romanesco broccoli are quite dramatic. Sprouting or Italian broccoli forms many florets or small heads but these do not produce a solid head.

Planting

Broccoli transplants are set out in Ontario from April 5 to May 30 and again in August. Transplants for a fall setting can be produced along with cabbage and cauliflower transplants, taking about 4-6 weeks from seeding to setting into the garden. Fall planted broccoli often produces higher yields than spring plantings.

Sprouting broccoli is sown directly into the garden in spring. Follow packet directions.

Broccoli has a relatively shallow, fibrous rooting system. Cultivate carefully or use thick mulch.

HARVESTING AND STORAGE

Harvest: Cut large terminal bud clusters before flowers open and then cut small side bud clusters as flowers develop over following weeks. Harvest with 15 to 20 cm of stalk. Harvest sprouting and other types according to packet instructions.

Approximate yields (per 3 m of row): 6-10 bunches or about 1.5 to 3 kg.

Storage: Very cold (0°C), moist (95% RH) conditions, 10-14 days

BRUSSELS SPROUTS

ENVIRONMENTAL PREFERENCES

Light: Sunny Fertility: Rich pH: 5.5-7.0

Temperature: Cool (15°-18°C)

Moisture: Keep moist, not waterlogged.

CULTURE

Planting: Sow seeds early- to midsummer. Seed can be sown indoors for transplants.

Days to maturity: 80-100 from seed.

Spacing: 30-45 cm x 60-75 cm

Hardiness: Hardy biennial. Treat as annual.

Fertilizer needs: Heavy feeder, side-dress with a balanced fertilizer 2-4 weeks after planting or when plants are 30 cm high.

CULTURAL PRACTICES

Brussels sprouts are grown for harvest in the fall because cool weather during maturity is essential for good flavour and quality. Brussels sprouts are tall (sometimes 60-100 cm), erect biennials that are grown as annuals. The sprouts develop in the leaf axils and mature along the stalk. The lowest leaves can be removed to hasten sprout development.

HARVESTING AND STORAGE

Harvest: When sprouts are hard, compact, and deep green about 2.5 to 3.5 cm in diameter, after frosty weather for best flavour. Twist or snap off of the stalk. The lowest sprouts mature first.

Approximate yields (per 3m of row): 1.8-2.7 kg

Storage: Cold (0°C), moist (95% RH) conditions, 3-5 weeks.

CABBAGE

ENVIRONMENTAL PREFERENCES

Light: Sunny Fertility: Rich

pH: 5.5-7.0

Temperature: Cool (15°-18°C) **Moisture:** Keep moist, not waterlogged.

CULTURE

Planting: Start seeds indoors for early spring transplants.

Days to maturity: 70-100 from seed.

Seed in beds or flats for fall transplants. Spacing: 35-45 cm x 60-90 cm

Hardiness: Hardy biennial. Treat as annual.

Fertilizer needs: Medium feeder, use starter fertilizer when transplanting, side-dress three weeks later (60 ml, 10-10-10 or the equivalent per 3 m of row).

CULTURAL PRACTICES

Cabbage can be grown in the garden from March to December. It will withstand temperatures as low as -9° to -70°C. Start plants indoors 4-6 weeks before the first date when plants can be set out, or sow a few seeds in your cold frame or garden every month to have cabbage plants thereafter. It takes about 3 weeks to get plants ready from seeding to set during the summer months. Plant only the earliest varieties after July 1. It is best not to plant cabbage family crops in the same spot year after year, since diseases and insect pests will build up. Rotate crops within your garden.

Plant spacing affects head size. Close spacing (30 cm apart in the row) produces small heads. Average spacing is 35 to 45 cm apart in rows 60 cm apart.

Large-headed varieties for sauerkraut are spaced wider. Small-headed varieties are fast maturing and can be succession planted throughout the season. Heads can be left on the plant in the garden for about 2 weeks in the summer, 3-4 weeks in the fall.

HARVESTING AND STORAGE

Harvest: When heads become firm; size will vary with variety, fertility, and spacing. If unable to harvest at maturity, bend over to break part of the roots to reduce head splitting.

Approximate yields (per 3 m of row): 4-10 kg

Storage: very cold (0°C), moist (95%RH) conditions, 4-5 months.

CARROT

ENVIRONMENTAL PREFERENCES

Light: Full sun

Fertility: Medium to rich

pH: 5.5 to 7.0

Temperature: Best shape and quality when grown between 13°-24°C. Temperatures over 21°C reduce root length.

Moisture: Average to moist, well-drained.

CULTURE

Planting: Direct seed into loose, friable soil which is free from rocks, clods, or debris. Plant when the soil temperature has reached at least 7°C. Carrots take several days to germinate, so try marking the rows by sprinkling a few radish seeds in with them. Cover seed with 0.8 to 1.3 cm of soil and keep moist. Carrots are best planted in the spring and fall. They do not grow well during hot weather.

Days to harvest: 65-75

Spacing: Thin to 2.5 to 5 cm apart. **Hardiness:** Hardy biennial. Treat as annual.

Fertilizer Needs: Light to medium-heavy feeder. Incorporate pre-plant fertilizer according to the soil test; may also band fertilizer 5 cm below the seed at planting time.

CULTURAL PRACTICES

For most efficient use of garden space, plant in wide rows and thin equidistantly to 2.5 to 5 cm apart. If not too crowded, wait and pull the largest roots when they are big enough to eat, leaving the smaller roots to grow. Use row covers to speed early crops and exclude insects. Hill soil over the tops of the roots to prevent development of green shoulders. **Uniform soil moisture is critical to producing sweet, crisp, carrots.**

There are *five* main types of carrots to choose from:

Chantenay Type - These are 5 to 6.5 cm in diameter at the shoulder and 13 to 15 cm long with a medium to large neck. Colour is medium to light orange with a red core. It is better for shallow, heavy soils than the long, skinny Emperor types.

Emperor Type - They are 18 to 20 cm long with a shoulder diameter of 3.5 cm. The roots are deep orange in colour with a lighter orange core. The roots become woody when fully mature, but are excellent when harvested at their prime.

Danvers Type - The shape is conical with a top diameter of 5 to 6.5 cm and length of up to 18 cm. They are deep orange with a light center. Quality is excellent in young roots; becomes fibrous with age.

Nantes Types - The shape is nearly cylindrical with a blunt tip, 15 to 18 cm long and 3.5 cm in diameter. The roots are bright orange with a small core. The tops are often small and require careful digging at harvest.

Miniature and Oxheart Types - Baby carrots are sometimes termed Amsterdam types. The roots are 1.3 to 1.7 cm in diameter and only 6.5 to 7.5 cm long. Stump-rooted or round carrots are suitable for heavy, clay soil or container gardening.

For winter harvest, mulch with at least 30 cm of straw before the ground freezes. Cover the straw with a tarp or sheet of plastic. Prevent the ground from freezing and the carrots will be available for digging all winter.

HARVESTING AND STORAGE

Harvest: Pull or dig when roots reach the appropriate size for the cultivar.

Approximate yields: 1 to 3 kg per 3 m row, depending on the row width.

Storage: Topped carrots can be stored up to 4-5 months at 0°C and 90%-95% RH without noticeable loss of quality. When harvesting carrots in the garden, immediately cut off the tops and compost them. This will decrease moisture loss from the roots and help them stay crisp.

CAULIFLOWER

ENVIRONMENTAL PREFERENCES

Light: Sunny

Fertility: Rich pH: 6.0-7.0

Temperature: Cool (15°-18°C)

Moisture: Keep moist, not waterlogged

CULTURE

Planting: Set out 5-7 week old transplants 2-3 weeks before the frost-free date. Seed in beds or flats for fall transplanting or direct seed into garden soil. Avoid tough, overly mature transplants. They will produce "button heads".

Days to maturity: 50-80 from transplanting

Spacing: 35-60 cm x 60-90 cm

Hardiness: Half-hardy biennial

Fertilizer needs: Heavy feeder; use starter fertilizer when transplanting, side-dress three weeks later and as needed (100 g 10-10-10 or the equivalent per 3 m of row).

CULTURAL PRACTICES

Planting

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 an inch or less in diameter, usually due to environmental stress—overgrown transplants, hot and cold temperatures during the head formation period. If this condition occurs, fall cauliflower production should be tried. Fall cauliflower should be sown in mid to late July.

Blanching

Blanch cauliflower when the head is about 5 to 7.5 cm. 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 4-8 days but may take longer in the fall. If weather is warm during the blanching period, tie the leaves loosely to allow air circulation. Self-blanching types which have leaves that grow up over the head may eliminate the need for this practice.

HARVESTING AND STORAGE

Harvest: Cut before flower sections begin to separate. The curd should be compact, firm, white, and fairly smooth. Leave a ruff of leaves surrounding head when harvested to prolong keeping quality. Cauliflower heads become grainy when over mature.

Approximate yields (per 3 m of row): 3.5 to 5.5 kg

Storage: very cold (0°C), moist (95% RH) conditions, 2-4 weeks.

CORN

ENVIRONMENTAL PREFERENCES

Light: Sunny

Hardiness: Tender annual

Fertility: Rich

pH: 6.0-7.0

Temperature: Warm (15°-24°C) Moisture: Average

CULTURE

Planting: Seed after danger of frost is past; super-sweet varieties should be planted when soil temperatures reach 18°C.

Days to maturity: 63-100

Spacing: 25-30 cm x 60-90 cm minimum of three rows side by side (preferably four rows) to ensure good pollination

Fertilizer needs: heavy feeder; side-dress twice: when plants are 30 to 45 cm high and again when tassels appear with 100 g of 10-10-10 (or the equivalent) per 3 m of row.

CULTURAL PRACTICES

Variety Selection

Sweet corn varieties differ significantly in time to maturity and in quality; yellow, white, hi-coloured, standard, and super-sweet varieties are available. Most varieties planted are hybrids that have been bred for greater vigour and higher yields. A continuous harvest can be planned by planting early-, mid-, and late-season varieties. Successive plantings of the same variety can be made every two weeks or when the last planting has three to four leaves (corn sown in early spring will take longer because of cool temperatures). Use only the earliest varieties for July plantings. Keep in mind that several caterpillar pests may be present in great numbers by late summer.

Pollination

Pollination is a very important consideration in planting sweet corn. Because corn is wind-pollinated, block plantings of at least three to four 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 cross-pollinate readily. To maintain desirable characteristics and high quality, extra-sweet and standard sweet corn should be isolated from each other by distance (350m) or planting time (two weeks). Sweet corn plantings must be isolated from field corn as well. White and yellow types will also cross-pollinate, but the results are not disappointing.

Super-sweet

The newly developed extra- or super-sweet types convert sugar into starch more slowly than standard varieties (they stay sweeter longer). Growing the super-sweet varieties does present challenges.

Seeds may germinate erratically and seedling vigour is low. The plants must be well watered at all times (especially after seeding) and often benefit from some type of support.

Early Corn

Early-maturing varieties tend to produce relatively small plants. Plant them in rows 75 cm apart with plants 20-25 cm apart. For medium to large plant varieties use a 90 cm row spacing with plants 30 cm apart in the row.

Baby Corn

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 simply immature corn. Several specialty varieties are available that have a dwarf habit (takes up less space) and produces 0.6 cm diameter cobs at maturity. Harvest when the silks develop but ears are not yet fertilized.

Suckers/Support

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. Support the growing stalks with one or two strands of heavy string around the perimeter of the planting, to prevent lodging (plants falling over) during thunderstorms. Larger, block plantings are less susceptible to wind damage than smaller plantings or isolated rows.

Mulching

Mulching is helpful in corn growing because adequate moisture is required from pollination to harvest to guarantee that ears are well filled. Since main crops of corn usually ripen during Ontario's drier periods, it is especially critical to maintain soil water supplies. Mulching reduces the need for supplemental watering and keeps the moisture content of the soil fairly constant. Most organic mulches are suitable, including sections of newspaper covered with straw.

Keeping It Fresh

Field heat can be removed from the ears by plunging them in ice-cold water (add a few drops of bleach and a drop of lemon juice per 4 litres of water) for 1-2 minutes. Then store in the refrigerator (5 ears to one 4 litre plastic bag) until ready to use. The corn will remain fresh for 1 week. However; the conversion of sugars to starches will continue in storage resulting in corn that is less sweet.

HARVESTING AND STORAGE

Harvest: In early morning when husks are still green, silks dry brown, kernels full size and yellow or white to the tip of the ear; at milky stage (use thumbnail to puncture a kernel - if liquid is clear the corn is immature, if milky it's ready, and if no sap, you're too late). Cover un-harvested ears checked by this method with paper bags to prevent insect or bird damage. Experienced gardeners can feel the outside of the husk and tell when the cob has filled out. Corn matures 17-24 days after first silk strands appear, more quickly in hot weather, slower in cool weather.

Approximate yields (per 3 m of row): 2-5 kg or roughly 10-20 ears.

Storage: (0°F), moist (95% RH) conditions; keeps 4-8 days, but standard varieties become starchy after a few days.

CUCUMBERS**ENVIRONMENTAL PREFERENCES**

Light: Sunny

Fertility: Rich

pH: 5.5-7.0

Temperature: Hot (18°-27°C)

Moisture: Keep moist, not water-logged; mulch helps maintain moisture.

CULTURE

Planting: Seed in garden after danger of frost has passed and soil has warmed, or use plants sown indoors in peat pots 3-4 weeks prior to planting time. Plant second crop around July 1. Handle transplants gingerly and disturb the root system as little as possible. Thin seedlings by cutting excess plants with scissors rather than by pulling.

Days to maturity: 50-65 from seed.

Spacing: 30 cm x 120-180 cm in rows, 60-90 x 120-180 cm in hills (two to three plants per hill); closer if trellised.

Hardiness: Very tender annual.

Fertilizer needs: Moderate feeder; side-dress one week after blossoming begins and again 3 weeks later (100 g 10-10-10, or the equivalent, per 3 m of row).

CULTURAL PRACTICES**Variety Selection**

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. There has been a significant increase in disease resistance in cucumber varieties in recent years. Try to select resistant varieties when possible.

New varieties of cucumber are being released that 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 produces the fruit, 10-20 male flowers are produced. Some of the new varieties produce plants that have only female flowers, while others have a greater proportion of female to male flowers. These plants tend to bear fruit earlier and more heavily with a more concentrated set.

Parthenocarpic cucumbers are all female and seedless because the fruit is produced without being pollinated. If this type of cucumber is planted near other varieties, pollination will occur and seeds will form. This type is usually grown in greenhouses or enclosed in a floating row cover.

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 20°, uneven moisture, and storage of cucumbers near other ripening vegetables.

Up, Up and Away

Most varieties of cucumber vines spread from row to row. Training on a trellis or fence along the edge of the garden will prevent this and also lift the fruit off the soil. Plant four to five seeds per foot thinning to a 25-30 cm spacing when plants are 10-15 cm high.

Benefits of Trellising Include:

- *increased total yields and yield per square metre*
- *longer and straighter fruit*
- *no soil borne fruit rot; vines dry-off faster*
- *no walking on vines*
- *easier to pick; longer harvest*

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.

Pollination

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 are usually included in the seed packet. Poor cucumber set is common during rainy weather when bees are inactive. Avoid using broad-spectrum insecticides.

Plants respond to mulching with soil-warming black plastic in the spring for earlier harvest. Organic materials are useful in the summer to hold soil moisture and keep the fruit clean in non-trellised plantings.

HARVESTING AND STORAGE

Harvest: Pickling cucumbers should be 5 to 7.5 cm long. Slicing cucumbers should be 12 to 20 cm long depending on the variety. Remove by turning cucumbers parallel to the vine and giving a quick snap. This prevents vine damage and results in a clean break. Working in the vines when leaves are wet may spread diseases. Wait until after morning dew or rain evaporates.

Approximate yields (per 3 m of row): 3.5 to 4.5 kg.

Storage: medium cool (7°-10°C) and moist (95% RH) conditions.

EGGPLANT**ENVIRONMENTAL PREFERENCES**

Light: Sunny

Fertility: Rich

pH: 6.0-7.0

Temperature: Warm (21°-30°C) Moisture: Average

CULTURE

Planting: Transplant after danger of frost, when soil is thoroughly warm. Use 8-10 week old transplants.

Days to maturity: 55-80 from transplanting.

Spacing: 45-60 cm x 60-90 cm

Hardiness: Very tender annual.

Fertilizer needs: Heavy feeder; side dress 100 g 10-10-10, per 3 m of row (or the equivalent) after first fruits form.

CULTURAL PRACTICES

Standard eggplant varieties produce tear-shaped, glossy purple black fruit 15-25 cm long. The long, slender, Japanese eggplant has a thinner skin and a more delicate flavour. Ornamental varieties are available and edible, but are of poor eating quality.

Warm to hot weather throughout the season is necessary for good production. Seeds germinate quickly at 21-32°C, and plants should be grown for 8-10 weeks before setting them out. Cold temperatures will stop plant and root growth, reducing plant vigour and yields. Using hot caps or cloches protects plants from cold conditions. Black plastic mulch with a soaker hose or drip system underneath, can greatly increase yield and hasten maturity.

Though eggplants do well in hot weather, they must have well-drained soil. When plants are about 15 cm high, nip back the growing tip to encourage branching.

Support plants with cages or trellis to prevent lodging (plants falling over). Protect plants from damaging flea beetles with floating row covers.

HARVESTING AND STORAGE

Harvest: Pick fruits when immature, about two-thirds the maximum size, when skin is still very glossy with a uniformly deep purple colour. When the side of the fruit is pressed slightly with thumbnail and an indentation remains, the fruit is ripe. Long, slender Japanese eggplant may be ready to harvest from finger or hot dog size. Discard over-ripe fruit of dull colour with brown seeds. Mature fruit should not be left on the plant as this will reduce overall productivity.

Approximate yields: (per 3 m of row): 9 kg

Storage: cool (7°-10°C), moist (90% RH) conditions; 1 week.

GARLIC

ENVIRONMENTAL PREFERENCES

Light: Full sun
Fertility: Medium feeder
pH: 6.0-7.0
Temperature: Cool
Moisture: Average

CULTURE

Planting: Plant individual cloves in early to mid-October so they have time to grow roots and a few leaves. Plant 2.5-5 cm deep, similar to onion sets, in soil heavily amended with organic matter. Large cloves produce larger bulbs than small cloves. Spring plantings produce smaller bulbs because size is related to the number of leaves initiated prior to bulbing.
Days to maturity: 250-270 days (fall planted)
Spacing: 7-10 cm apart in the row; improve efficiency by planting double or triple wide rows.
Hardiness: Hardy perennial.
Fertilizer needs: See onions.

CULTURAL PRACTICES

Cultivate very carefully so the shallow root system is not disturbed. Elephant garlic is actually a form of leek (*Allium ampeloprasum*, *Ampeloprasum* Group), but it forms large cloves, resembling garlic. One can purchase bulbs from groceries or mail-order suppliers. Top-setting (hard-necked) garlic produces bulbils on the top of the plant. These small bulbs can be replanted or consumed.

HARVESTING AND STORAGE

Harvest: Pull bulbs when the leaves collapse, but do not knock the tops over prematurely. Allow to dry in a cool, well-ventilated location out of direct sun. After a few days of drying, the tops can be braided into strings or ristras and allowed to finish drying.

Approximate yields: 2-4 kg per 3 m row.

Storage: cool (0°-3°C), dry (65%-70% RH) conditions; 6-9 months. To avoid botulism poisoning, do not store fresh garlic in oil unless it is kept in the freezer.

HORSERADISH

ENVIRONMENTAL PREFERENCES

Light: Full sun
Fertility: Rich
pH: 5.5-6.8
Temperature: Cool to moderate
Moisture: Average

CULTURE

Planting: Grown from root crowns and root cuttings (sets).
Days to maturity: About 7 months.
Spacing: Plant 7-15 cm deep, 0.5 m apart in rows spaced 75 cm apart.
Hardiness: Hardy perennial.
Fertilizer needs: Apply manure in the fall and plant crowns in the spring. For large roots, work the soil to a depth of at least 25 cm or more.

CULTURAL PRACTICES

In the home garden, roots can be dug in the fall and replanted immediately. When making the root cuttings, cut the top straight across and the bottom at a slant so you will know which way is up. Roots may be placed vertically or slanted downward, but the top and bottom should not be reversed.

Horseradish can become invasive if not contained by a large pot or barrier. Many new plants will emerge from broken roots.

HARVESTING AND STORAGE

Harvest: Horseradish makes its greatest growth during late summer and early fall and is typically harvested in October or early November. Small, slender roots are as pungent and flavourful as large roots and less woody.

Storage: Cool, dark, humid conditions.

Processing: If possible, perform all processing activities outdoors. Prepare by peeling the roots and removing all blemishes. Grate the root directly into white wine vinegar or distilled white vinegar. Do not use cider vinegar, as it causes the grated horseradish to turn dark in a short time. Refrigerate the prepared product at all times to keep it pungent. It will keep for a few weeks. Do not heat process, as it destroys the pungency. Keep the roots in cold storage and grate as needed. Horseradish may also be dried and powdered, but it is less pungent.

LEEEKS

ENVIRONMENTAL PREFERENCES

Light: Full sun

Fertility: Rich

pH: 6.0-6.8

Temperature: Cool

Moisture: Keep moist, not waterlogged

CULTURE

Planting: Start seeds indoors for early spring transplants or later in the summer for a fall crop. Transplant deeply to force long, thick, blanched stems. Transplants can be set in trenches that can be filled in over the growing season.

Days to maturity: 70-120, depending on the cultivar.

Spacing: 15 cm apart in the row or equidistantly in wide rows or bed.

Hardiness: With protection, hardy biennial.

Fertilizer needs: Medium to light feeder. Side-dress in June with compost tea or other balanced soluble plant food.

CULTURAL PRACTICES

Leeks are related to onions but instead of forming a bulb, the stem continues to thicken, forming a green sheath of furled leaves. Blanching the stems by hilling up soil around them will make your leeks tenderer and mild but isn't absolutely necessary. You can blanch your shanks at the base by transplanting the leeks into a bed of light soil. Use a dibble or dowel about 3 cm in diameter to make holes in the soil about 13 cm deep. Drop a transplant into each hole. Do not fill in with soil, but water gently and the soil will wash in.

Leeks are a long-season crop. Mulching is essential to keep the weeds out and the moisture in. In fall, protect the plant with a heavy blanket of straw or leaves so they can be harvested throughout the winter. Leeks left to grow in the spring will go to seed and can be the start of a self-perpetuating leek bed. Leeks left to flower may also produce bulblets at the base of the plants. These can be separated and used to propagate a new crop.

HARVESTING AND STORAGE

Harvest: Dig or pull. Leeks have large root systems so digging is sometimes easier. They can be harvested any time, from green onion size to before a killing frost. If covered with mulch, they can be dug throughout the winter.

Approximate yields: 2 or more kg per 3 m row, depending on planting style.

Storage: Will keep about one month in the refrigerator, longer in the ground (mulched and dug as needed).

LETTUCE

ENVIRONMENTAL PREFERENCES

Light: Sunny, tolerates shade; prefers shade in summer.

Fertility: Moderately rich

pH: 6.0-7.0

Temperature: Cool (15°-21°C)

Moisture: Moist, but not waterlogged; frequent, light waterings.

CULTURE

Planting: Sow leaf or butterhead types as soon as soil can be worked in the spring, or in late summer.

Crisphead and cos types may be transplanted in early spring and fall. Days to maturity: 40-80 depending on type.

Spacing: leaf, cos, or butterhead, 10-25 cm x 30-60 cm; crisphead, 30-40 cm x 45-75 cm.

Hardiness: Hardy annual

Fertilizer needs: Medium-heavy feeder; work in lots of organic matter prior to planting. Use starter solution on transplants, sidedress every week after planting with compost tea or balanced liquid fertilizer.

CULTURAL PRACTICES

Lettuce is an easy to grow, cool-season crop which can withstand light frost. It is a biennial plant grown as an annual. Floating row covers are very useful in promoting rapid growth in the early spring and minimizing slug and other pest feeding. Sunlight and high summer temperatures usually cause seedstalk formation (bolting) and bitter flavour. Slow-bolting or heat-resistant varieties (e.g., oak-leaf types) are available and are recommended for extending the lettuce-growing season. Shade cloth and floating row cover will also help to protect summer grown lettuce from direct sunlight and high temperatures. For succulence and high yield it is important to overhead water lettuce every day, especially dry, warm periods. Several types of lettuce are commonly grown in gardens.

Types

Crisphead - also known as iceberg. It has a tightly compacted head with crisp, light green leaves. Many gardeners find this type difficult to grow because it requires a long, cool season and runs to seed as soon as temperatures rise. 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 - (Bibb and Boston) loose-heading types with dark green leaves that are somewhat thicker than those of iceberg lettuce. Butterheads develop a light yellow, buttery appearance. Small-headed varieties are good choices for succession plantings. It may be started indoors for an even longer season. Bibb lettuce becomes bitter under high summer temperatures.

Romaine or cos - less commonly grown by gardeners, but a very nutritious lettuce that deserves attention. Relatively easy to grow, forms upright heads with wavy, attractive leaves.

Leaf - Most gardeners who grow lettuce raise the leaf type, either with green or reddish leaves. Fast-growing and long-lasting, this type can be grown with little care. Sow leaf varieties in rows, 30-60 seeds per metre, in rows 20-30 cm apart. Thin individual plants 10-20 cm apart, depending on variety. Leaf lettuce also grows very successfully in a wide bed arrangement; seedlings are thinned to 10-20 cm on all sides.

Lettuce is best planted in succession, or using different varieties that mature at different times. Leaf and Bibb lettuces do well in hotbeds or greenhouses during the winter and in cold frames in spring and late fall.

Cultivate carefully, as lettuce is shallow-rooted. Use frequent, light waterings to encourage rapid growth, but do not over-water, as this may contribute to root and leaf diseases. Overhead watering should always be done in the morning to give plants time to dry off. Mulches are helpful in maintaining soil moisture and preventing soil borne diseases.

Plant early spring lettuce in full sun or soil that will warm enough for rapid growth. Plant long-season lettuces, 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. Interplanting — planting between rows or within the row of later-maturing crops like tomatoes, broccoli, and Brussels sprouts — is a space-saving practice.

Some lettuces are attractive in flower borders.

HARVESTING AND STORAGE

Harvest: Leaf lettuce can be used as soon as plants are 10-15 cm tall. Use the older, outer leaves which contain high levels of calcium first. You may wish to harvest every other one of the largest plants to accomplish thinning. Bibb lettuce is mature when the leaves begin to cup inward to form a loose head. The heads will never become compact. Cos or Romaine is ready to use when the leaves have elongated and overlapped to form a fairly tight head about 10 cm wide at the base and 15-20 cm tall. Crisphead is mature when leaves overlap to form a head similar to those available in groceries; heads will be compact and firm.

Approximate yields (per 3m of row): 2-4.5 kg

Storage: cool (0°C), moist (95% RH) conditions; 2-3 weeks. Crisphead lettuce will keep about two weeks in the refrigerator. Leaf and Bibb will store as long as four weeks if the leaves are dry when bagged. If lettuce is to be stored, harvest when dry, remove outer leaves but do not wash, place in a plastic bag and store in the crisper drawer.

"Cut and Come Again"

For continuous harvests of quick and easy salad greens: sow a raised bed thickly with a mixture of your favourite salad greens (with maturity dates close to one another). Shear the plants with sharp scissors when they are 15-25 cm tall. Take off 5-10 cm or cut them to the crown. They will quickly re-grow if watered and fertilized. Sow a second bed. Turn under the plants in the first bed when they become over-mature and bitter.

MELONS

ENVIRONMENTAL PREFERENCES

Light: Sunny

Fertility: Medium

pH: 6.0-7.5

Temperature: Hot (21°-29°C)

Moisture: Average

CULTURE

Planting: Seed after all danger of frost is past and when soil warms, or begin transplants in peat pots 3-4 weeks before this time. Melons grown from transplants can be harvested as much as four weeks earlier than melons grown directly from seed.

Days to maturity: 80-100 days from transplanting

Spacing: Muskmelon hills 45-60 cm, watermelon hills 1.5-2.5 m apart.

Hardiness: Very tender annual.

Fertilizer needs: medium feeder; use a starter solution for transplants. Side-dressing with excessive nitrogen may lower yield or quality, or both. Late-maturing varieties, however, may need some side-dressing at fruit set.

For Sweeter Melons...

An excess of moisture or lack of boron and magnesium may result in poor-flavoured muskmelons. To remedy the problem, apply a mixture of 55 ml Epsom salts plus 24 ml Borax per 4 litres of water. Spray when the vines begin to run and again when fruits are 2.5-5 cm in diameter (based on University of Maryland Research). Keep plants well-watered until fruits are half grown.

CULTURAL PRACTICES

Muskmelons and watermelons are warm-season crops requiring a long growing season. Most varieties are not well suited to small gardens because of the space requirement. Muskmelons and watermelons grown on black plastic mulch will produce larger and earlier harvests. If possible, run a soaker hose or drip irrigation line under the plastic. "Seedless" watermelon varieties have lower germination and seedling vigour and require more careful management.

Growing on a trellis allows closer spacing (rows 1 m apart), but each trellised melon must be supported by a sling made of a material that dries quickly to prevent rot. Old nylon stockings, cheesecloth, and other netlike materials make good fruit slings.

Pollination: 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 melon). So-called "seedless" watermelons are genetic triploids and require a second diploid variety to set fruit. Poor melon set is common during rainy weather when bees are inactive.

HARVESTING AND STORAGE

Harvest: Muskmelons are harvested at "full slip", that is, when the stem separates easily at the point of attachment. Honeydew melons are cut off the vine after they turn completely yellow. These melons will rot if left on the ground for too long. For watermelons, the best indicators are a yellowish colour on the underside where the melon touches the ground and a dead tendril or curl near the point where the fruit is attached to the vine. You may also thump the fruit, listening for the dull sound of ripe fruit, rather than a more metallic sound; however, this technique takes some practice, and if you have just a few fruit, it is probably wise to include all of the above when making your decision.

Approximate yields (per 3m of row): 2-18 kg

Storage: medium-cool (4°-10°C), moist, (80%-85% RH) conditions.

OKRA

ENVIRONMENTAL PREFERENCES

Light: Full sun

Fertility: Rich

pH: 5.8-6.5

Temperature: Very warm (21o to 35°C)

Moisture: Water deeply, yet infrequently, to avoid cooling the soil.

CULTURE

Planting: Sow seed outdoors after soil has warmed to 21°C or sow indoors and transplant to the garden after all danger of frost has passed, to avoid a delayed crop. Hard seed coat can be softened by soaking in buttermilk or weak vinegar solution for 24 hours or by scratching the seed coat with a file or rasp. Seeds can also be pre-sprouted prior to planting.

Days to maturity: 50-60

Spacing: 30-40 cm apart in the row with 1 m between rows.

Hardiness: Very tender annual.

Fertilizer needs: Heavy feeder, needs a continuous supply of nitrogen for prolonged pod set. Side-dress at least one time.

CULTURAL PRACTICES

Because okra is a tropical crop, it may be difficult to grow in most parts of Ontario. Only one flower opens on a single stem in a single day. The fruit can be green, creamy-white or burgundy coloured.

Pinching back young plants will encourage branching and multiple stems.

HARVESTING AND STORAGE

Harvest: Most plants are spiny, so wear gloves and use clippers or a knife to cut pods from the plants. Harvest 7-10 cm long pods approximately one to three days after the flowers open, before pods get woody. For continuous harvest, remove any over-mature pods so plants will continue to bloom.

Storage: Okra pods become pitted if stored for very long in the refrigerator. To avoid chilling injury, store in a cool location no lower than 7°C.

ONIONS

ENVIRONMENTAL PREFERENCES

Light: Sunny (green onions tolerate partial shade).

Fertility: Rich

pH: 5.5-7.0

Temperature: Cool during foliar development; medium-hot during bulbing and curing. **Moisture:** Moist, but not waterlogged.

CULTURE

Planting: Use sets, seeds, or transplants in spring for bulbs and for green or bunching onions. Seed may be started indoors 8 weeks before setting out; use sets in the fall for perennial or multiplier types of onions.

Days to maturity: 85-120 (mature bulbs)

Spacing: Standard 2.5-15 cm x 30-60 cm wide row 10 x 10 cm rows up to 50 cm apart. Plant close, then thin, using thinnings as green onions.

Hardiness: Bulb onions - hardy biennial; green or bunching - hardy biennial; Egyptian or Perennial (Multiplier) – hardy perennials

Fertilizer needs: Heavy feeder; apply 1.8-2.3 kg 10-10-10 per 10 m² (or the equivalent) before planting, use starter solution for transplants, and sidedress 1-2 weeks after bulb enlargement begins (100 g 10-10-10 or the equivalent, per 3 m of row).

CULTURAL PRACTICES

Onions are often grouped according to taste (mild and strong-flavoured), colour (white, yellow and red) and use (storage or freshly eaten). Globe varieties tend to keep longer in storage.

Onion varieties also have different requirements as to the number of hours of daylight required to make a bulb. If the seed catalog lists the variety as long day, it sets bulbs when it receives 15-16 hours of daylight and is adapted to Northern summers. Short-day varieties set bulbs with about 12 hours of daylight and are used in the southern United States for winter production.

Onion foliage grows best during cool weather while bulb formation requires high temperatures. For bulb production, plant seedlings or sets in early spring. Set 2.5 to 5 cm apart and 2.5 cm deep in the row. Thin to 10 cm apart and eat the thinned plants as green onions. Avoid sets more than 2.5 cm in diameter because they are likely to produce seed stalks. Planting too early-exposure to cold temperatures - also causes seed stalk development. Multiplier onions should be set in the autumn until late October or early November. Plant 10 cm apart in rows 30-60 cm apart.

Bulbs compete poorly with weeds because of shallow root systems. Shallow cultivation is necessary; do not hill up soil on onions as this can encourage stem rot. Ensure ample moisture, especially after bulbs begin enlarging.

HARVESTING AND STORAGE

Harvest: Harvest green onions when tops are 15 cm tall; bulb onions should be harvested when about two-thirds of the tops have fallen over. Careful handling to avoid bruising helps prevent 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 out of direct sun for 1-2 weeks. Tops may be left on or cut off; but leave at least 2.5 cm of the top when storing. Thorough curing will increase storage life.

Approximate yields (per 3 m of row): 4.5-6.8 kg

Storage: cool (0°C), dry (65%-70% RH) conditions; 6-7 months.

PEAS

ENVIRONMENTAL PREFERENCES

Light: Full sun

Fertility: High; peas fix little nitrogen so it should be applied as recommended by soil test.

pH: 6.2 to 6.8; growth is inhibited by acid soils; 6.0 and lower.

Temperature: Cool. Plant growth is favored by intermediate temperatures (18°-21°C) while flowering is accelerated by long days with low temperatures.

Moisture: Average to high. Critical as plants approach maturity.

CULTURE

Planting: Sow seed in garden 2.5 to 7.5 cm apart in early spring when soil temperatures reach at least 4°C. Pre-germinate seed for earlier harvests.

Days to maturity: 50 to 70

Hardiness: Hardy annual

Fertilizer needs: Heavy user of nitrogen. Incorporate a balanced fertilizer before seeding. Planting area can also be treated with commercial bacterial inoculants to encourage the formation of beneficial nodules.

CULTURAL PRACTICES

Types - There are three main types of peas commonly grown in the home garden. English or garden peas, edible pod peas (snow peas) and snap peas. Starchy peas have a smooth, round dry seed. Sugary peas have wrinkled seeds and superior flavour and quality. "Leafless" types of pea, such as 'Novella', develop a rigid tendrill system that interlocks with adjacent plants. Plants remain erect which helps reduce pod disease problems. Growing plants in wide or twin rows or on a fence will accomplish the same.

Planting - For efficient use of garden space, plant in wide rows or with 45 cm between rows. Twin rows may be spaced 20-25 cm apart in rows 45-60 cm on center. Plants grown together will hold each other up. Cultivars vary in branching habit. Un-branched types should be planted closer together while branching types are planted farther apart. Late, tall cultivars can be trellised to improve growth and make harvest easier.

Peas are hardy, but seed germination is delayed when soil temperatures are below 4°C. Warmer soils (up to 24°C.) will speed germination and emergence, but late crops are more likely to suffer from heat stress. If soil temperatures are high, shade the rows to prevent overheating, or pre-germinate seed at cooler temperature inside and plant as soon as the root radicle appears. Adequate soil moisture is critical at pod fill.

HARVESTING AND STORAGE

Harvest: *Garden peas* - harvest and shell when pods are plump and well-filled but before seed becomes starchy or over mature.

Edible pod - when pods are large and flat but before seed begins to enlarge. Seed should be approximately 3 mm in diameter.

Snap peas - when pods are plump, much like regular peas (pods are also eaten). Most cultivars develop "strings" along the suture of the pod. These should be removed before cooking or eating.

Storage: Cool quickly to remove field heat; 0°C is ideal. Store in the refrigerator in a vented plastic bag.

PEPPERS

ENVIRONMENTAL PREFERENCES

Light: Sunny

Fertility: Medium-rich

pH: 5.5-6.5

Temperature: Warm

Moisture: Average

CULTURE

Planting: Set out transplants after soil has thoroughly warmed in the spring; start seed indoors 6-10 weeks before the average frost-free date.

Days to maturity: Sweet and hot types; 70-85 from transplants. Numex types, pasilla, poblano; 100-120 from transplants.

Spacing: 30-45 cm x 75-90 cm, double staggered rows on 60 cm wide beds work very well.

Fertilizer needs: light-medium feeder; use starter solution for transplants, side-dress with 100 g of 10-10-10 (or the equivalent) per 3 m of row after first fruits set

CULTURAL PRACTICES

Pepper varieties can be divided into three groups which can all be grown successfully in Ontario:

- Sweet - bell, banana, sweet cherry, pimento
- Hot - serrano, jalapeno, cayenne, habanera, piquin, tabasco.
- Southwestern/Mexican - Numex, poblano, pasilla, mulatto.

Peppers generally have a long growing season and suffer slow growth during cool periods. Set out 6- to 8-week-old transplants after the soil has thoroughly warmed in the spring to get a head start toward harvest. Pinch out early flower buds and small fruits to produce stronger, more prolific plants. Mulching can help to conserve water and reduce weeds. Plant stems become very brittle and should be supported with cages or short trellises.

Very hot temperatures will slow or stop pod production. Plant peppers where they will receive some afternoon shade and cool down your plants with a water spray during hot, dry weather.

HARVESTING AND STORAGE

Harvest: Harvest sweet peppers when they reach full size. When allowed to mature on the plant most varieties turn red, yellow, purple, orange or brown, are sweeter, and increase in vitamin A and C content. Cut pods, rather than pulling, to avoid breaking branches. Hot peppers can be harvested green or allowed to ripen and change colour on the plant. Entire plants may be pulled and hung upside down just before a killing frost.

Approximate yields (per 3 m of row): 1-2.5 kg

Storage: Medium-cool conditions (7°-10°C), moist (95% RH); 2-3 weeks.

POTATOES

ENVIRONMENTAL PREFERENCES

Light: Sunny

Fertility: Very rich pH: 4.8-6.0

Temperature: Cool (13°-18°C)

Moisture: Uniform moisture (especially while tubers are developing).

CULTURE

Planting: Seed pieces with at least one good eye are planted in early spring; will resist light frost. Whole seed potatoes can be cleanly cut into 2-4 pieces.

Days to maturity: 90-120

Spacing: 20-30 cm x 60-90 cm

Fertilizer needs: Heavy feeder; add high phosphorus fertilizer (75 ml 10-20-10 per 3 m of row or the equivalent) before planting; side-dress about 6 weeks after planting when tubers begin forming (200 g 10-10-10 or the equivalent per 3 m of row).

CULTURAL PRACTICES

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 early from April 15 to May 15, depending on your location. Hard frosts and freezes may set back growth. Potatoes prefer cool springs and moisture throughout the growing season. Crops can be successfully planted as late as late June in Ontario for fall harvest and storage of new potatoes, but yield may be reduced.

Avoid planting in a turned-under-lawn site as grub worms may damage developing tubers.

Purchase certified seed stock that has been inspected for diseases that lower yields. Saving your own seed potatoes is worthwhile if stock is disease-free. Seed potatoes should be firm and un-sprouted. Wilted and sprouted potatoes have reduced vigour. Large potatoes about 175 g in weight can be cut into four seed pieces. Each seed piece should have at least one good bud or eye. Plant potatoes in furrows cut side down, 7-15 cm deep. Later crops should be planted 13-15 cm deep.

Pull a ridge of soil over each row when planting. Drag a hoe across the ridges just before the sprouts break through to eliminate weeds. Later cultivation should be shallow and far enough from the plants to prevent damage. When the tops have grown too large to allow cultivation, a finishing cultivation, sometimes called laying by or hilling up is used. Laying by involves throwing soil over potatoes to shield them from the sun, which can cause greening or scalding. Green portions on potatoes taste bitter and contain a poisonous alkaloid. Cut off and discard green areas before using.

HARVESTING AND STORAGE

Harvest: Dig early potatoes when tubers are large enough to eat. Harvest potatoes for storage two weeks after the vines die down or just after the first light frost nips the vines. Leave tubers on ground for a few hours before bringing them inside. Do not wash your potatoes prior to storage. Avoid skinning tubers when digging and avoid long exposure to light.

Approximate yields (per 3 m row): 3-7 kg

Storage: Medium-cool (10°C), moist (90% RH) conditions; 6-8 months. Sprouting is a problem at higher temperatures.

RADISH

ENVIRONMENTAL PREFERENCES

Light: Full sun/partial shade

Fertility: Average

pH: 6-6.5

Temperature: Cool

Moisture: Keep moist, not waterlogged.

CULTURE

Planting: Sow seed as soon as the soil can be worked in the spring. Storage roots become spicy hot and woody with rising temperatures. Can also be planted in the fall.

Days to maturity: 25-35

Spacing: 2.5 to 5 cm or more in rows or equidistantly in wide rows or beds, depending on the variety grown.

Hardiness: Hardy annual

Fertilizer needs: Avoid excess nitrogen to prevent all growth from going to the tops.

CULTURAL PRACTICES

There are several types of radishes. Most people think of the red radishes grown in early spring, but there are also summer or daikon radishes from Japan and winter storage radishes.

Because cool-season radishes grow quickly, it is wise to plant only a few every five days for several plantings. This way, you'll have a steady supply of radishes, rather than one large harvest.

Because radishes germinate and grow very quickly, they are handy for marking the rows of slower germinating crops such as carrots, beets, lettuce, and kohlrabi. Simply sprinkle a pinch of radish seed in the row with these other crops as you plant. The radishes will spring up in a few days, defining each row. If you use this method, you will have more than enough radishes to use without planting an additional row.

RHUBARB

ENVIRONMENTAL PREFERENCES

Light: Full sun/partial shade

Fertility: Rich

pH: 5.0-6.8

Temperature: Cool

Moisture: Average; established plants are drought tolerant.

CULTURE

Planting: Plants are started from crown divisions containing at least one bud. Seed propagation is not generally used due to extreme variation among seedlings. Plant early in the spring as soon as the soil can be worked.

Spacing: 1.2 x 1.2 m

Hardiness: Very hardy perennial.

Fertilizer needs: Rhubarb is a long-term perennial crop; soil should be amended heavily with manure and compost before planting. A complete fertilizer can also be applied according to soil test results. After the tops have died back in the fall, mulch with additional composted manure.

CULTURAL PRACTICES

Planting

- Look for roots that are full, slightly moist, and have colour. Roots that are dry brown or soggy black indicate poor storage and will probably not give good results.
- Check crowns for signs of viable buds. Inspect plants for signs of insects or disease.
- Once you have the crowns, keep the roots cool and moist by misting occasionally. If it is necessary to keep the crowns for more than a few days, place in cold storage (not freezing) or else heel them 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 that are discoloured or dried out.

Leave the Leaves Alone!

It was believed the primary toxic substance in rhubarb leaves was oxalic acid. It is now known, however, that the primary toxic substance in rhubarb leaves is anthraquinone glycoside - not oxalic acid. Anthraquinone glycosides are present in rhubarb leaves (½% -1% by weight), especially in early summer. Studies have shown that ingesting 10 to 20 grams of fresh rhubarb leaves causes vomiting. The freezing of rhubarb, pre- or post-harvest, does not decrease the toxicity of rhubarb leaves or make rhubarb stalks unsafe to eat.

HARVESTING AND STORAGE

Harvesting: Rhubarb should not be harvested until the second growing season after planting and then only lightly. It can be harvested heavily in the third year. Pull stalks from the plant rather than cutting them. Harvest the largest stalks first, leaving the smaller ones to grow and be harvested over a four to six week period.

After the initial spring harvest, plants should be allowed to grow vigorously all summer long to replenish the carbohydrate reserves in the crown. The stalks can be harvested again just before the first frost. There is no evidence indicating the stems from frosted rhubarb are unsafe. The quality, however, probably won't match the spring crop. Approximate yield: 1 kg or more per plant. **Storage:** Store in a plastic bag in the crisper section of the refrigerator.

SPINACH

ENVIRONMENTAL PREFERENCES

Light: Full sun, tolerates partial shade.

Fertility: Rich

pH: 6.0-6.8

Temperature: Cool

Moisture: Keep moist, not waterlogged.

CULTURE

Planting: Sow seed 1 to 1.5 cm deep early in the spring after soil temperatures have reached 7°C.

Days to maturity: 37 to 55 (regular spinach). Spacing: 7.5 cm apart in rows or equidistantly in wide rows or beds.

Hardiness: Hardy annual.

Fertilizer needs: Heavy feeder, incorporate lots of compost or 45 ml 10-10-10 (or equivalent) per 3 m of row before planting.

CULTURAL PRACTICES

Make several small plantings several days apart, sowing the seed in wide rows. Use floating row covers to exclude spinach leaf miners and to speed the growth of the plants. There are two types of regular spinach - **smooth leaf** and **savoy leaf**. The savoyed types have more texture, but soil and sand tend to catch in the crinkles of the leaves.

Other types of spinach include **perpetual** spinach which is actually a type of chard, **New Zealand spinach**, and **Malabar spinach**. New Zealand spinach prefers hot weather and should be planted after all danger of frost has passed. It will seed itself and come back year after year. Malabar spinach, a vine with glossy green leaves and purple stems and fruit, can be harvested throughout the summer although it tends to get strong-flavoured when the weather gets hot.

Regular spinach bolts as the days grow long and temperatures rise. Make a final harvest when the plants send up their flower stalk. Till under the residue and plant something new. Because spinach tolerates frost, it is a good crop for the fall garden and with protection can be harvested into December. Seed can be sprinkled on melting snow in late winter for an early spring crop.

HARVESTING

Harvest: Use thinnings when small; cut full-size leaves leaving the crown to re-grow; make a final harvest when small flower stalks start to form.

New Zealand and malabar spinach can be harvested continuously throughout the summer.

Approximate yields: 1 kg per 3 m of row.

SQUASH

ENVIRONMENTAL PREFERENCES

Light: Sunny

Fertility: Medium-rich

pH: 6.0-7.2

Temperature: Warm (18°-24°C) **Moisture:** Average

CULTURE

Planting: Sow seed after danger of frost has passed and soil has warmed, or use plants sown indoors in peat pots 3-4 weeks prior to planting time. Plant a second crop of summer squash around July 1. Handle transplants gingerly and disturb the root system as little as possible. Thin seedlings, by cutting excess plants with scissors rather than by pulling.

Days to maturity: 50-65 from transplants (summer squash); 75-100 (winter squash).

Spacing: Hills (two to three plants per hill) 1 x 1-1.5 m; single plants 0.5-1 m x 1-1.5 m.

Hardiness: Very tender annual.

Fertilizer needs: Medium feeder, side-dress 4 weeks after blossoming begins (100 g 10-10-10 per 3 m of row).

CULTURAL PRACTICES

Summer squash grows on non-vining bushes. There are many varieties having different fruit shapes and colours. The three main types include the yellow straight neck or crooked neck; the white, saucer-shaped, scallop or patty pan; and the oblong, green, gray or gold zucchini. Winter or storage squash can grow on either vining or bush-type plants. There are many sizes and colourful varieties of hard-shelled squash: Acorn, Butternut, Buttercup, Hubbard, Turban and Kabocha types. All require a long growing season to fully mature. Soil containing plenty of well-rotted compost or manure is ideal, although good crops may be grown in average soils that have been adequately fertilized. For extra early fruit, plant seeds in peat pots in greenhouse or hotbeds. Squashes are warm-season plants and do not do grow well until soil and air temperatures exceed 15°C. Seed or transplants can be planted through black plastic to hasten maturity. Organic mulches are also very beneficial.

Pollination: Many squashes will produce male flowers for 1-2 weeks before the first female flower is observed.

This is a normal growth habit and varies with cultivars. For a squash 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 squash). Poor fruit set is common during rainy weather when bees are inactive.

HARVESTING AND STORAGE

Harvest: For summer squash, harvest when immature, only about 15-20 cm long and 4 to 5 cm in diameter for elongated types, 7 to 10 cm in diameter for patty-pan types, and 10 to 18 cm long for yellow crookneck. If the rind is too hard to be marked by the thumbnail, it is over-mature. Remove old fruit to allow new fruit to develop. Check plants daily once they begin to bear. Winter storage of hard shelled squash varieties should be harvested when mature and shell colour begins to deepen.

Approximate yields: 9-35 kg (per 3m of row).

Storage: cool (0°-10°C), moist (90% RH) conditions; will keep 5-14 days.

SWEET POTATOES

ENVIRONMENTAL PREFERENCES

Light: Full sun

Fertility: Rich

pH: 5.0-6.8

Temperature: Hot

Moisture: Average

CULTURE

Planting: Plant rooted cuttings (slips) in ridges after the soil has warmed to 18°C.

Days to maturity: 90-120

Spacing: 30 cm apart in rows spaced 1 m apart.

Hardiness: Very tender annual.

Fertilizer needs: On light, sandy soils side-dress with nitrogen 1 to 2 times during the growing season. Apply phosphorus and potassium as indicated by soil tests.

Slips For Certain

Sweet potatoes can be grown only in the warmest areas of Ontario but slips are often difficult to find. Sweet potatoes are storage roots, not tubers. New shoots will emerge along the entire root. The process from bedding to planting, takes 6 weeks. Here are some tips for growing your own:

- *Buy certified seed stock at a garden center or your favourite varieties from a market. Wash the latter to remove anti-sprouting chemicals.*
- *Cover the bottom of a 20 cm deep container or box (with drainage holes) with 5 to 7.5 cm of sand or soil-less growing mix.*
- *Slice your roots lengthwise and place them cut-side down in the container. Cover with 5 to 10 cm of sand or mix.*
- *Keep your roots moist, warm (24°-30°C) and covered with plastic until plants emerge.*
- *Remove plastic. Grow plants directly under cool, white fluorescent tubes for 14-16 hours per day.*
- *Pull slips from bedded roots and plant after danger of frost. Slips will be rootless; keep them well watered.*
- *Slips could also be continued under lights until planting time.*

CULTURAL PRACTICES

Sweet potatoes like hot weather and grow slowly until the soil warms to 18°C. Planting in ridges allows the soil to warm faster in the spring, improves drainage, and gives the roots room to expand. Ridging also makes harvesting easier.

Two types of cultivars are produced. Those with moist flesh are derived from the cultivar 'Porto Rico' (Georgia Jet, Centennial, Vardaman), are sometimes called yams. (The true yam *Dioscorea* spp. is grown primarily in tropical and semitropical areas for its tubers). The dry, lighter-coloured roots termed 'Jerseys' are better adapted to northern areas where they produce short, chunky roots. They do not store as well.

HARVESTING AND STORAGE

Harvest: Harvest as soon as the roots reach eating size, and before a frost. If vines get frosted, dig them immediately. Decay in dead vines passes down to the roots. If immediate digging isn't possible, cut away vines and throw loose soil over the rows to protect them from the cold. Digging is easier if the vines are first cut off.

Do not allow the roots to become chilled in cold soil or after they are dug. Temperatures below 13°C can cause chilling injury. Sweet potato foliage is edible and very nutritious. Ideally, the roots are cured at 29°C and 90%-95% RH for 4-8 days. At lower temperatures, it takes longer for the cuts to heal on the roots (suberization).

Approximate yields: A 3m row will yield 9-18 kg of sweet potatoes under ideal growing conditions. **Storage:** After curing, store at 13°-55°C at 85%-90% RH for maximum storage life.

TOMATOES

ENVIRONMENTAL PREFERENCES

Light: Sunny

Fertility: Medium-rich

Temperature: Warm (21°-27°C)

Moisture: Moist, but not waterlogged.

CULTURE

Planting: Transplant after all danger of frost is past and when the soil has warmed.

Days to maturity: 65-90 from transplant. **Spacing:** 45-90 cm x 120-150 cm

Hardiness: Tender annual.

Fertilizer needs: Heavy feeder; use starter solution for transplants. After first fruits appear, side-dress every 2 weeks with compost tea, balanced soluble fertilizer or 100 g 10-10-10 (or the equivalent) per 3 m of row.

CULTURAL PRACTICES

Tomatoes are valuable garden plants; they require relatively little space and can yield 4-7 kg or more of fruit per plant. There are many different types and varieties available from seed catalogs:

- Midget, patio, or dwarf tomato varieties have very compact vines best grown in hanging baskets or other containers. The tomatoes produced may be, but are not necessarily, the cherry type (2.5 cm diameter or less). Some produce larger fruit. These plants are usually short-lived.
- 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 large, 2 m specimens (Sweet 100). One standard cherry tomato plant is usually sufficient for a family.
- Compact or determinate tomato plants may include cultivars of the above two categories. Determinate refers to the plant habit of growing to a certain size,

setting fruit, and then declining. Many commercial and early-ripening tomato varieties are determinate and will often produce tomatoes throughout the summer.

- 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, long-season tomatoes that are popular with home gardeners.
- Beefsteak-type tomatoes are large-fruited types, producing a tomato slice that easily covers a sandwich. The whole fruit often weighs as much as 1 kg or more. These are usually late to ripen, so plant some standard-sized or early tomatoes for longest harvest.
- Paste tomatoes have small to large pear-shaped fruits with very meaty interiors and few seeds. They are less juicy than standard tomatoes, do not have a central core and are excellent for canning and sauces.
- Varieties with orange, yellow, pink, purple, brown or striped fruits, are becoming more commonplace in seed catalogs.
- Heirloom tomatoes refer to older, open-pollinated varieties grown for eating quality, colour, shape and/or genetic preservation. Many have "potato leaf" foliage. These varieties can be located through seed exchanges and specialty catalogs.
- 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 green or partially ripe. If properly stored, they will stay fresh for 6-12 weeks. The flavour does not equal that of summer vine-ripened tomatoes, but fresh, home-grown tomatoes are welcome at Christmas and do taste better than store bought fruit.

Planting

When you are ready to put home-grown or purchased plants into the ground, select stocky transplants about 15-25 cm tall. Set tomato transplants in a trench 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. Avoid setting the root ball deeply into cold soil.

Pruning

Suckers are shoots that arise from axils (the angle where a plant stem and leaf branch meet). These shoots will eventually produce flowers and fruit. However, moderate pruning will increase fruit size, hasten ripening and keep your plants more manageable.

Prune staked tomatoes to either one or two main stems (plant spacing can be reduced in these situations). Remove all other suckers weekly. It is especially important to remove suckers that emerge from the plant base. Pinch shoots off with your fingers.

Figure 13-E: REMOVING “SUCKERS” FROM TOMATO PLANTS



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Support

Staking, trellising or caging makes caring for tomatoes easier than letting them sprawl:

Fruit rots are reduced. Less space is required. Harvesting takes much less work.

Use wooden stakes 2 m long and 3 to 5 cm wide. Drive them one foot into the soil about 10 to 15 cm from the plant soon after transplanting. Attach heavy twine or strips of cloth to the stakes every 25 cm. As the plants grow, pull the stems toward the stakes and tie loosely.

Growing tomatoes in wire cages is another popular method. Cage growing allows the tomato plant to grow in its natural manner, but it keeps the fruit and leaves off the ground. 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.

If the cages are heavy duty, they will last many years. Pruning may still be necessary to avoid rank growth of foliage. Space cages at least 1.2 m apart and secure cages to the ground with stakes.

HARVESTING AND STORAGE

Harvest: Harvest when fully vine-ripened but still firm; most varieties are dark red. Picked tomatoes should be placed in shade. Light is not necessary for ripening immature tomatoes. Some green tomatoes may be picked before the first killing frost and stored in a cool (13°C), moist (90% RH) place. When desired, ripen fruits at 21°C. (DO NOT REFRIGERATE TOMATOES).

Approximate yields (per 3 m of row): 7-20 kg

Storage: Green tomatoes - medium cool (10°-21°C), moist (90% RH) conditions; 1-3 weeks. Ripe tomatoes - cool (7°-10°C), moist (90% RH) conditions; 4-7 days.

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Revised by the Master Gardeners of Ontario Inc. from the Maryland Master Gardeners Handbook.

CHAPTER 14: SMALL FRUITS

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SMALL FRUITS

INTRODUCTION

Many small fruits — strawberries, currants, blackberries, grapes, blueberries and raspberries are well-suited to Ontario growing conditions. But surprisingly, few homeowners choose to grow these crops. Some of the advantages to growing small fruits include:

- Easy and inexpensive to establish; relatively cold-hardy and long-lived.
- Produce first crop more quickly than tree fruits with fewer insect and disease problems.
- Easily maintained: plants produce high yields per square meter.
- Are nicely integrated into urban and suburban landscapes. For example, currants and blueberries make attractive landscape plants.
- Low in calories, high in nutrition; versatile in cooking, baking, food preservation and wine making.

PLANNING THE SMALL FRUIT GARDEN

Locate your small fruit planting in full sun as close to your home as possible. Blueberries, currants and gooseberries will tolerate partial shade. Space in or near the vegetable garden is usually preferred. Where space is a limiting factor, small fruits may be used in place of ornamental plants of comparable size. Strawberries may be used as a border to a flower bed or as a ground cover. Grapes and raspberries may be planted parallel to the garden on a trellis or a fence along a property line. High bush blueberries may be planted to form a dense hedge or used in a foundation planting around the home. Select a site that is free from frost pockets, low wet spots, and exposure to strong, prevailing winds.

Small fruits thrive in deep, well-drained soil high in organic matter, but will yield well on average garden soil with adequate fertilization and care. They tend to have shallow, fibrous root systems and do not tolerate "wet feet".

Take a soil test at least 6 months prior to planting and adjust pH and fertility levels according to test recommendations. A 6.0- 6.5 pH is desirable with the exception of blueberries (see blueberry section). Grow and turn under a green manure crop like oats, buckwheat or rye on the selected site or incorporate lots of compost prior to planting.

Special attention should be given to cultivar selection. They must be adapted to your soil and climatic conditions. If possible select cultivars with the fewest insect and disease problems. **Table 14-1** lists some recommended cultivars for Ontario conditions.

Table 14-3 provides fertilization guidelines. Organic gardeners would, of course, substitute compost, rotted manure, fish emulsion, etc. Small fruits are not "heavy feeders" but timely applications of fertilizers are essential. Be careful not to burn foliage with liquid or granular fertilizers. **Keep fertilizers 20 to 30 cm from crowns.**

Overcrowding frequently results in poor air circulation, weak plants and low yields. It also makes insect and disease control more difficult. When possible, select sites where early morning sun shine will dry the foliage more quickly. For best results, small fruit plants should be set no closer than the minimums indicated in **Table 14-2**.

SOME SUGGESTED SMALL FRUIT VARIETIES

Table 14-1: SMALL FRUIT VARIETY SELECTION CHART

STRAWBERRIES	
Variety	Comments
June-bearing	
Earliglow	The standard for early varieties. Very fine flavour; medium size fruit.
Annapolis	Large, firm, light red fruit with good flavour.
Allstar	Productive mid to late season cultivar with elongated flavourful berries.
Cavendish	Very large, firm fruit with good flavour. Mid-season harvest.
Jewel	Large, bright red, firm berries. Susceptible to verticillium and red steele.
Lateglow	Large, late berry.
Guardian	Vigorous mid-season cultivar. Large, firm, very flavourful fruit.
Kent	Vigorous plants with large fruit that ripens after Lateglow. Similar to Guardian.
Other strawberry varieties include: Veestar, Bounty, Glooscap, Governor Simcoe, Honeoye, Micmac, Midway, Redcoat, Sparkle, Vantage and Vibrant. Zone 3a to 7b.	
Day-Neutral	
Tristar	Sweet, medium size fruit. Good disease resistance. Most productive in the fall.
Tribute	Vigorous, disease resistant plants with medium size berries. Somewhat acidic flavour.
RASPBERRIES	
Variety	Comments
Red (June-bearing*)	
Latham	Mid season, cold-hardy variety that tolerates virus diseases. Flavourful, firm fruit.
Killarney	Vigorous, productive plants with small to medium flavourful berries. Recommended for colder climates.
Nova	Very vigorous, cold-hardy cultivar. Medium-sized mild fruit. Early to mid-season harvest.
Comet	Hardy, vigorous, erect plants. Fruits are large with excellent flavour.
* Bloom late April to late May; ripen June to July.	
Red (primocane-bearing) (Fall-bearing)	
Heritage	Widely-adapted, vigorous variety that suckers freely. Fruit is medium size of very high quality and tolerates light frosts. Harvest from mid to late August through severe frost or freeze.
Autumn Bliss	Similar to Heritage but ripens 2 weeks earlier.
Other red raspberry varieties include: Boyne, Festival, Heritage, Madawaska, Williamette and Royalty. Zones 3a to 7b.	
Black **	
Allen	Vigorous, winter-hardy plants with disease resistance and large, high quality fruit.
Jewell	Vigorous and very productive mid-season cultivar with large, fine-flavoured fruit and good disease resistance.
Haut	Medium size fruits; high yielding plants.
Bristol	Large fruit of excellent quality. Erect, vigorous plants but not as productive or disease resistant as other varieties.
** Bloom April-May; ripen June-July before red raspberries.	
Purple ***	
Royalty	Large fruit that becomes sweeter as it reaches full purple colour. Very vigorous and productive canes.
*** Bloom in June; ripen mid-July to mid-August.	
Gold	
Fallgold	Primocane-bearing type that ripens with Heritage. Fruit is fairly soft with excellent flavour.

Table 14-1: SMALL FRUIT VARIETY SELECTION CHART (cont'd)

BLACKBERRIES	
Variety	Comments
Thornless *	
Hull	Very vigorous, semi-erect canes. Large, sweet, firm fruit has excellent flavour.
Dirksen	Vigorous, productive and erect canes. Large, high quality fruit. Not as cold-hardy as other varieties.
Chester	Similar to Hull but ripens 10 days later. Very cold-hardy, productive canes with large, sweet fruit.
* May not be suitable for colder areas of Ontario.	
Thorny **	
Darrow	Tall, vigorous plants with erect canes. Good winter-hardiness. Firm, medium berries with good, sub-acid flavour. Ripens early.
Cherokee	Erect and productive cultivar with medium size fruit.
Shawnee	Late, productive plants that are very cold-hardy. Large and flavourful fruit.
** More cold-hardy and sweeter than thornless types. Thornless varieties tend to be more productive, however.	
TABLE AND JUICE GRAPES	
Variety	Comments
Seedless	
Canadice	Small to medium size, early red grape with excellent grape flavour. Keeps long on the vine. Reliable and productive with some black rot resistance.
Himrod	Golden yellow fruit with fine flavour that keeps well. Very cold-hardy; moderate disease resistance.
Mars	Very hardy, productive and dependable. Large, blue fruit that ripens mid-season.
Reliance	Dependable, early season variety; very hardy vines. Large, high quality, red fruit will store for 3 months.
Vanessa	Red, medium size fruit ripens mid-season.
Seeded	
Concord	The standard table grape; was introduced in 1843. Large, blue-black grapes. Very vigorous and productive vines that are black rot susceptible.
Niagara	A white Concord. Large, attractive fruit makes excellent juice. Very cold-hardy.
Buffalo	Similar to Concord but ripens earlier and has some disease resistance. Vigorous vines; heavy bearer.
Steuben	Late, very large, blue fruit. Distinctive spicy flavour. Hardy and vigorous with some disease resistance. Ripens before Concord.
Alden	Very large, "meaty", blue-black fruit. Very vigorous vines require close pruning. Ripens before Concord.
Other grape cultivars include: Baco Nair, Seyval, Gamay, Chardonnay, Cabernet Franc, Chambourcin, Riesling, Seneca, Sovereign, Coronation, New York, Muscat, Suffolk Red, Festivee, Agawam, and Yates. Many only hardy to Zones 5b to 7b.	
BLUEBERRIES	
Variety	Comments
Bluetta	Short, compact, medium vigorous bushes. Medium size, crack-resistant fruit with good flavour.
Bluejay	Very vigorous bushes with mummy berry disease resistance. Large, firm, slightly tart berries. Fruit does not drop or crack.
Blueray	Very productive and vigorous variety that performs well in hot climates. Large, high quality berries.
Bluecrop	Leading variety; hardy and consistent with vigorous, upright canes. Fruit is large, firm and crack-resistant.
Elliott	Very late and ornamental bush with red wood. Small to medium size fruit does not crack or drop.
Northland	Hybrid between the highbush and lowbush blueberry. For the colder regions of Ontario. An early ripening variety.
Other blueberry cultivars include: Jersey and Patriot. Zones 4a to 7b.	

See also [Suggested Berry Varieties for Ontario \(OMAFRA\)](#)

VARIETIES AND PLANTING

Small fruits are easy to propagate. However, mature plants may be symptomless carriers of virus diseases.

Planting certified virus-free stock is recommended.

When planting brambles (raspberries and blackberries) it is best to eradicate any wild blackberries within 45 m. Also, black raspberry plants are quite susceptible to mosaic virus and should not be planted close to red raspberries. It is also worth noting that black currants are an alternate host for white pine blister rust disease.

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 well grown plants are not cheap. Place your order early, specifying cultivar, size, and grade of plants desired and preferred time of shipment. It is best to have the plants arrive when you are ready to set them out.

When your order arrives, unpack the bundles and inspect the plants. The 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 either be kept in cold storage or heeled-in. Wrap them loosely in a plastic garbage bag, or other 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 carefully heel them 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.

Generally, one or two year old virus-free plants are set out one month before the first fall frost or right after the last spring frost. Plants should be planted at the same depth or slightly deeper than they were planted in the nursery. The planting hole should be 2-3 times the rootball width so that roots can be spread out. Large quantities of organic matter should not be added to the planting hole. It is better to incorporate modest amounts of well-rotted manure compost or peat moss throughout the eventual root zone. Keep young plants well watered. Blueberries in particular will not tolerate water stress and require an acidic soil with a pH below 5.5.

MULCHING AND IRRIGATING

Organic mulches are always beneficial to small fruits. They help to:

- Suppress weeds.
- Maintain even soil temperatures.
- Hold moisture in soil.
- Add organic matter.
- Protect overwintering plant crowns.
- Keep fruits clean.

Mulching is also preferred because even **shallow cultivation around small fruits can cause root damage.** Straw, shredded leaves, rotted sawdust, grass clippings, newspaper and compost can be used. Chopped pine bark, pine needles and sawdust are good materials to use around blueberries. Winter mulch can be spread around plants as soon as the ground freezes. This helps prevent the freezing-thawing cycle which can heave and damage plants.

PRUNING & TRAINING

Like so many aspects of gardening, pruning and training small fruits is part art, part science. Here are a few general guidelines.

- Prune in late winter or early spring before growth begins.
- Use sharp pruning shears or clippers.
- Always remove twisted, diseased and broken canes.
- Bury or "hot" compost the trimmings, or remove them from the vicinity of the planting area.
- Don't be afraid to prune! Small fruits can make excessive growth, especially if over-fertilized or neglected.
- Irrigation is also very beneficial to small fruits. The rule of thumb is 2.5 cm of water per week during the growing season (250 litres per 10m²). This need increases during flowering and fruiting. To discourage disease problems, water early in the morning and avoid wetting the foliage. **Soaker hoses or drip irrigation lines work very well in a small fruit planting.**

Table 14-2: SPACE REQUIREMENT, YIELD, BEARING AGE, AND LIFE EXPECTANCY OF SMALL FRUITS

	Minimum Distance Between Rows (m)*	Between Plants (m)	Annual Yield/Plant (kg)	Year of First Crop (Years)	Average Life (Years)
Blueberry **	2	1.2	2.7-3.6	3-4	20-30
Blackberry (thornless)	2.5	1	0.7	2	5-12
Raspberry – red	2.5	0.6	0.7	2	5-12
Raspberry – black	2.5	0.8	0.7	2	5-12
Raspberry – purple	2.5	1	0.7	2	5-12
Grape – American	2.5	2.5	11	3	20-30
Grape – French-American	2.5	2.5	11	3	20-30
Strawberry – June bearing	1	0.6	0.5-0.9***	2	3
Strawberry – everbearing	1	0.3	0.2	1	2
Strawberry – day neutral	0.3	0.3	0.2	1	2
Currant	2.5	1.2	2-3	2-4	10-20
Gooseberry	2.5	1.2	2-3	2-4	10-20
* For mature plants. ** More than one variety should be planted for highest yield. All other small fruits are self-fertile. *** Per parent plant grown in the matted row system.					

Table 14-3: FERTILIZING SMALL FRUIT

Crop	Soil pH	1 st Year	2 nd Year	3 rd Year
Strawberries				
June-bearing	6.0	0.5-1 kg of 10-10-10 per 30 m of row, six weeks after planting; repeat in August.	1 kg of 10-10-10 per 30 m of row in August before new buds form.	Same each succeeding year.
Day-neutral	6.0	0.5-1 kg of 33-0-0 once a month June-September per 30 m of row	0.5 kg of 33-0-0 once a month May-September per 30 m of row.	Same each succeeding year.
Grapes				
All varieties	5.5 - 6.5	55 g (60 ml) of 10-10-10 per plant in early spring.	55 g (60 ml) of 10-10-10 per plant in early spring.	115 g (125 ml) per plant 4 th year - 225 g (250 ml) per plant 5 th year - 450 g (500 ml) per plant; then 450g per plant each succeeding year.
Brambles				
All varieties	6.0 - 6.5	2.3 kg of 10-10-10 per 30 m of row in early spring.	2.3 kg of 10-10-10 per 30 m of row in early spring.	4.5 kg of 10-10-10 per 30 m of row in spring - same each succeeding year.
Blueberries				
All varieties	4.3 - 5.3	None	115 g of 21-0-0 per plant before flowering. Scatter in a ring 40 - 45 cm from plant	Increase by 28 g per year until the 6 th year; then use 225 g per plant each succeeding year. Avoid fertilizers containing nitrates or chlorides.
Currants & Gooseberries				
All varieties	6.0 - 6.5	100-200 g of 10-10-10 per plant in early Spring.	100-200 g of 10-10-10 per plant in early Spring.	Same each succeeding year
Note: 33-0-0 is ammonium nitrate. 21-0-0 is ammonium sulfate. - Keep granular fertilizers 30 cm away from plant crowns. - Well-rotted manure and composted yard waste can be used in place of manufactured plant foods. - Reduce nitrogen rates if plants become overly vigorous and spindly and produce small crops. - Have soil tested every 3-5 years.				

STRAWBERRIES

Strawberries are the ideal fruit crop for growers with very limited space. The plants are low-growing perennials that fruit either in June (for the appropriately named "June bearers") or throughout the summer for the day-neutral types. Plants can be grown successfully in rows,

beds, or even in pots and make an attractive groundcover when not fruiting.

The strawberry plant is composed of leaves, a crown (a compressed, modified stem), and a root system. In heavy clay soils, 90% of the roots may be located in the top 15 cm of soil. This shallow root system is, in part, responsible for the strawberry plant's sensitivity to both water deficit and excess.

Runners, or stolons, arise from buds at the base (axils) of the leaves; they are the strawberry plant's device for asexual propagation.

Several diseases - verticillium, red steale and powdery mildew – can be very damaging. **Always buy registered, disease-free or tissue cultured plants.**

CULTIVAR SELECTION

June-bearing Strawberries

The June-bearing strawberry is the type most commonly grown in Ontario. See **Table 14-1** for some suggested varieties.

Day-Neutral Strawberries

More recently developed, day-neutral strawberry cultivars bear fruit throughout the growing season. They are highly productive and have very flavourful berries. Day-neutral plants have three peaks of production each year: June, mid-summer, and late-August through frost. The summer crop is often very small due to high temperatures. Lay down a heavy straw mulch to keep soil temperatures low. However, even with this precaution, day-neutral cultivars may not perform well during hot weather.

Everbearing Strawberries

These cultivars bear two crops during the year, and are generally not as high quality or productive as the day-neutral types.

SITE SELECTION AND PLANTING

Strawberries perform best in sunny locations in well-drained soils enriched with organic matter. As with most small fruits, strawberries will not tolerate "wet feet". If only poorly drained soils are available, build a raised bed. Daughter plants or "runners" can become invasive so many gardeners grow strawberries in borders, containers and restricted beds.

Set field-grown plants out in April when the soil begins to warm. Tissue cultured plants are grown in a greenhouse and are more cold-sensitive; don't plant them until after the last frost date.

Trim roots to within 10 to 15 cm of the crown and set plants with half the crown below the soil level and roots fanned out (see **Figure 14-A**). Keep new plants well-watered.

June-bearing varieties are typically trained to a "hill system" with plants spaced 30 cm x 30 cm and all runners removed, or a "matted row" system where plants are spaced 60 cm x 90 cm and runners may be thinned at renovation (see **Figures 14-B and 14-C**). In either case, flowers are removed the entire first season. Early fruit production should be sacrificed to encourage strong vegetative growth.

Figure 14-A: SETTING STRAWBERRY PLANTS:

- a) too deep
- b) correct
- c) too shallow
- d) cut roots here before planting.

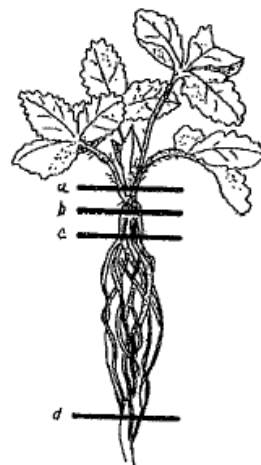


Figure 14-B: HILL SYSTEM



Figure 14-C: SPACE MATTED ROW SYSTEM



OVERWINTERING

To prevent winter heaving of crowns and protect overwintering flower buds, cover the plants and aisle-ways with 10 cm of organic mulch. Do this after the soil freezes and the plants are dormant. Pull the mulch back in early spring to allow for soil warming and more rapid fruit maturation. Re-apply thick mulch when fruits begin to develop. Plastic covering as mulch is not recommended; however, in the far north, if plastic is laid under the straw, it will aid in overwintering strawberry plants.

Floating row covers are useful in preventing winter damage, promoting early bloom, protecting blossoms from spring frosts and excluding flying insect pests. Blossoms are pollinated by wind and insects; be sure to remove the row cover once flowering begins.

RENOVATION

Most strawberry beds will continue to produce for 3-5 years. This production life can be maximized through renovation. This simple technique is used in the matted row system to remove excess growth and invigorate the planting.

Immediately after the end of harvest, beginning in the second year, mow plants to a height of 5 to 7.5 cm, or just above the crowns. Top-dress with 450 g of 10-10-10 fertilizer per 25 plants then rototill or spade under "daughter" plants leaving a 45 cm wide growing bed. Reverse this process in the 4th or 5th year by turning under the "mother" plants and allowing "daughter" plants to form the new 45 cm wide beds. (It helps to drive a short stake in the ground at the head of each row during the initial planting so that the "mother" plants can be identified). After a period of years, berry yields usually drop due to diseases and environmental stress. You can then replant your berry patch in a new location with fresh plants.

HARVESTING AND STORAGE

Strawberries should be left on the plant 1-2 days after reaching full colour. Pick early in the morning by twisting stem and fruit from the vine. Process as soon as possible to preserve nutrients and flavour. They can be refrigerated for 3-5 days. 250 ml of strawberries contains 140% of the minimum daily requirement for vitamin C.

GRAPES

Grapes have been cultivated for thousands of years. The grapevine adapts relatively well to a wide range of soils and can be grown and manipulated rather easily.

PLANTING GRAPES

1. Plant in early spring, 3-4 weeks before last frost.
2. After setting plants, remove all but one cane with up to six buds.
3. After shoot growth commences and danger of spring frost is past, remove all but the two strongest shoots.
4. Maintain an adequate water supply at least until mid-June. Supplement rainfall to ensure the equivalent of 2.5 cm of rain per week.
5. Remove all flower clusters.
6. Keep an area 45 to 60 cm wide around the plants free of weeds.
7. Remove all suckers - maintain only two shoots.
8. Keep vines off the ground and tied either to stakes or trellises.

PRUNING GRAPES

You can train your grapes to numerous shapes: arbors, fences, decorative trellises, etc. Although there are several systems for pruning grapes, the four-cane Kniffin system is considered to be the simplest to follow. This system involves the use of a heavier top wire (No. 9) and a lighter bottom wire (No. 10 or 11) stretched between posts to support the vine. The bottom wire should be 75 cm and the top wire 140 cm above the ground. Tie the young vine to a stake, and as the vine grows tie it to the bottom wire. After additional growth, tie it to the top wire. This promotes straight trunk growth in the vine (see **Figure 14-D**).

Grapes fruit on second year wood. Select fruiting canes on the basis of cane diameter. Buds on the moderately large diameter canes (pencil thickness) will be more productive than those on small canes. Consequently, you should retain large diameter canes and prune out weak canes. Leave 10 to 15 buds per cane for fruit production on a mature vine.

This will give you a total of 40 to 60 fruit buds on the 4 laterals of the vine. The number of buds that you should retain for fruiting is determined by the vigour of the vine. If the vine is weak, leave no more than 40 buds; retain 60 or more if the vine is vigorous.

The small stubs labeled "Sp" in **Figure 14-F** are 2-bud spurs, which will provide the fruiting cane for the following year. Prune in March or April when any damage caused by winter injury can be determined. Leave more buds after particularly harsh winters. **Ignore the heavy sap flow from fresh pruning cuts made in late spring. This will not weaken or damage your canes.** The sap may cause contact dermatitis in some individuals. Wear gloves when pruning.

HARVESTING

Before harvest, protect fruit from birds to allow fruit to mature before picking. Use plastic net over the vines or small paper bags over individual bunches to exclude birds from the fruit. For best quality, bunch grapes should be fully ripe when harvested. They will not improve in sugar content or flavour after being removed from the vine. Most cultivars should be used immediately, as they do not keep well after ripening. Cut bunches off with a knife or shears to avoid bruising the fruit and damaging the vine.

Figure 14-D: A young grapevine tied first to a stake and later to the bottom wire.

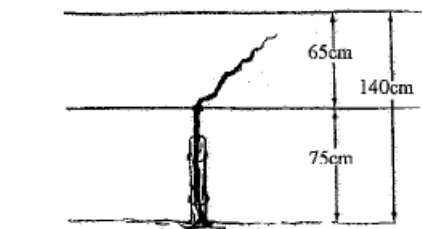


Figure 14-E: A young vine illustrating branches "a" that should be removed entirely and branches "b" that should be cut back to two buds to form the fruiting canes for the lower wire.

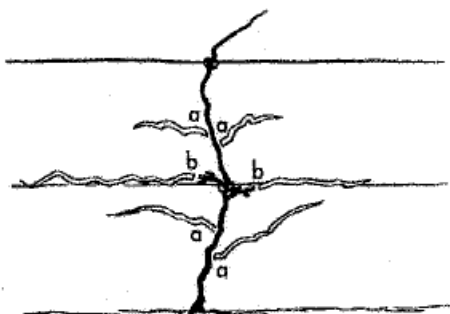
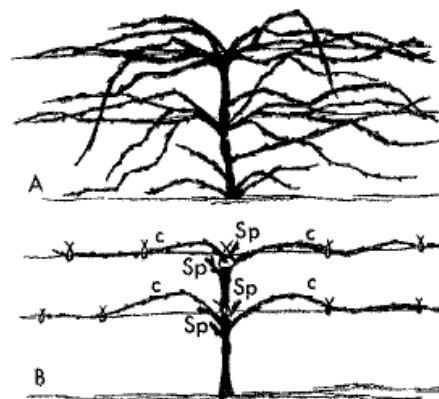


Figure 14-F: A mature dormant vine (A) before pruning and (B) after pruning according to the four-cane renewal (Kniffin) system — Sp, renewal spur; c) fruiting cane. The letter "c" illustrates the fruiting cane that developed from one of the buds of the cane that was cut back to two buds.



BRAMBLES

Brambles are defined as any species belonging to the *Rubus* genus. This covers a large number of plants found growing in the woods and fields surrounding us. However, the brambles of interest to the home gardener are raspberries (red, black, and purple types) and blackberries (thornless and thorny types).

The word "type" is used intentionally, because the difference among them is not only the colour of the fruit, but the growth habit (and hence the cultural practices), disease problems, and other characteristics.

Red raspberries may be either of two types. Summer-bearing red raspberries fruit from late June to August. They have the typical biennial life cycle of a bramble: canes that emerge in the spring (primocanes) grow and overwinter and produce flowers and fruit in the second growing year (floricanes). Fruiting canes die and are removed after harvest. Primocane-bearing types such as 'Heritage' fruit during the first year. Primocane-bearing raspberries are the exception to those having the life cycle outlined above. Also called "everbearing" raspberries, they will fruit again in the spring on the buds below those which fruited the previous fall. Gardeners typically mow these "everbearing" types to the ground in late winter to harvest a single crop the following late summer.

Because both of these red raspberries produce new canes (suckers) primarily from the root system, they are usually grown in a hedgerow. They are the most winter-hardy type of raspberry.

Black raspberries initiate new canes from the crown of the plant rather than from root suckers. Because of this, they are grown in a "hill" system; each plant is grown independently, with pruning and maintenance done on a per plant basis. Unlike red raspberries they require summer tipping, because individual canes will grow to unmanageable lengths. Black raspberries bear their fruit in late June through July, and are the least cold-hardy of the raspberries. Black raspberries may not be reliably hardy in more northern parts of Ontario.

Purple raspberries initiate new canes predominantly from the crown, but may sucker between plants as well. They are essentially grown like black raspberries and are intermediate in cold hardiness. Purple raspberries may not be reliably hardy in more northern parts of Ontario.

Gold raspberries are also available, although not widely grown. The predominant cultivar 'Fallgold,' is a primocane bearer and is grown in an annual system like the red primocane bearers.

Eastern blackberries can be thorny and erect, or thornless and trailing. Thornless types are much more cold sensitive (to -17°C) and grow best in the southern or warmer portions of Ontario. Because of their trailing growth habit, they require trellising. Thorny types often have excellent fruit quality, but the thorns are brutal. Generally, thorny types of blackberries will tolerate winter temperatures down to about -20°C.

CULTIVAR SELECTION

Cultivar selection is perhaps the most important decision you will make. Consult Table 14-1 for some appropriate varieties.

PLANTING BRAMBLES

For raspberries, virus-indexed, tissue-cultured plants should be planted in early spring. Avoid poorly drained soils and sites where *Verticillium*-susceptible crops (tomatoes, potatoes, peppers, eggplant and strawberries) have been grown. If available, use tissue-cultured blackberries as well. Prune back bare root plants after transplanting (see Table 14-4). Healthy, potted plants do not require any initial pruning. Plants should have flower blossoms removed in the first year to encourage plant establishment.

PRUNING BRAMBLES

Fruiting canes of all brambles, except the primocane bearing types, will die after fruiting is completed. Remove these dead canes immediately after fruiting to facilitate air circulation through the hedge. With fall-fruiting raspberry varieties such as Heritage, the pattern of cane growth and fruiting is similar, but it is partially compressed so that fruiting begins during the first growing season. Flower buds that are initiated on the top third of the primocane break and flower in late July and begin fruiting in August. These canes generally finish fruiting with the first frost. The bottom section of fall-fruiting raspberry primocanes behave as other red raspberries and will bear a subsequent spring crop before dying back.

Since the pattern of primocane development and fruiting is similar for all bramble species, they are pruned similarly. For example, all plants require heading back cuts as well as the removal of weak damaged and diseased canes. Table 14-4 and Figures 14-G, 14-H, 14-I and 14-J summarize the training and pruning systems used for each bramble species.

Early spring is the best time to prune in Ontario, because winter damage can be fully assessed. However, raspberries can be pruned any time canes are fully dormant.

HARVEST AND POST HARVEST CARE

Brambles, like all small fruit crops, should be harvested in the morning after dew has dried. This allows a minimum of field heat buildup in the fruit and will result in longer shelf-life. Ripe berries will detach easily. They should be rolled off the plant, rather than squeezed or pulled, and put in shallow containers. Deeper containers tend to crush berries in the lower layers. Do not allow overripe berries to remain on the canes. Refrigerate berries immediately. Raspberries can be kept for up to a week under these conditions. Blackberries will keep several days longer.

PRUNING AND TRAINING BRAMBLES

Figure 14-G: Training red raspberries: (A) Hill system, trained to a stake; (B) Hedgerow system, vines tied to a wire; (C) Hill system tied to a wire.

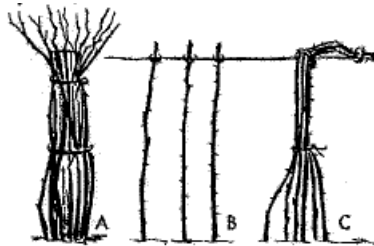


Figure 14-H: Pruning purple and black raspberry plants: (A) Top the new canes at "a"; (B) Laterals that develop after tip of cane is removed; (C) Pruned plant with 15 to 20 cm of the laterals left.

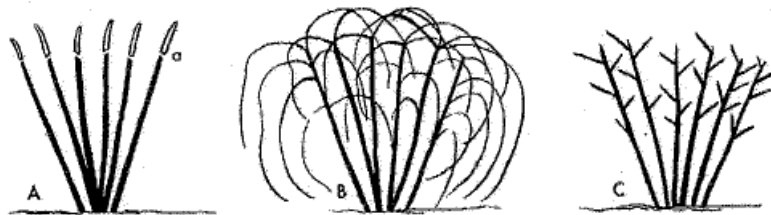


Figure 14-I: (A) Top the young erect blackberry canes at "a" when 85 to 90 cm in height; (B) lateral development after topping; (C) plant after laterals have been cut back.



Figure 14-J: A thornless blackberry supported by a two-wire trellis: (A) Before pruning; (B) after pruning.

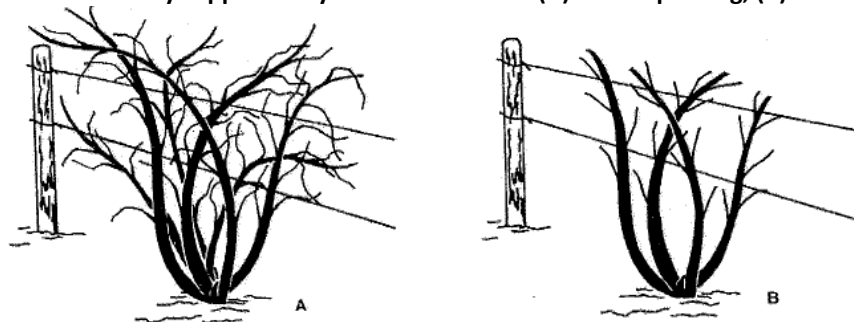


Table 14-4: RECOMMENDED CULTURAL SYSTEMS AND PRUNING PRACTICES FOR BRAMBLES

Species	Cultural Systems	Pruning		Established Plants
		Summer at Planting	Pruning of Primocanes	Dormant Pruning (winter to early spring)
Red raspberry (Figure 14-G)	Hill system consists of 4 or 5 canes per hill, tied together and/or to a post for support. Plants can also be grown as a hedge, and tied to a 2-wire trellis.	Head back to ground level	None.	Head canes back to $\frac{3}{4}$ of their length. Remove weak canes. Space canes to 5 per hill or at 15 cm if grown on a trellis. Remove fruited canes, if not done during previous summer.
Red raspberry (fall-fruited) (Figure 14-G)	Hedge.	Head back to ground level.	Narrow the hedge to 45cm if necessary. Harvest fruits during August and September.	Cut canes off near the ground level
Black raspberry (Figure 14-H)	Hill system.	Head back to 5-7.5 cm above soil	Tip canes at 90 cm to force lateral branches. (Remove at least 10 cm of growth.)	Head back laterals to 30 cm. Remove weak canes, leaving about 5 per hill. Remove dead (fruited) canes, if this was not done during the previous summer
Purple raspberry (Figure 14-H)	Hedge.	Head back to 5-7.5 cm above soil.	Tip canes at 90cm to force lateral branches. (Remove at least 10 cm of growth.)	Head back laterals to 45 cm. Remove weak canes, leaving about 5 per hill. Remove dead (fruited) canes, if this was not done during the previous summer.
Thorny blackberry (Figure 14-I)	Hill system. Plants must be tied to a trellis.	None (remove dead wood, if any)	Tip primocanes to about 90 cm to force lateral branches. (Remove at least 10 cm of growth.)	Remove weak canes. Space canes at about 15 cm within the hedge. Narrow the hedge to 45 cm. Head back laterals to 45 cm. Remove dead (fruited) canes, if this was not done during the previous summer.
Thornless blackberry (Figure 14-J)		Head back to 5-7.5 cm above soil.	Tip at top wire of trellis.	Tie 4 or 5 vigorous canes per hill to the trellis. Top canes, if not tipped during previous summer, at 2 m and cut back laterals at 45 cm. Remove laterals that rise too low on the cane making picking difficult. Remove dead (fruited) canes, if this was not done during the previous summer.
Note: Hill system refers to spacing plants and not allowing them to form a hedge. It does not imply that the soil around the plants should be mounded-up.				

BLUEBERRIES

Several species of blueberry are indigenous to North America. These include the lowbush blueberry (*Vaccinium angustifolium*), found across Ontario; and the highbush blueberry (*V. corymbosum*). This section pertains solely to the highbush blueberry which is most commonly cultivated in home gardens.

THE BLUEBERRY PLANT

The blueberry plant is a perennial, consisting of a shallow root system and woody canes that originate from the crown of the plant. The root system is very fibrous but devoid of root hairs (root hairs function in most plants by increasing the surface area of the root for water and nutrient uptake). This characteristic makes the blueberry plant very sensitive to changing soil water conditions.

A mature, cultivated blueberry usually has 15 to 18 canes. Growth habits vary among cultivars, with some bushes growing very upright, and others having a more spreading growth habit. Fruit is borne on buds formed the previous growing season.

SITE SELECTION AND PREPARATION

Cold Hardiness

Healthy, mature blueberry plants will generally tolerate very cold temperatures, although there is some cultivar variation. Winter injury is more likely to occur when a period of mild winter weather is followed by severe cold. Most varieties require 750 hours of chilling below 7.2°C. In many parts of Ontario this requirement is usually met by no later than early February. After the chilling requirement is met, the plant loses its dormancy and thus its cold hardiness, making it increasingly susceptible to cold injury as the season progresses.

SOIL PREPARATION

Blueberries are in the Heath family, and thrive in acidic soils (pH 4.3 - 5.3) high in organic matter. Amending the entire planting site (not just the individual holes) with peat moss, shredded leaves and or composted sawdust will help lower soil pH and improve water holding capacity. The final growing medium should be 50% organic matter. Soil pH readings above 6.0 can be lowered $\frac{1}{2}$ a unit by incorporating iron sulfate at the rate of 700 g/10 m². For example, reducing a soil pH from 6.8 to 5.3 would require 2.1 kg/10 m².

If necessary, sulfur powder or iron sulfate can be used in later years. Low pH can result in manganese or aluminum toxicity, while high pH results in the unavailability of certain nutrients, most notably iron.

The year before planting, eliminate all noxious weeds and increase soil organic matter by incorporating manure or cover crops. Test the soil and amend according to test recommendations. The effects of sulfur (to lower the soil pH) and phosphorus (if needed) require time, so these materials should be added the fall before planting. **Do not plant blueberry plants in high pH soils without amending them first!** Sulfur does not move through the soil readily so surface sulfur applications after the plants are in place are not very effective in lowering the pH.

Irrigation and Mulch

Mulch and irrigation are essential for a healthy planting and consistent yields. Blueberry plants require at least 2.5 cm of water per week (250 litres/10 m²). Pine bark mulch, rotted sawdust, and compost are good mulches. Apply them to a depth of 10 cm and replenish whenever necessary. Avoid mulches with high pH, such as mushroom compost.

Overhead (sprinkler) irrigation can be used on blueberries, but trickle or drip irrigation is preferred because it conserves moisture and does not wet the foliage. The trickle line can be placed directly under the mulch. Overhead irrigation has the advantage of cooling the plants and the berries during extremely high temperatures.

Cultivar Selection

You can select a combination of cultivars that can provide a continuous harvest from July through mid-September. Blueberries are only partially self-fertile so will produce more and larger berries if two or more varieties are planted. See **Table 14-1** for some recommended varieties.

PLANTING BLUEBERRIES

Prune back 50% to 60% of the wood immediately after planting. Remove all of the flowers from two-year-old plants to encourage root growth. Some of the flowers should also be removed the following year, to ensure good establishment. Set plants out in early spring as soon as you can work the soil. Set plants 2.5-5 cm deeper than they were grown at the nursery.

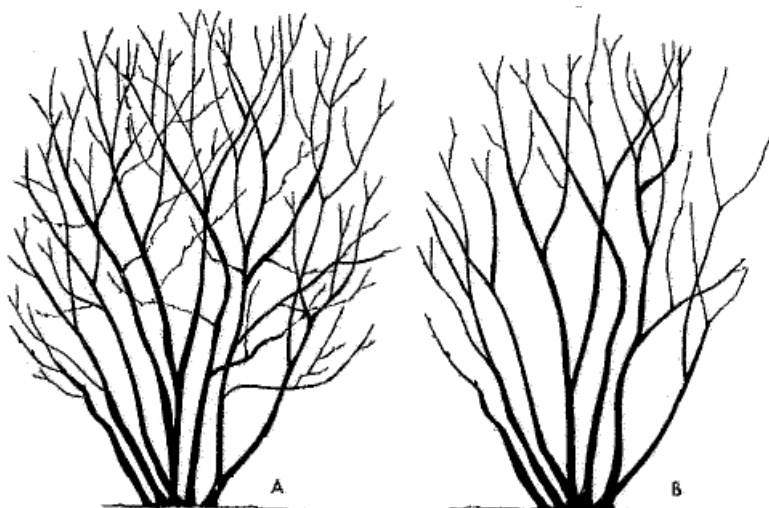
PRUNING BLUEBERRIES

Pruning invigorates the plant, forcing essential new growth from the base of the plant. The guiding principle behind blueberry pruning is to constantly renew the older, decreasingly productive canes by cutting them out to force new canes. The plant will continually replace old canes with new canes, with a majority of the canes in a productive, intermediate stage. Pruning will also increase fruit size and improve quality.

In February or March following the third, fourth and fifth growing seasons, plants may need light pruning. Remove a few of the small branches or twigs in the center of the bush. Fruit is produced on wood grown the previous season, and the largest berries are produced on moderately vigorous wood (30 to 45 cm in length). All weak growth should be removed (see **Figure 14-K**).

A healthy plant should be 1 to 2 m tall at maturity. Remove the lowest branches and thin out branches in the center. The lower branches bear fruit that becomes dirty and difficult to pick; the center branches produce small, poorly coloured and late-ripening fruit. Removing small twigs and one or two of the weak branches at the base of the plant each year, will force the plant to produce vigorous new growth and a good crop of large, well-coloured berries. When you fail to remove older branches the new canes are likely to be willowy and produce only a few berries at the top.

Figure 14-K: Four-year old blueberry bush: (A) Before pruning; (B) after pruning. Pruning reduced the fruit buds by about 75%. In very fertile soils a large number of fruit buds might be left for a heavier crop.



HARVEST AND POSTHARVEST CARE

A mature blueberry plant will produce 2.5 to 3.5 kg of fruit per year. Harvest begins in June and may continue through mid-September with late varieties. Berries turn blue 3 to 4 days before they attain maximum sweetness and flavour. They should be picked every 7 to 10 days. Do not pick berries with a reddish tinge, since they are under-ripe and do not ripen after picking.

Blueberries, like other fruits, should be picked in the morning after the dew has evaporated. If picked in the afternoon, the berries will contain field heat, which will reduce storage life.

GOOSEBERRIES AND CURRANTS

Gooseberries and currants (*Ribes* spp.) have enjoyed great popularity in the past, particularly in Europe, where in the 1800s, up to 722 cultivars of gooseberry were in existence, and "gooseberry clubs" were established by enthusiasts. Most of the European cultivars were large fruited and sweet as a result of centuries of selection and breeding, while American types had less desirable flavour and more disease resistance. The gooseberries grown today are primarily hybrids of these two types, offering good flavour as well as disease (mildew) resistance.

While seldom eaten fresh, due to their tart flavour,

currants make excellent jams and jellies. Gooseberries and currants are woody perennial shrubs that reach a height of 1 to 2 m when mature. Plants are self-fruitful and, unlike other fruiting plants, tolerate partial shade.

LEGAL RESTRICTIONS

There is often confusion as to the legality of growing gooseberries and currants. They can serve as alternate hosts to white pine blister rust (*Cronartium ribicola*), a fungus that needs both *Ribes* and white pine to complete its life cycle. If you have white pine nearby, you may want to consider growing less susceptible types of *Ribes*. Black currant (*Ribes nigrum*) is by far the most susceptible species, and for this reason many areas still prohibit its cultivation. Red and white currants are less susceptible, and gooseberries are the least susceptible.

CULTIVAR SELECTION

Gooseberries

Pixwell is nearly thornless; very productive, but fruit is only of fair quality. Leaves turn purple in the fall.

Poorman is red-fruited, large, and flavourful. It is the best cultivar of the American types for the home garden.

Several European cultivars are available from specialty nurseries. Fruit of the European types is usually larger and better flavoured. However, they generally do not have as much mildew resistance as the American types.

Currants (Black)

Consort was developed in Canada and has resistance to white pine blister rust. Productive plants; fruit have the characteristic musky flavour.

Crusader is similar to Consort except later. Should be grown with a second variety.

Currants (Red)

Red Lake is a vigorous, hardy and productive cultivar. Fruits are large, bright red when mature, and of good quality. The long-stemmed clusters are easy to pick.

Wilder is very much like 'Red Lake' high yielding with high-quality berries. It also has more resistance to leaf spot diseases.

Currants (White)

White Grape has a light amber, large, mild-flavoured fruit.

White Imperial has very attractive and sweet fruit that will hang on the bush for several weeks. Vigorous and productive.

Jostaberry is a black currant, gooseberry cross. The thornless, vigorous plants reach 1.5 m in height. Hardy and disease resistant. Large fruit has mild, black currant flavour.

PLANTING AND NUTRITIONAL REQUIREMENTS

Select a cool, moist partially-shaded site. In fall or early spring, plant well-rooted 1- or 2-year-old dormant plants, cutting back the top portions of the plant to 15 to 25 cm. Remove flower blossoms from plants in the first year to encourage plant establishment and growth for future years. Well-established plants can fruit for 10-15 years or more.

PRUNING GOOSEBERRIES AND CURRANTS

Currants and gooseberries produce fruit at the base of 1 year-old wood, with the greatest production on spurs of 2 and 3 year-old wood. After 3 or 4 years the older wood becomes less productive and therefore should be replaced gradually with young shoots by a thinning and renewal process.

Prune dormant plants in early spring just before growth resumes. Remove canes that drop on the soil or canes that shade out the center of the plant. After the first season of growth, remove all but six to eight of the most vigorous shoots. After the second season, retain four or five 1 year-old shoots and three or four 2 year-old canes. Following the third season, keep three or four canes each of 1, 2 and 3 year-old wood. In subsequent years, remove all of the oldest canes.

There are numerous fruit culture publications available from the OMAFRA. This is a partial list.

Agdex#		Order
210	Publication 360, Guide to Fruit Production: Ch. 5: Berry Crops; Ch. 6: Grapes	
206/510	Soil Management for Orchards and Vineyards	92-120
230	Growing Red Raspberries in Ontario	105
	Insect & Disease Identification Guide for Grapes Pest Management	03-039
231/612	Grape Phylloxera	88-125
232/20	Dayneutral Strawberries	89-099
232/600	Strawberry Clipper Weevil: A Major Pest of Strawberry	99-031
232/600	Tarnished Plant Bug: A Major Pest of Strawberry	92-108
234/20	Growing Blackberries, Purple and Black Raspberries	88-056
235/12	Blueberries for Home Gardens	90-046
236/12	Currants and Gooseberries	98-095
237/12	Raspberries and Blackberries for Home Gardens	99-030
238/10	Elderberries for Home Gardens	95-005

North American Fruit Explorers Inc. is a network of individuals devoted to discovering, developing, cultivating, evaluating and appreciating superior varieties of fruits and nuts. This is an excellent society for amateur fruit growers. It publishes a journal, *Pomona*, that is devoted to articles written by members. Membership information can be obtained online at <http://www.nafex.org>

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Revised by the Master Gardeners of Ontario Inc. from the
Maryland Master Gardener Handbook.

CHAPTER 15: TREE FRUITS

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TREE FRUITS

INTRODUCTION

Apples, pears, peaches, plums and cherries can thrive in Ontario home orchards when given proper care.

Backyard fruit production allows you to:

- Grow cultivars that are not readily available in grocery stores.
- Control the level of pesticides used.
- Gain a greater understanding of the processes of nature that interact with the tree to produce these wonderful fruits.

However, it is also time-consuming, demanding a year round commitment by the gardener. Tree fruits can be grouped into two categories: pome fruits and stone fruits. Both pome fruits, apples (*Malus*) and pears (*Pyrus*) share many cultural similarities and pest problems. Likewise, the stone fruits, peaches, plums, apricots, nectarines and cherries (*Prunus*) share cultural, pest and disease similarities.

POLLINATION

Bees pollinate fruit trees. For most fruit trees, cross pollination is very important to ensure adequate crops. Some varieties like Stayman and Summer Rambo apples and Magness pear are pollen sterile. They produce no viable pollen and require an excellent pollinator to set fruit. Generally, it is recommended to plant 2 - 3 different varieties of apples or pears and at least 2 varieties of plum, sweet cherry or apricots. Peaches, nectarines and sour cherries are generally self-fruitful. (see **Table 15-1**).

SITE SELECTION

The planning and care that goes into the site selection process will pay big dividends over the entire life of the orchard. An ideal location is:

- Well drained but not droughty
- In full sun
- Without frost pockets

The number of flower buds that a tree will form is directly related to the amount of sunlight received. This will therefore affect the quantity and quality of fruit. Fruit trees should be planted in full sun.

Usually, the side of a hill that is too steep to be tilled for gardening will work well. Cold air will drain down the hill, helping to limit frost damage in the spring. Plant the trees from the top of the hill to three quarters of the way down the hill. Frost problems are common on stone fruits. For this reason, apricots and sweet cherries are not recommended for colder areas of Ontario. Early blooming apricots often produce a crop only once or twice every 5 years, due to late spring frost.

A direct southern exposure should be avoided whenever possible. The warmer temperatures on a southern slope speed many stone fruits into early bloom, increasing the probability of exposure to frost.

Northern exposures shaded by buildings are also poor choices. Light levels will be too low for adequate fruit development.

Deep, well drained soils are necessary for most fruits. Pears are somewhat tolerant of clay soils. Stone fruits, particularly peaches, do not tolerate "wet feet". By contrast, sandy soils drain too quickly leading to drought stress and nutrient deficiencies. An ideal garden soil is always preferred: loam to sandy loam soil.

The soil should be tested to determine fertility and pH. It is much easier to correct nutrient deficiencies before planting than to continually amend the site. Fruit trees prefer a soil pH of 6.0-6.5. The season before planting, amend the soil by applying organic matter and lime, if required. These amendments should be applied over a 3 m x 3 m area per tree.

PLANNING A FRUIT TREE GARDEN

Table 15-1: BEARING AGE, HEIGHT AND POLLINATION OF TREE FRUIT

Fruit	Bearing Age (yrs)	Tree Height (m)	Pollination* Requirement	Notes
Apple	2-10 (See Table 15-3 for details)	1.8-7.5 (See Table 15-3 for details)	Mostly self-sterile; requires a pollinator	Golden Delicious is self-fertile, Mutsu, Jonagold and Arkansas Black produce sterile pollen. They must be grown with two additional varieties.
Pear	4-5	4.5-5.5	Mostly self-sterile, requires a pollinator	Asian and domestic varieties are compatible. Seckel and Bartlett are incompatible. Magness produces sterile pollen and must be grown with two additional varieties.
Peach and Nectarine	3-4	6.1	All recommended peach and nectarine varieties and self-fruitful	
Sour Cherry	3-5	4.5	Self-fruitful	
Sweet Cherry	4-7	7.5	Mostly self-sterile, requires a pollinator	Stella, Lapins and Vineland are self-fertile and do not require cross-pollination.
Plums	3-5	3-6	Mostly self-sterile	Stanley, Damson, Italian, Veeblue and Reine Claude are self-fertile, European type varieties. Most Japanese varieties listed as self-fertile will produce larger crops when planted with a pollinator. Plant 2 or more European varieties or 2 or more Japanese varieties, but not one of each type. Apricot-plum crosses (pluots, apriums and plumcots) can be pollinated with suitable Japanese plum varieties.
Apricots	3-4	6.1	Self-fruitful	Trees bloom early and blossoms are often damaged by late spring frosts. Late blooming varieties are recommended e.g., Harlayne and Harval.
* To ensure cross-pollination, be certain that the selected varieties are pollen-compatible and share a similar bloom time. Crabapple trees, Callery pear trees (Bradford) and ornamental plum and cherry trees will cross-pollinate their respective fruiting "cousins", provided bloom time is similar.				

Table 15-2: TREE FRUIT VARIETY SELECTION CHART

APPLES	
Variety - <i>a, b</i>	Comments
Redfree*	Earliest scab and cedar-apple rust resistant variety; moderately resistant to fireblight and powdery mildew. Red apple with cream-coloured flesh. Excellent flavour; ripens mid-late August.
Liberty	High quality dessert apple. Red fruit; sub-acid to tart flavour. One of the most disease resistant varieties available.
Freedom Jonafree	Slightly less disease resistant than Liberty. Thin-skinned, red fruit with sub-acid flavour. Hard, dark red fruit that is crisp and slightly tart. Moderately resistant to fireblight, powdery mildew and apple-quince rust.
Spartan	McIntosh x Newton Pippin; small to medium sized fruit. High quality dessert apple that keeps well. Good disease resistance (not to apple scab).
Empire	McIntosh x Red Delicious; dark red fruits of excellent quality. Good keeper; very vigorous, early bearing trees.
Golden Delicious	Good all-purpose apple. Self-fertile, heavy producer. Fruit from spur strains tends to russet more than non-spur strains.
MacFree Ginger Gold Mutsu	Large fruit with 90% red blush over tough, green skin. Flavour similar to McIntosh. Deep yellow skin, crisp, firm, white flesh; upright, does not tend to russet; good keeper. Golden Delicious x Indo; very large, light green to yellow fruit. It is a triploid and produces sterile pollen. Ripens mid-October.
<i>a</i> Listed in order of ripening. <i>b</i> *Bolded varieties have some resistance to fireblight, apple scab, cedar-apple rust and powdery mildew; highly recommended for the backyard grower.	
EUROPEAN PEARS	
Variety - <i>a, b</i>	Comments
Harrow Delight Moonglow Harvest Queen Seckel Magness	Juicy, medium-sized fruits. Smooth flesh, no grit cells. Productive trees. Medium to large, dull green fruits with pink blush. Smooth, fine flesh; excellent quality. Hardier and earlier but very similar to Bartlett. Can be nearly "tree-ripened". Very sweet, small fruits. Referred to as the "sugar pear". Medium-sized fruits of excellent quality. Pollen is sterile; must be grown with two other varieties. Must be kept in cold storage for 1 month prior to eating.
<i>a</i> Listed in order of ripening. <i>b</i> All listed varieties have fireblight resistance. Bartlett, Bose, Cornice, Anjou and Clapp are all fireblight susceptible.	

Table 15-2: TREE FRUIT VARIETY SELECTION CHART (cont'd)

PEACHES	
Variety - <i>a</i>	Comments
Candor	Early, medium sized fruits. Semi-freestone, resistant to bacterial spot but susceptible to pit splitting.
Garnet Beauty	A sport of Redhaven. Medium to large, fuzz-less, red fruit. Firm, yellow, semi-freestone flesh. Vigorous and productive.
Reliance Redhaven Loring	Very bud hardy variety.
Newhaven Cresthaven Redskin	Very popular peach. Red, semi-freestone fruits. Requires thorough thinning.
Jerseyglow	Medium to large red fruits over a yellow background. Can produce heavy crops but blooms early.
Golden Delicious	Similar to Redhaven. Very reliable with good disease resistance. Medium to large golden fruits overlaid with red. Vigorous trees require thorough thinning. Large fruit, very high quality. Blooms over a long period. Vigorous tree developed at the University of Maryland in 1931.
MacFree Ginger Gold Mutsu	Medium to large, firm flesh. Vigorous tree, spreading and moderately resistant to bacterial spot.
<i>a</i> Listed in order of ripening.	
EUROPEAN PLUMS	
Variety	Comments
Stanley	Medium sized, dark blue freestone, oval in shape. Greenish-yellow flesh. Good for fresh eating, drying and canning. Ripens mid-August.
Bluefree Italian Prune	Later and larger than Stanley. Yellow, freestone flesh. Medium to large, purple-black fruits. Excellent quality, freestone flesh. Productive trees.
JAPANESE PLUMS	
Variety - <i>a</i>	Comments
Shiro Santa Rosa Methley Ozark Premier	Round, yellow fruits sometimes with pink blush. Very juicy clingstone that ripens late July. Very large, round, red-purplish fruits. Very high quality, clingstone flesh. Round, purple fruit with red blush. Ripens early to mid-July. Vigorous tree. Large, red fruit with yellow clingstone flesh. Harvest early to mid-August.
<i>a</i> Japanese varieties are somewhat less susceptible to brown rot.	

Table 15-2: TREE FRUIT VARIETY SELECTION CHART (cont'd)

BLACK CHERRIES	
Variety	Comments
Ulster	Medium sized fruit with dark skin and flesh.
Stella	Self-fertile, vigorous large trees (9 m). Large, dark red fruit.
Sam	Early ripening, large, black cherry. Large, vigorous, upright trees. Blooms later than most other varieties.
Hedelfingen	Very productive trees that come into bearing quickly. Good quality, black fruit with some cracking resistance.
Van Lapin	Fruit similar to Bing, but firmer. Vigorous, productive tree can tolerate harsh weather. Self-fertile, heavy producer. Fruit have good crack resistance and ripen mid July.
SOUR CHERRIES	
Variety	Comments
Montmorency	Very old, standard variety. Red fruits with yellow flesh. Tree reaches 4.5 m at maturity with a spreading habit. Ripens in mid to late June.
Meteor	Genetic dwarf; reaches 2.5-3.7 m at maturity. Fruit similar to Montmorency.
North Star	Genetic dwarf; reaches 1.8-3.7 m. Heavy producer that often begins bearing in second year. Mahogany-coloured fruit is crack resistant and can remain ripe on the tree for up to two weeks.
APRICOTS	
Variety - <i>a</i>	Comments
Harcot	Early ripening, productive trees.
Veecot	Medium to large fruit with orange, freestone flesh.
Harlayne	Medium sized fruit with orange, freestone flesh. Productive and cold-hardy.

PLANTING

Trees should be planted so that the graft union (the point where rootstock meets scion wood) is 5 to 10 cm out of the ground after the ground settles. Generally, trees should be set out 2.5 cm deeper than they were planted in the nursery. The diameter of the hole is much more important than the depth of the hole. The hole should be big enough to lay the roots out without crossing over or bending any back. Before planting, remove any roots that are broken or damaged with sharp pruners. Backfill the hole, firmly packing the soil around the root system, and water in well. Do not add fertilizer to the planting hole or leave a depression around the tree. Place a 7.5 cm layer of organic mulch under the tree's dripline tapering to "0" cm at the trunk. The tree should be watered deeply throughout the first season.

Dwarf apple varieties need to be supported or staked over their entire life. Standard varieties may require support for the first few years.

Do not allow your trees to bear fruit before their third season. Remove blooms on the central leader and thin fruits heavily on the scaffold limbs. Root establishment in the young orchard should take priority over fruiting. Once roots are developed, fruiting will follow.

FRUIT THINNING

The practice of fruit thinning apples, pears and stone fruits will help contribute to your orchard's success. Thinning is done for two reasons. First, a certain portion of the fruit is removed so that the remainder will develop adequate size and quality; secondly, the thinning process serves to increase the plant's ability to form flower buds for the next year, provided the thinning is done early enough. Failure to thin can lead to biennial bearing problems—over production one year, followed by a year of extremely low yields. Thinning also reduces the total load on the branches, thus reducing breakage. Thinning is necessary for apples, nectarines, pears, plums, and peaches.

Hand thinning is the easiest and safest method for removing excess fruit. Begin hand thinning when the fruits are about 1.5 cm in diameter. Start at one end of a branch and systematically remove fruit, leaving one fruit every 15 to 20 cm. Insects and diseases are more difficult to control when fruits hang in clusters. Keep in mind that **only 7%-10% of the tree's flowers are needed to set a full crop of fruit.**

POME FRUITS: APPLES & PEARS

Apples and pears, botanically referred to as pomes, are excellent candidates for the home garden, as long as the grower is committed to the attention to detail and pest management that the crop requires.

There are many insect and disease pests of apples and pears and it is challenging to grow quality fruit in Ontario without the use of pesticides. To minimize problems, you should consider purchasing disease-resistant cultivars. Integrated Pest Management (IPM) is a broad-based approach to reducing pest problems. The Ontario Ministry of Agriculture and Food (OMAFRA) has many excellent publications available to help growers deal with pest and disease problems (see a sample of publications on page 15-16).

CULTIVAR SELECTION

A list of recommended varieties can be found at the end of the chapter. You may notice that some apple varieties such as 'Red Delicious' and 'Golden Delicious' are also available in various strains. A strain is a mutation of a certain variety that has been selected and propagated for an improved characteristic. A strain may differ in fruit characteristics, growth characteristics, or both. There are many strains of some varieties. For example, approximately 250 different strains of Red Delicious have been described and cultivated.

The most common strain difference is between spur strains and nonspur strains. **Spurs** are short, stubby slow growing branches that support multiple fruit blossoms and may remain fruitful for 7-10 years or more. They are common on apple, pear, and cherry trees. Spur types, because of their compact form of growth, are ideally suited for home gardeners with limited space. Fruit spurs and leaf buds are spaced closer than on nonspur trees. On spur types, two-year-old wood will usually form fruit buds rather than develop side shoots. **As a general rule of thumb, spur strains of a variety will result in trees only about 60%-70% as large as the nonspur types of that variety.**

Nursery Stock Selection

The old adage "you get what you pay for" holds true when buying fruit trees. Bargain plants may not be healthy or may be a variety not adapted to your area. Buy only trees of recommended varieties from a reliable source.

The following are a few points to keep in mind when purchasing fruit trees:

1. A healthy one year-old whip, approximately one to two metres tall, 1.5 cm caliper with a good root system, is preferred.
2. A smaller tree with a good root system is more desirable than a large tree with a poor root system.
3. Trees that are two years or older are often not as good as one year-old trees. The older trees frequently do not have enough buds on the lower portion of the trunk to develop a good framework.
4. Trees that appear stunted, poorly grown, diseased, or insect injured should not be purchased.
5. Check the label closely to make sure that you are getting the variety and rootstock that you desire.

STANDARD TREES VERSUS DWARF TREES

Fruit trees are vegetatively propagated by grafting scion wood of the desired variety to a clonal rootstock chosen for a specific characteristic. Varieties grown from seed will not produce trees with the same characteristics as the parent. Generally, seedling trees are inferior to the selected parent. Grafting solves this dilemma.

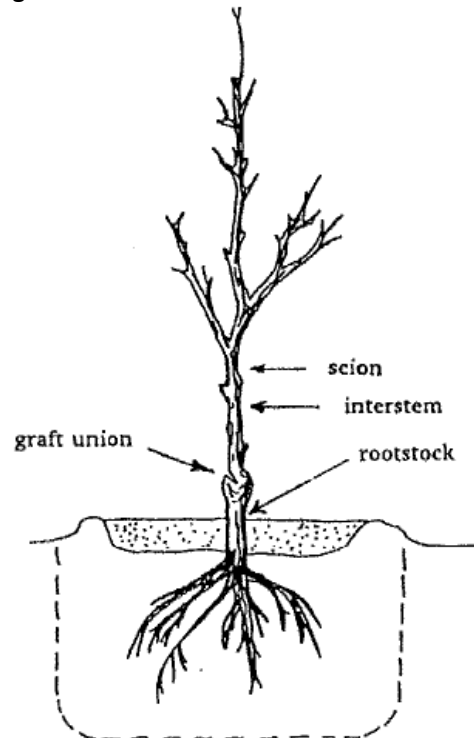
Rootstocks influence the size of the tree, age of bearing, winter hardiness and susceptibility to some diseases. A wide range of rootstocks exists for apples (see **Table 15-3**). Rootstock selections for other tree fruits are more limited. The two principal plant influences on tree size are the rootstock and the type of strain used (spur or non-spur). Other factors that will have an influence on ultimate tree size include general care, variety, and soil type, earliness of fruiting, and time and severity of pruning.

Trees on dwarf and semi-dwarf rootstocks are ideally suited for home fruit production. Although more expensive, the smaller trees are easier to prune, spray, and harvest, and begin producing fruit at an earlier age than full-sized trees. However, in the coldest parts of Ontario, zones 4 and colder, dwarf and semi-dwarf rootstocks may not be reliably hardy.

Therefore, standard rootstocks are recommended for these areas.

The interstem tree is another category of rootstock that may be available. It has a small stem section of M9 grafted between an understock, such as MM 111 or MM 106, and the variety. These trees are slightly larger than dwarf trees but smaller than the semi-dwarf. Because of the extra propagation needed, interstem trees are the most expensive. Current recommendations suggest planting these trees so that a portion of the M9 piece is above the soil line, about 2.5 to 5 cm.

Figure 15-A: PARTS OF A FRUIT TREE



Benefits of Dwarfing Rootstocks

1. *Earlier bearing*
2. *Harvest without ladder*
3. *Less pesticide used; better pesticide coverage*
4. *Improved cold hardiness and pest resistance*
5. *Less pruning required*
6. *Improved air circulation*
7. *Require less space; can be grown in small yards*

PRUNING NEW TREES

Remember that approximately one quarter of the root system was removed when your tree was dug at the nursery. To compensate, remove the top quarter of your whip to help re-establish the plant's previous shoot-to-root ratio.

On branched trees, remove poorly spaced and narrow-angled branches. Leave branches that are wide-angled and arranged spirally about 15 to 23 cm apart up the leader (trunk). Those branches left on the tree should be reduced by up to one-half their length and the leader should be cut about 30 to 38 cm above the top limb. Cut the leaders on non-branched whips back to three-quarters of their original length.

Chilling Hours

Fruit trees must undergo a specific chilling period to break dormancy and resume growth. Chilling hour requirements are often listed in fruit tree catalogs for available varieties. It is expressed as number of hours of exposure to temperatures below 7°C. Beware of "low-chill" varieties which may begin growing during warm days in February and March and are then damaged by late spring freezes.

Nutritional Requirements

Generally, apple trees need fertilizing each year. Nitrogen is the most important nutrient needed. Two other nutrients, phosphorus and potassium, are needed in relatively large amounts when the tree is young. After the trees reach maturity, an application of nitrogen is usually sufficient.

First Year Fertilization

One month after planting, broadcast 225 g of 10-10-10 fertilizer over a 0.6 m circle. Keep the fertilizer 15 cm away from the trunk and broadcast it evenly. **Do not put any fertilizer in the hole before planting.** In June following planting, broadcast another 225 g of 10-10-10 around your tree.

Subsequent Years

Increase the amount of 10-10-10 applied by 100 g per year up to a maximum of: 1 kg per tree for a dwarf tree, 2 kg per tree for a semi-dwarf, and 4 kg per tree for a standard tree. Maintain pH at 6.0 to 6.5.

Reduce these fertilizer rates if trees become overly vegetative (producing more than 30 to 35 cm of new shoot growth per year).

Watering During the First Year

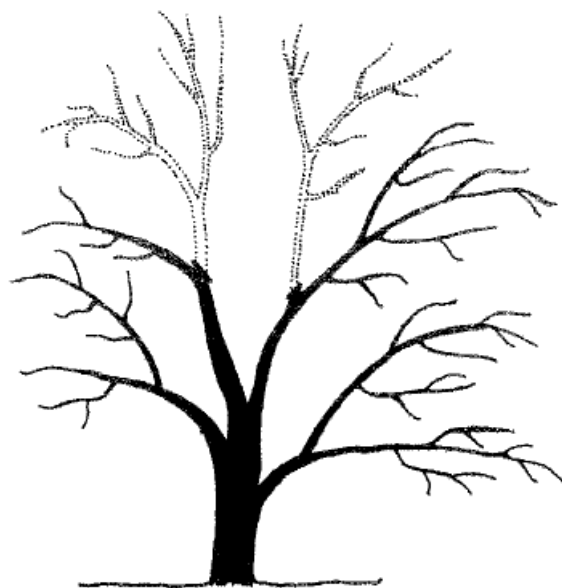
Watering the young tree for the first season following planting may be desirable depending on the rainfall up to that time. If less than 10 to 13 cm of rain has fallen since the trees were planted, 20 litres of water should be placed around the base of each tree. A small ridge of soil may be hoed around each tree to prevent runoff.

Pruning and Training Apple and Pear Trees

Fruit trees are pruned for the following reasons:

- To develop desired tree shape.
- To maintain tree at a desired size.
- To allow sunlight and spray materials to enter the centre of the tree.
- To improve fruit quality.
- To improve tree strength and induce branching.
- To improve air circulation within the tree and reduce the potential for disease.
- To remove dead or broken branches.

Figure 15 - B. Pruning an old neglected apple tree. Large cuts should be made close to remaining limbs. Renovate very tall trees over a 2-3 year period. Severe pruning will lead to the growth of many vigorous water sprouts.



PRUNING YOUNG TREES

The purpose of pruning a tree in the first 3-4 years after planting is to control its shape by developing a strong, well-balanced framework of a central leader with scaffold branches. Unwanted branches should be removed or cut back early to avoid the necessity of large cuts in later years. Your trees should have a Christmas tree shape with the lowest scaffold branches having the widest spread. For a thorough discussion of pruning consult OMAFRA Factsheet 210/24, "Pruning Fruit Trees".

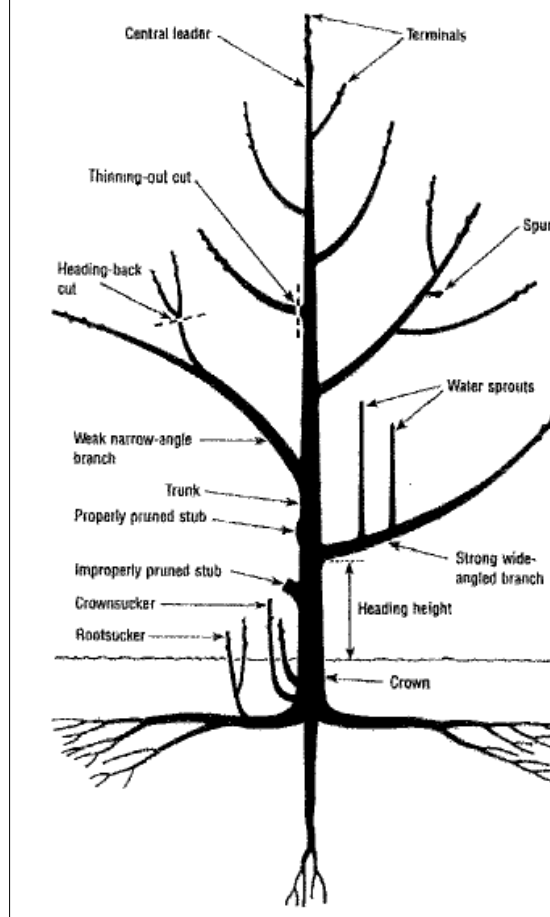
The most vigorous, upright shoot will become your central leader. Select 4-5 evenly spaced scaffold branches the season after planting, for the first tier. Head back your central leader so that it is 15 to 25 cm above the first tier. Select a second group of scaffold branches the second year that is 0.6 to 0.9 m above the first tier. It is very important to force these scaffold branches to grow at a 60°-90° angle from the trunk; use limb spreaders if necessary.

The use of limb spreaders can aid in earlier fruit production, improved tree shape, strong crotch angles, and better fruit colour. Spreader can be either short pieces of wood with sharpened nails driven into each end, wooden, spring-type clothespins or sharpened metal rods. The spreaders will need to remain in place for 1 to 2 years until the branch "stiffens up."

Pruning in Succeeding Years

Continue to head back the new terminal growth by one-fourth each year and remove any upright limbs. Any broken or diseased limbs should also be removed. Always maintain the central leader as the highest point on the tree. The ends of the primary and secondary scaffolds should be kept below the top of the tree. Prune the trees every year in late winter (February or March).

Figure 15-C: TERMS USED IN TREE PRUNING



PRUNING TIPS

- Pruning should be done in late winter. Winter pruning of apple trees consists of removing undesirable limbs as well as tipping terminals to encourage branching.
- Excessive pruning encourages excessive shoot growth, delays fruiting and reduces quality of fruit on young trees.
- Older trees (25 years and older) will produce higher quality fruit following a vigorous pruning.
- Prune young trees (up to 10 years of age) lightly. Encourage lateral branching on the major limbs by summer tipping. Tipping, or pinching off, the terminal one-half inch of new shoot growth in mid-June will encourage lateral branching. Trees from 1 to 4 years old are best suited to this practice.

Table 15-3: APPLE AND PEAR TREE SPACINGS AND PROBABLE YIELDS ON VARIOUS ROOTSTOCKS

	Approximate size (% of seedling)	Age at bearing (years)	Approximate lifespan (years)	Suggested spacing (m)	Average yields for trees at least 10 years old (litres)
Apple:					
Dwarf					
Malling 27 *	15-20	2	10-15	1.5 x 4	35-53
Malling 9 a*	30	2-3	15	1.8 x 4.3	35-70
Mark*	35	3-4	15	2 x 4.5	70-106
Malling 26 b*	40	3-4	15	2.4 x 4.9	106-144
Ottawa 3	30-50			3 x 3	70 or more
Semi-Dwarf					
Malling 7 or 7A	60	3-4	20	3.7 x 6	352-423
Standard					
Seedling d	100	6-10	40	5.5 x 8	880 or more
Interstem trees	40	4-5	15-20	6 x 8.5	352- 423
Pear:					
Interstem trees			15-20	3 x 5.5	176-352
Seedling			35-45	6 x 8.5	529 or more
* Require support a Attractive to rodents b Fireblight susceptible c Apple interstem trees are composed of either Seedling MI06 or MM111 roots, a 15 to 20 cm stempiece of M9 or M27 and the scion variety on top. Pear interstem trees are composed of Quince root, a 15 to 20 cm piece of Old Home pear trunk, plus desired scion. d May reach 6 to 9 m in height					

- Be sure to remove all dead and/or broken limbs when you prune.
- Make your thinning cuts back to within 0.5 cm of the branch collar; do not leave stubs.
- Remove sucker growth from the interior of the tree and around the base of the trunk annually.
- Thinning out cuts (entire limb or shoot removal) is associated with increased flower bud production on apples. Heading-back cuts (shortening the ends of branches) encourage shoot growth.
- Remove and dispose of prunings from the orchard area. Dead wood will harbor disease organisms that can spread back into the tree.

Occasionally a tree does not grow as well as it should during the first year. If this happens prune the tree back to a whip and start over. You will delay fruiting by a year but you will have a more manageable tree.

Pear trees do not require as much pruning as apple trees. Wide crotch angles are not essential because pear trees have tougher wood that is less apt to split. Spreaders will help to encourage flowering and fruiting in young trees. The same general pruning and training guidelines should be followed.

HARVESTING

Apples are picked when fully sized and coloured. They will twist easily off the tree. European pears should not be allowed to ripen on the tree. The flesh will become gritty and soft. Pick pears when they are still hard and full-sized, with a slight change in background colour. They will also twist off the tree quite easily. Store pears in a refrigerator or other very cool location.

STONE FRUITS: PEACHES, NECTARINES, PLUMS, APRICOTS, AND CHERRIES

Peaches, nectarines, plums, apricots, and cherries are all members of the *Prunus* genus, and are thus closely related. They are commonly referred to as "stone fruits" because the seed is very large and hard.

Most stone fruits are native to warmer climates of the world and are therefore very susceptible to injury from low winter temperatures. In addition, they bloom earlier in the spring and the flowers frequently suffer damage from spring frost. Because of this, the backyard culture of stone fruits can be quite challenging.

- Stone fruits are susceptible to a wide range of insect and disease pests.
- Nectarines are most susceptible to brown rot disease.
- Sweet cherries tend to crack as harvest nears if excessive rainfall occurs.
- Peaches, nectarines, and apricots are less hardy than cherries and plums.
- Stone fruits should only be planted on the very best sites, with excellent air and water drainage and protection from high winds.

CULTIVAR SELECTION

Currently, there are no suitable dwarfing rootstocks for peaches, nectarines, plums, apricots or cherries under Ontario conditions. See **Table 15-2** for a list of various cultivars and a list of recommended cultivars at the end of the chapter.

NUTRITIONAL AND WATER REQUIREMENTS

Incorporate 225 g of 10-10-10 fertilizer per plant into your soil prior to planting. Do not place fertilizer in the planting hole. In subsequent years, broadcast 200 g of 10-10-10 per tree under the tree in early spring. Increase the amount applied another 200 g per year up to 2 kg per tree regardless of age. Maintain pH at 6.0 to 6.5. Never fertilize after July 15. Late fertilization encourages soft growth which may be winter-killed and interferes with the tree's overall ability to harden-off for the dormant period.

Stone fruits are more shallow-rooted than pome fruits and are less drought-tolerant. Peaches are most sensitive to drought at final swell when the fruit is rapidly increasing in size. Water the tree deeply at this time.

PRUNING AND TRAINING STONE FRUIT TREES TO AN OPEN CENTRE

Young trees should be pruned to develop a strong, well-balanced framework of scaffold branches. (See OMAFRA Factsheet 210/24, "Pruning Fruit Trees" for a more detailed discussion.) Unwanted branches should be removed or cut back early to avoid the necessity of large cuts in later years. **Because stone fruit trees bear fruit on wood that grew the previous year**, the pruning system best suited to keep the fruit-bearing surface close to the ground is called "open centre." Pruning and training the trees to this system produces a vase-shaped tree. All stone fruits are very susceptible to brown rot. Open centre trees allow optimum air circulation and light penetration into the tree's centre, both important factors in reducing the development of brown rot on fruit.

At Planting

If you purchase an unbranched tree or one with no branches at least 50 cm above the soil line, cut the tree back to 65 to 75 cm after planting. Otherwise, your tree will grow major branches too high above the ground.

If you purchase a tree with healthy branches located at least 45 cm above the soil line, select three or four branches; one at each of the compass points. Choose branches that are growing at a 60° to 90° angle from the trunk. Cut these scaffold branches back by one-half to a healthy outside-facing bud. Remove all branches that are less than 45 cm above the soil line and cut the tree off just above the topmost selected branch. During the summer, pinch off any shoots that begin to grow toward the centre of the tree.

WINTER AFTER PLANTING

Stone fruit trees are very susceptible to a disease called *Cystospora* canker. If pruned in the winter the tree cannot protect the pruning wounds from infection by this disease. **Prune your trees from bud swell through petal fall in the spring.**

First, remove any broken or diseased branches. Second, cut out any vigorous upright shoots that may have developed on the inside of the main scaffolds. Your tree should be vase-shaped, with no branches in the centre.

Second Winter

During the second winter after planting, you should begin to develop secondary or sub-scaffold branches on the primary scaffolds.

Select two to three limbs per branch that developed during the second summer. They should be spaced 15 to 20 cm apart, 45 to 60 cm from the main trunk, and on opposite sides of the tree. Remove all other limbs. Head the chosen side limbs back by one-half. Head back the primary scaffold by one-half. Large, vertical growing limbs on the primary scaffolds should be completely removed, leaving only the less vigorous wood for fruiting.

Third and Subsequent Years

After careful pruning and training the first two years, heavy pruning should not be necessary. Light, corrective pruning should maintain the open centre. Thin out and shorten inside limbs to prevent shading of the centre. Prune every year to keep the tree within its allotted space and to prevent limb breakage. Remove vigorous upright branches and leave the less vigorous ones. Head back limbs to encourage the development of new fruiting wood.

Pruning Mature Trees

As your peach trees begin to bear heavily you must prune severely in order to stimulate new growth. Peaches are produced on the previous year's growth and the best fruiting wood is 30 to 45 cm long. Short, thin shoots and very long shoots are not as productive.

Limit the height and spread of older mature trees by removing large branches from the upper side of scaffolds, leaving only small fruit-producing shoots. Head back the primary scaffold branches to an outside-growing side branch. Remove or cut back damaged portions of larger branches. Maintain the open centre to prevent shading of the interior portion of the tree.

Allow stone fruits to ripen on the tree. Their sugar content will not increase after they are picked. Harvest fruits while still firm, however, to minimize fruit disease problems.

Figure 15-D: FRUIT BUD DEVELOPMENT IN FRUIT AND NUT TREES



Source: Flint, M.L. 1990. *Pests of the Garden and Small Farm*. Publication 3332. University of California, Division of Agriculture and Natural Resources.

Early spray applications are timed according to fruit bud development. Important stages include:

- Dormant - just before bud swell in spring.
- Green Tip - buds are open at tips exposing green tissue.
- Half Green - one centimetre of green tissue is projecting from bud.
- Tight Cluster - blossom buds are exposed but tightly pressed; stems are short.
- Pink- blossom buds are pink with fully extended stems.
- Bloom - from blossom opening through petal-fall. Do not use any insecticides during the bloom period.
- Petal-Fall - petals have fallen.

SUGGESTED TREE FRUIT CULTIVARS

SUGGESTED APPLE CULTIVARS		
Zone 7a	General Planting	Cortland, Delicious, Empire, Golden Delicious, Jersey Mac, Jonamac, Northern Spy, Paula Red, Spartan
	Limited Planting	Crispin (Mutsu), Elstar, Freedom, Fuji, Gala, Idared, Jonagold, Liberty, McIntosh, Novamac, Vista Bella
Zone 7b	General Planting	Delicious, Empire, Golden Delicious, Jersey Mac, Jonamac, Paula Red, Spartan
	Limited Planting	Crispin (Mutsu), Elstar, Freedom, Fuji, Gala, Golden Russet, Idared, Jonagold, Liberty, Macfree, McIntosh, Trent, Vista Bella
Zone 6a	General Planting	Cortland, Empire, Jersey Mac, McIntosh, Northern Spy, Paula Red
	Limited Planting	Crispin (Mutsu), Delicious, Elstar, Freedom, Gala, Golden Russet, Gloster 69, Idared, Jonagold, Jonamac, Liberty, Novamac, Vista Bella
Zone 6b	General Planting	Cortland, Delicious, Empire, Golden Delicious, Jersey Mac, McIntosh, Northern Spy, Paula Red, Spartan
	Limited Planting	Crispin (Mutsu), Elstar, Freedom, Fuji, Gala, Golden Russet, Jonagold, Idared, Jonamac, Liberty, Vista Bella
Zone 5b	General Planting	Cortland, Jersey Mac, McIntosh, Paula Red, Spartan
	Limited Planting	Golden Russet, Elstar, Empire, Freedom, Gala, Idared, Liberty, Novamac, Vista Bella
Zone 4 and colder	Careful site selection is critical when growing apples in colder regions of Ontario. New introductions as well as heritage or old-fashioned varieties of apple can be grown successfully in Zones 4 and colder. Suitable nursery stock may, however, be difficult to find. The following varieties are recommended for Zone 4 and colder: Atlas, Battleford, Carlos Queen, Dudley Winter (North Star), Duchess (of Oldenburg), Fireside, Goodland, Haralson, Heyer 12, Mantel, Milwaukee, Minnesota 447, Norland, Northwest Greening, Red Astrachan, September Ruby, State Fair, Tolman (Sweet), Wealthy, Wolf River, Yellow Transparent.	
Some of these cultivars may not be widely available.		
SUGGESTED PEAR CULTIVARS		
Zone 5b to 7b	General Planting	Bartlett, Anjou, Bose, Flemish Beauty
	Limited Planting	Giffard, Clapp's Favorite, French Barlett, Harrow Delight
Zone 4 and colder	The selection of pear varieties available to home gardeners in Zones 4 and colder is limited. The following varieties are recommended for these areas: Flemish Beauty, John, Luscious, Patent, Sierra, Summer Crisp, Ure	
Some of these cultivars may not be widely available.		

SUGGESTED PEACH CULTIVARS		
Zone 7a	General Planting	Candor, Garnet Beauty, Redhaven, Vivid, Veeglo, Canadian, Loring, Madison, Cresthaven, Redskin, Babygold 5, Babygold 7.
	Limited Planting	Harrow Diamond, Early Redhaven, Harbelle, Sunhaven, Brighton, Harson, Harken, Harbrite, Harrow Beauty, Vanity, Biscoe, Harcrest.
Zone 6b	Limited Planting	Garnet Beauty, Redhaven, Harbrite, Harrow Beauty, Vanity, Madison, Biscoe, Harcrest, Redskin.
Some of these cultivars may not be widely available.		
SUGGESTED PLUM CULTIVARS		
Japanese Zone 7a, 7b only	General Planting	Early Golden, Shiro
	Limited Planting	Vanier
European Zone 5b to 7b	General Planting	Veeblue, Stanley, Valor, Verity
	Limited Planting	Damson, Voyageur, Victory
Some of these cultivars may not be widely available.		
SUGGESTED SWEET AND SOUR CHERRY CULTIVARS		
Sour Cherry Zone 5b to 7b	General Planting	Montmorency
	Limited Planting	Northstar, English Morello
Sweet Cherry Zone 7a to 7b	General Planting	Viva, Valera, Viscount, Bing, Vogue, Vic, Hedelfingen, Van
	Limited Planting	Vista, Vega, Venus
Some of these cultivars may not be widely available.		
SUGGESTED APRICOT CULTIVARS		
Zone 7a	Limited Planting	Harcot, Veecot, Hargrand, Vivagold, Harlayne, Goldrich, Harval.
Some of these cultivars may not be widely available.		

OMAFRA PUBLICATIONS

AGDEX #	TITLE	ORDER #
206/510	Guide to Fruit Production 2013-2013	360
	Soil Management for Orchards and Vineyards	92-120
210	Ontario Tender Fruit IPM Plant Nutrition	
	Fruit Production Recommendations 2012-2013	360
210/24	Pruning Fruit Trees	90-121
210/24	Repair Grafting	88-029
210/560	Irrigation Scheduling For Fruit Crops	90-069
605	Six Elements of Effective Spraying in Orchards and Vineyards	09-039121
210/613	Beneficial Insects In Tree Orchards In Southern Ontario	96-029
210/624	Scale Insect Pests Of Tree Fruit	90-120
	Nematodes Ontario Apple IPM	
211/20	Producing Quality Empire Apples	89-126
211/21	Crabapple Pollenizers For Apples	92-016
211/30	Disease Resistant Apple Cultivars	91-011
211/36	Apple Rootstocks	90-118
211/50	Evaluating Maturity of McIntosh and Red Delicious Apples	00-025
211/66	CA Storage Recommendations For Apples 2012	12-045
211/620	Mite Pests Ontario Apple IPM	92-051
	Rosy Apple Aphid	
310	Integrated Pest Management for Apples	
	Apple Diseases and Disorders	
	Flayspeck And Sooty Blotch Of Apple	
	Green Apple Aphid	
	Powdery Mildew	
	White Apple Leafhopper and potato leafhopper	
	Wooly Apple Aphid	
211/690	Bitter Pit Control In Apples	92-027
	Comstock Mealybug	
	Peach Silver Mite	
	Obliquebanded Leaf Roller	
212/624	Oriental Fruit Moth	
	Plum Curculio	
	Ontario Grape IPM	
	Peach and Nectarine IPM Guide	
	Peach Leaf-Curl	
	Bacterial Canker	
	Fruit Trees in the Home Garden	
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North American Fruit Explorers Inc. is a network of individuals devoted to discovering, developing, cultivating, evaluating and appreciating superior varieties of fruits and nuts. This is an excellent society for amateur fruit growers. It publishes a quarterly journal, *Pomona*, that is devoted to articles written by members. Membership information can be obtained by writing to: *Pomona*, RR 1, Box 94, Chapin, IL 62628 or going to <http://www.nafex.org/index.php>.

Revised by the Master Gardeners of Ontario Inc. from the Maryland Master Gardener Handbook.

CHAPTER 16: HERBS

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INTRODUCTION

Herbs are associated with those plants which flavor our foods or perfume our homes. Yet over 25% of our modern drugs contain plant extracts as active ingredients, and research continues to isolate valuable medicines from plants used in traditional folk medicine.

Interest in herbs has revived over the past decade, due to recent concern for nutrition and health and a desire to experience natural flavors and fragrances. As a group, herbs are relatively easy to grow.

PLANNING A HERB GARDEN

Culture

Begin your herb garden with the herbs you enjoy using the most. For example, choose basil, oregano and fennel for Italian-style cooking, lavender and lemon verbena for making potpourri, or chamomile, peppermint and catnip if you want to grow your own teas.

Site and Soil

Some of the herbs familiar to Canadians, such as lavender, rosemary, thyme, bay laurel, marjoram, dill and oregano, are native to the Mediterranean region. These herbs grow best in:

- Soils with excellent drainage.
- Bright sun.
- Moderate temperatures.

When growing herbs:

- Plant herbs in average garden soil with organic matter added to improve structure and drainage.
- Choose a site that receives at least six hours of direct sun each day.
- Avoid ground where water stands or runs during rain.
- Compensate for poor drainage with raised beds.
- Adjust the pH to within a range of 6.5 to 7.5.
- Heavy applications of fertilizer, especially those containing large amounts of nitrogen, may decrease the concentration of essential oils in the lush green growth. Apply balanced fertilizers sparingly to leafy, fast-growing herbs.

Most herbs require little special care after being established. Plan your herb garden by grouping herbs according to light, soil and moisture requirements. Most herbs enjoy full sun, but a few tolerate shade.

Herbs can be classified as either annual, biennial, or perennial. Be aware of the growth habits of the plants before you purchase them. In planning your garden, place perennials together to avoid disturbing them when planting annual herbs.

More Basil

Gardeners often pinch basil flowers to maintain plant vigor. This can become a daily chore. Instead, pinch off the entire flower stalk from its point of attachment. You will promote lateral branching and productivity while reducing the number of flowers that need pinching.

If you want to start your herbs indoors, sow them six to eight weeks before setting them out (refer to the guidelines in **Chapter 7**). Some perennial herbs are more difficult to begin from seed; some need chilling treatment or stratification, and others may need up to four weeks for seed germination. Most perennial herbs sold as transplants have been propagated vegetatively.

To plant a transplant, prepare a hole for the root ball at least three times the width of the roots, amending the soil with organic matter. Place the plant into the hole, refill with amended soil, and water well. Water frequently until the plant is established.

Certain herbs—borage, anise, caraway, chervil, coriander, cumin, dill, fennel and parsley—should be sown where they will grow. They do not transplant well.

MAINTENANCE

To conserve moisture and prevent mud from splashing onto plants, mulch your garden after planting.

- Use 2.5 to 5 cm of organic material.
- Avoid wood chips or composted sawdust, which promotes sudden wilts.
- For Mediterranean herbs, mulch with white "concrete" sand or gravel to provide drainage and light reflectance.

Watering needs vary with the herb.

- Irrigate once a week to the equivalent of 2.5 cm rain per week (250 l/10 m²).
- Established perennial herbs are quite drought tolerant.
- Annual herbs welcome extra water.
- Water herb plants only when the surface of the soil feels dry, but before the plants look wilted.
- Rosemary and thyme have little moisture reserve and should not be allowed to wilt.
- Don't over-water; root rots may occur.

PEST AND DISEASE CONTROL

When spaced and grown properly, herbs rarely suffer severe disease or insect damage.

- Natural predators and parasites usually keep mite and aphid populations below damaging levels.
- Cultural, biological and physical control techniques should be used on culinary herbs.
- Insecticidal soap is useful against severe outbreaks of aphids, mites and whiteflies.
- Hand-pick larger pests such as beetles and caterpillars.
- Remove plants that succumb to diseases.

PROPAGATION

Propagate your herbs by layering, dividing or making cuttings, or by collecting the seeds and planting them in the spring (see **Chapter 7**).

To layer an herb, select a branch growing near the plant's base that can be easily bent to the earth. Remove the foliage and branches from it and settle the stem into the soil, anchoring it with a wire shaped like a "U." Keep the stem attached to the parent plant and maintain a good moisture level until it is rooted. Then snip off the new plant and transplant to its new location.

Take a cutting in spring or early summer when the plant is actively growing. Cut an end piece that is not yet woody, about 7.5 to 10 cm long. Strip the leaves and stems off the bottom end, dip it in rooting hormone, and then place it in a moist rooting medium such as vermiculite or a peat and perlite mix. Cover the pot with plastic, preventing the plastic from touching the plant. Mist the soil daily as the cutting takes root. You'll know that it has rooted when new leaves begin to grow.

For information on dividing your herbs, see **Chapter 11**.

HARVEST

Herbs grow healthier and fuller if they are harvested frequently. Your method of harvesting depends on which herb you are harvesting and what you plan to do with it.

- Begin harvesting the herb when the plant has enough foliage to maintain growth. Up to ¾ of the current season's growth can be harvested at one time.
- Harvest early in the morning, after the dew dries but before the sun becomes hot.
- Harvest herbs before flowering; otherwise, leaf production declines.
- Oil concentration and flavor are most intense when leaves are harvested after flower buds appear but before they open.
- Pinch out stems to a leaf node to encourage lateral branching instead of picking off a leaf here and there.
- Herb flowers harvested to dry for craft purposes should be picked just before they are fully open.
- Annual herbs can be harvested until frost. Perennial herbs can be clipped from late spring until flowering or mid-August, whichever comes first.
- Perennial herbs that are allowed to overgrow and become woody tend to winterkill more easily.
- Stop harvesting about one month before the frost date. Later pruning could encourage tender growth that cannot harden off before winter sets in.
- Harvest tarragon or lavender flowers in early summer and then shear the plants to half their height to encourage a second flowering period in the fall if your growing season permits.

PRESERVATION

Herbs acquire their fragrance and flavor from oils which evaporate into the air when the leaves are crushed. Herbs can be used fresh or preserved for later use. Freezing is one of the easiest methods to preserve herbs:

- Rinse the herbs quickly in cold water, shake off excess, and chop coarsely.
- Freeze generous pinches of herbs in filled ice cube trays to prevent freezer burn.
- Or, loosely spread the herbs onto a cookie sheet to freeze, and then transfer the herbs into a large plastic bag and seal.
- When they thaw, herbs will be unsuitable for garnish, but they'll taste and smell nearly as fresh as the day they were picked.

Pickling herbs in vinegar or soaking them in oil is a good way to create a base for dressing and marinade recipes. Simply steep large sprigs of clean fresh herbs in white wine vinegar or good quality oil for several weeks. Refrigerate after the curing period is over.

Drying is the traditional method of herb preservation.

Don't wash the herbs before drying.

- Tie fresh herb stems into small bundles and hang upside down in a dark, warm, airy place.
- Spread herbs out on window screens to dry, out of the sun, turning often.
- Dry them with electric or solar dehydrators or use your oven. The pilot light in a gas oven or the oven viewing light in an electric oven, maintains a low gentle heat.
- Dry herbs in your microwave. Place the leaves on a paper plate or towel and microwave on low. Mix them every 30 seconds, watching to ensure that the herbs don't "cook".
- Dry herbs in a frost free refrigerator. The cold air drying the herbs circulates constantly. Heat is not used, so essential oils are not lost. Place the herbs in a paper lunch bag to dry and be sure that all other food containers are well-sealed to prevent migration of odours.
- Dry herbs to be used for crafts using drying powders such as sand, borax, kitty litter or silica gel.

Store dry herbs in an air-tight bottle; preferably brown glass, in a cool place out of direct sunlight and away from heat. Dried herbs lose flavor and potency after one year in storage.

USING HERBS IN COOKING AND CRAFTS

Substitute home-dried herbs in equal amounts for dry store-bought herbs in your favorite recipes. Dried herbs have a more concentrated flavor than fresh or frozen herbs. When substituting fresh or frozen herbs for dry herbs, double or triple the amount required in the recipe. 5 ml dried herb equals 10 ml fresh or frozen.

Dried flowers and leaves of herbs are useful craft items, too. They give color, texture and fragrance to arrangements, wreaths, and potpourri. Some people steep herbs in hot water to add to their baths. The local library has books that can give ideas and specific recipes.

HERBS AS HOUSEPLANTS

Most herbs that you can grow outdoors in containers can also be grown indoors as houseplants. Treat them as any houseplant. Keep them in a southerly window where they will get sun at least five hours a day or place them under fluorescent lights, set to shine 14-16 hours a day. Keep your plants away from drafts and temperature extremes.

Water regularly and thoroughly when the soil starts to dry out, with room temperature water. Bay, marjoram, oregano, sage and thyme need to dry out between watering. Mist indoor herb plants daily. Be careful not to over-water. Some tender herbs (rosemary, bay, lemon verbena, marjoram, scented geraniums, and camphor) do not survive our winters, and should be overwintered indoors.

HERBS FOR SPECIAL SITUATIONS

Moisture Loving Herbs	Herbs For Dry Situations	Bee and Butterfly Herbs	
Agrimony Angelica Bergamot Comfrey Elcampane Iris (Yellow Flag) Marsh Mallow Meadowsweet Mint Soapwort Sweet Cicely Sorrel	Chamomile Curry Plant Fennel Houseleek Hyssop Lavender Oregano Rosemary Sage Santolina Thyme Winter Savory	Agrimony Anise Anise Hyssop Basil Bergamot Borage Broom Catmint Chamomile Chives Clover Coltsfoot Comfrey Dandelion Elder Evening Primrose	Fennel Hyssop Lemon Balm Lavender Marjoram Marsh Mallow Mint Meadowsweet Mettle Parsley Pinks Rosemary Sage Thyme Yarrow
Shade Tolerant Herbs	Scented Flowering Herbs	Herbs for Houseplant Culture	
Ajuga Lady's Mantle Mint Pennyroyal Primrose Pulmonaria Sweet Violet Woodruff	Bergamot Catnip Chamomile Clove Carnations Curry Plant Evening Primrose Hyssop Pinks Lavender Lemon Balm Meadowsweet Marjoram	Basil Bay Chives Dill Garlic Chives Greek Oregano Ginger Marjoram Mints	Myrtle Parsley Pineapple Sage Rosemary Scented Geraniums Tarragon Thyme Winter Savory

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SELECTING INDOOR PLANTS

When purchasing a new house plant, remember that your first task is to select plants that can best withstand the particular conditions inside your home. It's easier to purchase a plant requiring the same environmental conditions your residence has to offer than to alter the environment of your home or office to suit the plants. Pay particular attention to the plants' light requirement.

To be assured that the plant you buy is healthy, check the undersides of the foliage and the axils of leaves for signs of insects or disease.

Select plants which:

- Appear to be free of insects and diseases.
- Show healthy foliage; avoid those having yellow or chlorotic leaves, brown leaf margins, wilted foliage, spots or blotches, or spindly growth.
- Have new flowers and leaf buds along with young growth.

MOVING HOUSEPLANTS

Move and transport your houseplants with care, especially in extreme temperatures, because they're easily shocked by changes in light intensity and duration, and changes in air temperature.

Tips:

- Hot summer and cold winter temperatures can damage plants.
- In the summer avoid shutting a plant in the car, because the temperature will rise rapidly.
- Shade the plant from direct sun while it is in the car, as foliage can be damaged by the sun shining through the window.
- During winter months, wrap plants thoroughly with paper bags or newspapers before the short run to the car.
- Warm them with the heater in the front of the car.
- Don't transport a houseplant in the car's trunk.

A plant may suffer from shock when moved from one location to another. To reduce shock, acclimate it by gradually changing the light levels it is exposed to.

Tips:

- When placing plants outdoors in summer, gradually increase light intensities.
- Reverse the process when plants are brought indoors in fall.
- Place a newly purchased greenhouse plant first in a high-light area of your home. Later move it to a spot that meets its light requirements.

REQUIREMENTS FOR HEALTHY HOUSEPLANTS

Light, water, temperature, humidity, ventilation, fertilization, and soil are the chief factors affecting plant growth, and excesses or deficiencies of any one of these factors will prevent a plant from growing properly indoors.

Light

Light is probably the most critical factor for house plant growth. The plant's growth, the length of active life, and energy derived from photosynthesis depend on the amount of light it receives. Houseplants can be classified according to their light needs - high, medium, or low light requirements.

Intensity, quality and duration are three important aspects of light that affect plant growth. When considering the growth of indoor plants, each of these factors can limit optimal growth.

Intensity:

- Light is measured in lux indicating the intensity of brightness that is perceived. 1 lux = 0.1 foot candles.
- A more common and useful assessment of light is verbal description i.e. low, medium, good or direct light.
- Depends upon the distance of the light source from the plant; the intensity decreases rapidly with increasing distance.
- Influences the manufacture of plant food, stem length, leaf colour, and flowering.
- Is affected by the direction the windows in your home face.
 - "Lowest light" spaces are north-facing windows or rooms that are artificially-lit.
 - "Average light" is available in east or west-facing windows.
 - "Bright light" is found when a south-facing window receives at least six hours of light from a southern exposure. The brightest light is available in a sun room or bay window.

- Other factors that can influence the intensity of light are: the presence of curtains; trees outside the window; weather; seasons of the year; shade from other buildings; the cleanliness of the window, and dust accumulation on the leaves.
- Reflective, light-coloured surfaces inside the room increase the intensity of light.

The Effect of Deficient Light

A geranium appears spindly or "leggy" with light green leaves and diminished flowering when grown in low light. The same plant grown in a bright light would be more compact, better branched and have larger, dark green leaves. Many houseplants fail after a healthy start because of inadequate light.

Duration:

- Is the length of time the plant receives light. Most foliage and flowering houseplants are indifferent to light duration.
- Is of some importance, but generally only to indoor plants that are photosensitive e.g., Poinsettia, Kalanchoe or Christmas cactus. Buds and flowers develop only when the day length is short - 11 hours of daylight or less.
- Plants receiving low light intensity respond to increased duration of light, as long as the plant is not sensitive to day length for flowering.
- Plants require some period of darkness to develop properly, so illuminate them for no more than 16 hours each day.

Quality:

- For proper plant development, red, far-red and blue wavelengths are most important.
- Quality of light can be improved if artificial light can be supplied.
- Cool-white fluorescent tubes produce blue light that keeps foliage plants from becoming leggy.
- Warm-white fluorescent tubes produce some red wavelengths and help promote flowering. (Blooming plants require additional far-red light sources).
- Plant growth lights are available and they combine the benefits of both above types and often provide additional far-red wavelengths.
- Incandescent bulbs produce predominantly red and far-red light but when used in combination with cool and warm fluorescent tubes provide near full-spectrum light conditions.

- High-pressure sodium, metal halide and combination type lighting is also available but at considerably greater cost. Some of these lighting types can also provide near full spectrum light conditions.

Remember that excessive light is just as harmful as too little. When a plant gets too much direct light, the leaves become pale, turn brown, and die. Protect houseplants from excessive direct sunlight during the summer months.

Water and Soluble Salts

A common question home gardeners ask is, "How often should I water my plants?" The plant itself will tell you. When it's too dry, a plant wilts and turns gray-green; when too wet, it drops leaves or turns yellow. Avoid both of these extremes.

Plants should not be watered on a schedule, but watered when they need it. Factors influencing plant watering include differences in potting media, humidity, temperature and pot type.

To test a plant for watering, you must feel the soil at the root zone. Because a plant's roots are usually in the bottom two-thirds of the pot, it doesn't need water until the bottom two-thirds dries out slightly. Another quick test is to lift the plant to check its weight change, caused by changes in soil moisture.

When you test for watering, pay attention to the soil. If your finger can't penetrate 5 cm deep, you may need a more porous soil mix or the plant may have become rootbound.

Water should be at room temperature. Rainwater, distilled water and most tap water is suitable for plants. Avoid water that is either very hard or very soft and never use chemically softened water.

Some plants require different water practices to assure good health.

- Succulents/cacti must dry out well between watering. Never allow these plants to sit in water.
- African Violets water from the bottom of the pot to prevent leaves from discolouring and the crown from rotting.
- Bromeliads keep water in the central whorl of leaves and if planted in soil, moisten the soil. Avoid water that contains calcium which promotes rot in the central core.
- Terrariums - use a mister or water down the side of the glass to prevent soil from splashing onto leaves. Terrariums do not need frequent watering.

Overwatering and under-watering account for a large percentage of tropical plant losses!

Soluble Salts Buildup

A problem of great importance to houseplants is the buildup of soluble salts in the soil, which can easily be avoided with proper watering techniques. Symptoms of this buildup include reduced growth, brown leaf tips, dropping of lower leaves, dead root tips, and wilting. In addition, a ring of salt deposits may crust around the pot at the soil line, around the drainage hole, or on the exteriors of clay pots.

Soluble Salts:

- Are minerals (fertilizers) dissolved in water.
- When water evaporates from the soil, the minerals stay behind and become concentrated, inhibiting the plant's uptake of water.
- If salts build up to an extremely high level, water leaves the root tips and roots become dehydrated.
- The weakened plant is more susceptible to attack from insects and diseases.
- One of the most common problems associated with high salt levels is root rot.
- All water contains dissolved minerals, but softened water contains more than others, and should be avoided when watering houseplants.

Prevent Soluble Salts Injury:

- Water the pot from the top until water runs out the bottom, washing out all the excess salts (fertilizer residue).
- Don't let the pot sit in the water that runs out.
- After watering, wait until the soil dries at the 5 cm depth before watering again.

To further prevent mineral buildup, flush with copious amounts of clear water to leach houseplants every 4 to 6 months:

1. Pour a lot of water at least twice the volume of the pot on the potting soil and let it drain completely.
2. Keep the water running through the potting soil to wash the salts out.
3. If a layer of salts has formed a crust on top of the potting soil, manually remove the salt crust before you begin leaching.
4. Leach a plant before you fertilize so that you don't wash away all the fertilizer you just added.
5. If the soluble salts level is extremely high or the pot has poor drainage, repot the plant.

The level of salts injurious to the plant varies with the type of plant and how it's grown. A plant grown in a greenhouse with excellent light and drainage will tolerate salt levels 10 times higher than one grown in the home. Some nurseries and plant shops leach plants before sale to remove excess salts. Leaching a newly purchased plant the first time you water it is a good practice.

Watering Plants without Mineral Buildup

Prevent salt build-up by choosing mineral-free water. The next time rain is expected, set some buckets outside and let them fill with rainwater, which has no added chemicals. If you use a dehumidifier, use the water in the drain pan, which is distilled water; on your plants. Otherwise, draw water for your plants the day before you plan to water them. A day's evaporation should clear the water of some minerals.

Temperature

Excessively low or high temperatures may stop growth, cause a spindly appearance, foliage damage, leaf drop or plant failure. However, most houseplants tolerate normal temperature fluctuations.

- In general, foliage houseplants grow best between 20°C and 27°C during the day and from 15° to 20°C at night.
- Most flowering houseplants prefer the same daytime range but grow best at nighttime temperatures of 13° to 16°C.
- A good rule of thumb is to keep the night temperature 5 to 10°C lower than the day temperature to induce physiological recovery from moisture loss, intensify flower colour, and prolong flower life.
- Indoor plants, especially flowering varieties, are sensitive to drafts or heat from registers. Protect them from sudden, brief changes in temperature. Do not locate your houseplants near heat or air conditioning sources.
- Temperatures on windowsills in the winter can drop to dangerously cold levels. Curtains or blinds can cut off the heat from the room and plants on the sill could freeze.

Humidity

Relative humidity is a measurement of the amount of moisture in the air expressed as the percentage of the total amount possible at a given temperature. When the atmosphere is warmer, it can hold more water vapour than it can when it is cooler. Most indoor environments lack sufficient humidity for healthy houseplants, particularly in the winter. With the exception of the cacti and succulents, all houseplants benefit from treatments to raise the humidity in their vicinity.

Mist plants frequently. Early in the day is best to allow the foliage to dry and reduce the risk of disease. An alternative is to place pots on a tray filled with pebbles and water to increase humidity in the area around the plants. If you group plants together in a room, they will collectively raise the humidity in their area. An automatic humidifier can provide extra humidity for plants and people in the home.

Some symptoms of low humidity include leaf damage—brown tips, leaf drop and generally poor response by foliage plants to appropriate care.

Nutrients

The goal in growing indoor plants is maintenance at a level where growth compensates for leaf loss. The goal should not be quick growth of a large plant. Large amounts of fertilizer are therefore unnecessary for most indoor plants.

For proper growth, plants need three major nutrients.

- Nitrogen - promotes lush growth and healthy green foliage.
- Phosphorous - promotes strong root development and increases the quantity of flowers and fruits.
- Potassium - increases resistance to disease and aids in the process of photosynthesis.
- Micronutrients are deficient in many houseplants, so replace them once a year. Fertilizing with a commercial fertilizer containing micronutrients or adding a small amount of well-composted, screened leaf mold or other compost will fill this need.
- Commercial fertilizers used for indoor plants are sold in granular, crystalline, liquid, stick and tablet forms.
- Most common fertilizers are water-soluble.
- Because magnesium leaches from the soil at each watering, replace it with a solution of 5 ml Epsom salts per 4 litres of water. Water two times each year or use the solution as a leaf spray.
- During the winter months, houseplants don't need fertilizer because reduced light and temperature result in reduced growth. Fertilizing at this time could harm some plants.
- Monthly applications of a dilute liquid fertilizer in the summer months will keep most plants healthy.
- Excessive fertilizer results in the buildup of salts and excessive, leggy growth.

GIVING PLANTS A SUMMER VACATION

Grown under the marginal conditions of most homes, houseplants become tired-looking. You can renew your plants by moving them outdoors during the summer months. Light conditions in the shadiest outdoor spot are better than light conditions in the sunniest spot inside. And indoor plants thrive outdoors in the high humidity of Ontario's summer.

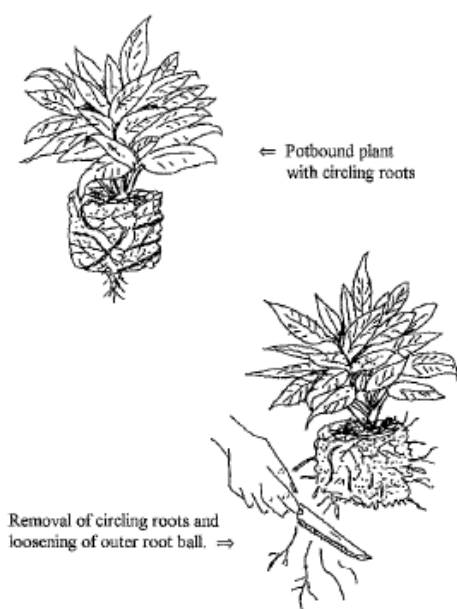
- Put your plants out only after night temperatures remain above 15°C. In most of Ontario, this is mid-June.
- Avoid sudden changes in light intensity. When placed in bright sunlight after a winter in a dimly-lit window, your plant will become bleached by photo-degradation of chlorophyll, permanently marring existing leaves and perhaps killing the plant. First place them in a shady position outdoors and gradually give them more light.
- Fertilize and water your houseplants outdoors more often than when they are indoors because of increased photosynthesis and growth.
- Reverse the process to return the plants to their home inside. Gradually move them to shady positions; cut back fertilization and watering to harden them for winter conditions.
- Check plants thoroughly for insects and treat infestations as necessary. When you finally bring them inside, quarantine them for a few weeks to be sure that overlooked insect infestations don't spread to other houseplants.

REPOTTING

Healthy, growing houseplants will need repotting from time to time, although plants can grow in a surprisingly small soil volume, if given adequate nutrients and water. Potting a plant in an excessively large volume of soil can lead to waterlogging of the roots, because the plant can't use the available water. If it's time to repot, you will see the roots of a foliage plant growing out of the drain hole.

Prepare your supplies before repotting. Choose a pot that has drainage holes in the bottom. The diameter of the new pot should be 5 cm larger than the current pot. If you're recycling a used pot, scrub soluble salts off with water and a brush; then wash disease-causing organisms from the pot in a solution of 1 part liquid bleach to 9 parts water. Allow the pot to dry thoroughly before placing the plant into it. Purchase a sterile soil media and moisten the necessary amount ahead of time. The day before you plan to repot a plant, be sure to water it well to reduce possible shock to the root system.

Figure 17-A: PREPARATION OF A HOUSEPLANT ROOT BALL PRIOR TO REPOTTING



Steps for Repotting:

1. Place a shard over the drainage hole to prevent leakage of soil. Don't fill the bottom of your pot with gravel. Over the shard, place enough new soil in the bottom of the pot to raise the root ball to an inch or two below the new pot's rim, allowing enough head room for watering.
2. Remove the plant from its old pot by knocking the container against a hard surface. Tilt the pot upside-down. Gently pull the plant from the pot, with your hand over the soil. If plant is pot bound, with roots encircling the root ball, cut vertically down the root ball about 1.3 cm into the healthy roots at 5 to 10 cm intervals. Remove any dead brown roots.
3. Place the plant into the pot, filling soil around the root ball, gently tamping it in with your fingers to eliminate air pockets.
4. Water thoroughly, but avoid further watering until the soil dries at the top.

Potting Medium

The potting soil or medium in which a plant grows should be porous for root aeration and drainage but also be able to retain water and nutrients. Most commercially prepared mixes are termed artificial, meaning they contain no soil.

- Products described as "potting soil" may not always be suitable for proper plant care. Such soils can be amended with products such as perlite, vermiculite or coarse sand to provide good aeration and proper drainage.
- Soil-less mixes are commercial mixtures that may contain the following items in varying amounts; peat moss, vermiculite, perlite, finely ground agricultural limestone, superphosphate, chelated iron and fertilizers.
- Artificial mediums such as soil-less mixes, are usually low in trace or minor elements and frequently do not have added fertilizers. It is therefore important to provide all required nutrients when watering.
- Potting soil or garden loam has a number of disadvantages as compared to artificial mediums. Soil is quite heavy; it may contain insects or disease and so must be sterilized before use. It tends to compact, thus reducing proper aeration.
- Any soil that contains garden loam must be pasteurized before use indoors. Spread soil on a tray and moisten slightly. Bake at 180°F/82°C for 30 minutes. Cool before using. Commercial potting soil may or may not be already sterilized.

The Right Mix for Your Houseplant

The mixture you buy should have the most efficient combination of elements for the type of plant you want to grow. Houseplant soils can be divided into three groups:

Foliage plants:

- Soil should be moderately rich, have a loamy base and hold moisture and fertility adequately.
- Mix about 5 ml of superphosphate per litre of mix to encourage good root growth.

Flowering houseplants:

- Soil should contain about 50% humus-rich materials, but not to the point that it is soggy after watering.
- Also add 5 ml of superphosphate per litre of soil mixture.
- This soil is generally used for African violets, gloxinias, begonias, calla lilies, and other tropicals.

Cacti and succulents:

- Mix does not need as much humus material.
- A high proportion of sand should be present in purchased mix.
- Additional fertilizers should not be required at planting time.

Containers

Handsome containers improve the appearance of plants, especially large floor plants. There are many pots on the market; each type has good and bad qualities.

Terra-cotta clay pots:

- Are porous and easily absorb and lose moisture, providing excellent aeration for plant roots.
- Roots grow near the pot's walls, because moisture and nutrients accumulate in the clay pores.
- Dry out rapidly.
- Are easily broken.

Ceramic pots:

- Are usually glazed and frequently lack drainage holes (not a desirable feature).
- Enjoy the ornamental ones for their outstanding aesthetic qualities, but remember that they're not necessarily good homes for plants.
- A plastic pot can be placed inside to allow for drainage.

Plastic or fibreglass containers:

- Are lightweight and easy to handle.
- Are relatively inexpensive.
- Are easy to clean and sterilize for reuse.
- Plants require less frequent watering and accumulate few soluble salts.

CULTURAL REQUIREMENTS OF SELECTED HOUSEPLANTS

Table 17-1: CULTURAL REQUIREMENTS OF SELECTED HOUSEPLANTS

Plant (Common Name)	Direct Light	Bright Light	Average Light	Low Light	Moist Condition	Dry Condition
Aloe vera		X	X			X
Aluminum plant		X	X		X	
Areca palm		X	X	X	X	
Asparagus-Meyeri	X	X				X
Asparagus-Sprengeri	X	X				X
Boston fern		X	X		X	
Burro's tail	X	X				X
Chinese evergreen		X	X	X		X
Coleus	X	X			X	
Corn plant		X	X			X
Croton		X	X			X
Devil's ivy (pothos)	X	X	X			X
Dumb cane	X	X	X			X
False aralia		X	X		X	
Fiddleleaf fig		X	X			X
German ivy (green)		X	X			
German ivy (variegated)		X	X			
Gold dust dracaena		X	X		X	
Grape ivy		X	X		X	
Heartleaf philodendron		X	X	X	X	
Jade plant	X	X				X
Japanese aralia		X	X		X	
Kangaroo ivy		X	X			X
Maidenhair fern			X	X	X	
Moses-in-the-cradle		X	X			
Norfolk island pine		X			X	
Parlor palm		X	X	X	X	
Peperomia		X	X			X
Piggyback		X	X		X	
Ponytail palm	X	X				X
Rubber plant	X	X			X	
Schefflera	X	X	X			X
Snake plant	X	X	X	X		X
Spider plant		X	X		X	
Strawberry begonia		X			X	
Swedish ivy	X	X	X			X
Tahitian bridal veil	X	X	X			X
Velvet plant	X	X				
Wandering Jew	X	X	X			X
Weeping fig		X				X

Table 17-2: COMMON HOUSEPLANTS THAT ARE TOXIC OR POISONOUS

<i>Those that are toxic will cause injury only if ingested in large quantities, and those that are poisonous can cause extreme injury, even when taken in small quantities. Poisonous houseplants are marked with an asterisk.</i>		
*Amaryllis Aralia Arrowhead Vine Buddhist pine Candelabra cactus Chinese evergreens *Common oleander *Coralberry Creeping rubber plant Crown of thorns Dumb cane Dwarf Schefflera English ivy	False Aralia Fiddleleaf fig Flamingo lily *Garden Croton Indian laurel Ivy tree Japanese Pittosporum Japanese spindle tree Kaffir lily Moses in the cradle Painted drop-tongue Paper flower Pothos	Pencil cactus Philodendrons Redbird cactus Rosary vine *Sago Palm Schefflera Showy rubber tree Starfish cactus Swiss cheese plant Weeping fig White Anthurium Zulu fig tree

INSECTS THAT AFFECT INTERIOR PLANTS

Aphids or plant lice

- They are soft bodied, pear shaped and range in colour from light gray to nearly black and from yellowish green to red.
- The damage is done by sucking sap from all parts of the plant causing plant to wilt or leaves to curl.
- They excrete sticky honeydew which attracts ants and black sooty fungus.
- While an aphid is feeding, it can pass on many viruses to the host plant.

Mealybugs

- They have white, soft bodies and have a tail-like filament at the end of the body.
- The damage is done by sucking the sap which causes the plant to dry and turn yellow.
- Mealybugs are protected by a waxy covering that resembles cotton balls.
- They also excrete sticky honeydew.

Two spotted Spider Mite

- Extremely small and barely visible to the naked eye.
- They have four pairs of legs and two dark spots on the back.
- The damage is done by sucking the sap from the underside of the leaves, causing the foliage to become speckled and dry.

- Mites spin fine webs that form a canopy which aids in movement from leaf to leaf.
- Thrive in hot dry conditions.

Scales

- Insects are small, flat, oval or circular spots on stems and foliage.
- They are protected by a hard waxy, often brown covering.
- Scale insects do not fly, most move very slowly.

Whiteflies

- Adult whiteflies resemble tiny white moths.
- Both adult and nymphs (young) feed on the underside of the leaves.
- They excrete sticky honeydew which attracts ants and fungus.

Control

- New plants should be isolated for several weeks to avoid risk of infesting other plants.
- Observe plants regularly and treat promptly if outbreak occurs.
- Contact local garden centre for sprays appropriate for home use.

A FINAL NOTE

Training and grooming distinguish the beginner from the more experienced indoor plant grower. Simple, quick activities keep your plants attractive and compact.

- Frequent pinching and pruning of tropical plants encourages new lateral growth and creates a bushy and compact plant. For the most part, this should be done when light levels are high. Growth in lower light conditions will produce spindly, leggy shoots.
- Pruning unwanted or damaged branches improves the appearance of the plant.
- Pruning an indoor plant can include removal of an entire branch or section of a plant for the sake of appearance.
- Disbudding means removing certain flower buds to obtain larger blooms from a few choice buds. It also eliminates flowering in a young plant or recently rooted cutting that should not bear the physical strain of flowering early.
- Provide trellises for climbing plants and vines, e.g. ivies, pothos or hoyas.

Finally, it is important to keep your plants clean and neat, coincidentally reducing insect and disease problems.

- Remove all spent flowers, dying leaves, and dead branches.
- Keep leaves dust free by washing with warm water and mild soap. Do not use detergent. Rinse afterwards. Cover pot to prevent soap from entering the soil.

If tips of leaves become brown and dry, trim them off neatly with sharp scissors.

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CHAPTER 18: INTEGRATED PEST MANAGEMENT (IPM)

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INTEGRATED PEST MANAGEMENT (IPM)

(A Common Sense Approach to Managing Problems in Your Landscape)

INTRODUCTION

Integrated pest management (IPM) represents a holistic approach to pest control. IPM is part of a total urban community ecosystem approach to gardening which promotes good management and stewardship strategies. It involves an understanding and careful examination of all factors (and their interrelationships) influencing plant growth. These include soil, water, air, nutrients, insects, diseases, landscape design, weeds, animals, beneficial organisms, weather and cultural practices. The goal is to manage problems at acceptable levels rather than attempting to eliminate them. In many cases, pest problems can be prevented by selecting the appropriate plant species for your particular site and providing the best possible growing conditions. Regular observation or monitoring of the plants in your landscape is critical in helping you to decide if a problem requires corrective action. Many factors impact plant growth. Too often, gardeners assume that plant problems are caused by pests and diseases. For example, insect damage may occur after a plant has been weakened by other factors including site problems, cultural practices or environmental and nutritional problems.

IPM is not a strictly organic approach to pest control. When necessary, chemicals are employed as a last resort in situations where it is legal to use them. Broad spectrum **residual insecticides** are no longer allowed for cosmetic purposes in the home garden. Residual pesticides remained effective in the environment for days, weeks, or months and had possible impact on beneficial organisms as well as pests. Since April, 2009, except where allowed (such as against noxious weeds), pesticides cannot be used in Ontario home gardens. Even before that date, IPM called for the least toxic solutions (physical, mechanical or biological controls) to be used first. The IPM approach compels you to consider your landscape as part of the larger community ecosystem to manage responsibly. The impact of your gardening and pest management decisions often extends far beyond your property lines.

GET TO KNOW YOUR ECOSYSTEM, LANDSCAPE AND GARDEN

Integrated pest management requires a good knowledge of the ecosystem including climate and local weather. Become familiar with the plant hardiness zone for your area, the temperature ranges for the various seasons, last average spring frost dates and first average fall frost dates, as well as their significance. Knowledge of such local weather statistics as average monthly precipitation, extent of snow cover, incidence of freezing rain, hours of sunshine and prevalent wind direction and speed are all useful in developing an integrated approach to garden management.

An extensive knowledge of your local landscape and garden is also essential if an integrated pest management approach is to be developed. Survey your landscape and note factors that influence plant hardiness and health, e.g., large bodies of water, slopes, and tall buildings. Note the distribution of sun/shade, exposed and sheltered areas. Identify special microclimates as well as frost pockets and frost barriers. Become familiar with soil conditions and drainage patterns.

Finally, before you can recognize or prevent problems, you need to become familiar with your plants, i.e., their growth habit and necessary conditions for good growth.

- Make a plan of your existing landscape and identify and note the location of your plants and trees.
- Note which look healthy and which seem to have problems.
- Know what your plants should look like. Are they growing normally?
- Be willing to remove plants with chronic problems (e.g., azaleas grown in full sun often have severe lacebug problems).
- Replace problem plant materials with plants adapted to your area and site conditions. Check gardening references and reputable local nurseries for ideas.

A HEALTHY GARDEN PREVENTS PROBLEMS

- **Soil building and fertility**
 - Incorporate organic matter in flower and vegetable beds regularly. Organic matter adds nutrients and encourages disease resistance.
 - Take a soil test every three years and adjust the pH accordingly.
 - Fertilize only as needed to maintain vigour.
 - Avoid over-fertilizing plants, as it can lead to pest problems.
- **Mulches**
 - Mulches maintain even soil moisture and prevent weed growth and soil erosion.
 - Protect plant roots and crowns from winter damage.
- **Choose the right plant for the right place**
 - Select well-adapted varieties for the site conditions.
 - Select disease or insect resistant varieties.
 - Purchase healthy, certified, disease-free seeds, transplants and nursery stock.
 - Plant at the right time.
- **Proper planting techniques**
 - Select suitable sites for the selected plants.
 - Prepare soil correctly.
 - Water new plants deeply until well established.
- **Irrigation techniques**
 - Avoid overhead watering and splashing soil onto plants.
 - Water trees and shrubs slowly and deeply.
 - Remember that the root zone can extend out 2 to 3 times the height of the tree beyond the dripline.
 - Check the depth of soil moisture after irrigation by digging a small hole or inserting a stick.
 - Use drip irrigation and soaker hoses where practical.
- **Remove or mow weeds**
 - Weeds rob plants of moisture and nutrients and are alternate hosts for pests and diseases.

- **Other cultural practices**
 - Prune to increase air circulation.
 - Avoid accidental root pruning through hoeing and tilling.
 - Don't work with plants when foliage is wet.
 - Use floating row covers to prevent pest problems.
- **Garden sanitation**
 - Remove and dispose of diseased or infested plant parts and any dead plants.
 - Rake up and dispose of diseased leaves and fruits.
 - Clean up and compost garden debris in the fall.
 - Clean and disinfect tools and equipment when working with diseased or infected plants.
- **Healthy transplants**
 - Use soil-less media to plant seeds.
 - Use clean, sanitized seedling flats and plant containers.
 - Do not over-water.
 - Acclimatize transplants that are grown indoors by slowly introducing them to outdoor conditions.
 - Protect new transplants and seedlings from cut worms and slugs with paper collars.

MONITORING: "CHECKING OUT YOUR LANDSCAPE"

Gardeners should observe both wild and cultivated plants carefully to effectively monitor plant health and potential problems. Weekly inspections of your garden will catch most problems before they become serious or get out of hand. Examine all plants carefully and thoroughly. Use a hand lens or magnifying glass if necessary. Where pests or disease symptoms are observed, identify the culprit and learn the life cycle, habits, characteristics, damage potential and best time to take action.

Practice applying the principles of the disease triangle. Determine what levels of infestation and damage you can tolerate with respect to safety, yield, economics or aesthetics. Keep up-to-date records of your observations and actions. Review these records periodically to determine if control strategies are appropriate.

BENEFICIAL INSECTS, MITES AND NEMATODES AND OTHER CREATURES

It is important that all creatures in your landscape not be viewed as pests. Hundreds of different insects, spiders and other beneficial organisms inhabit even the smallest yards. Together with your plants they comprise your unique backyard ecosystem. Most of these are either beneficial or innocuous. Some may be occasional feeders on favourite garden plants, but will not become damaging pests.

Concern for the environment, resistance to insecticides, and problems with pesticide safety sparked the need to find alternative means of controlling pests, while conserving beneficial organisms. It is important to recognize and distinguish pests and beneficial species.

Predators attack and consume pests directly. They are usually larger and more active than the prey they eat. For example, insect predators tend to move rapidly and have large eyes and forward pointing mouthparts.

Parasites use pests as food sources for their young. For example insect parasites lay their eggs in, on or near the pest insect. The offspring then grow in or on the host, eventually killing it.

Predatory and parasitic insects are often collectively referred to as beneficial insects or "beneficials". It is important to remember that many other beneficial organisms such as fungi, bacteria, earthworms and nematodes also exist in your yard.

SOME COMMON INSECT PREDATORS

Ladybird beetles (ladybugs, lady beetles): predators of aphids, mealybugs and other small insects. Adults vary in size from 0.3-1 cm long. The colour ranges from all black to black with red to yellow spots, or red to orange with black spots, or grayish with black spots; there are many species. Immatures are 0.3-1 cm long, alligator-like, segmented, and usually have short spines (bristles) on their bodies. The colour is usually gray to black with yellow to orange markings. Eggs are usually yellow, oval-shaped and laid upright in clusters on leaf undersides. It is not necessary to buy and release ladybird beetles. They will come into your landscape on their own now that residual insecticides are not sprayed.

Some commercially available ladybird beetles are not native species and should not be purchased.

Lacewings: predators of aphids and other small insects. Adults are 1-1.5 cm long, green or brown, with small heads and large eyes. The wings are longer than the body, transparent and have a fine network of veins. Larvae are spindle-shaped, yellow-brown and mottled. They have spines along their sides and long, curved mouthparts. Eggs are laid on the ends of long, fine stalks and are often attached to leaves or twigs. Lacewings are available commercially.

Syrphid or flower flies: aphid predators, adults 0.3-1.5 cm long. They resemble bees with yellow-black or white-black striped abdomens. Adults are often seen on flowers feeding on nectar. Larvae are grayish or greenish maggots and feed on aphids. Adult females lay eggs around aphid colonies and may be seen flying around aphid-infested plants. They are not available commercially.

Praying mantids: large, general predators. They will eat anything they happen upon, including each other. The adults are 6-10 cm long, green or brown with long bodies, large eyes and papery wings. Front legs are enlarged and adapted for grabbing prey. Immatures resemble adults but are smaller and wingless. Female mantids lay eggs in frothy masses glued to stems and twigs. Eggs are straw-coloured and resemble foam. Buying and releasing mantids is not recommended.

Ground beetles: large, general predators. Adults are 2-3 cm, fast moving, iridescent bluish-black in colour. They hide under rocks and other objects during the day. Larvae are elongated and dark brown-black with large heads. They are not available commercially.

Predatory mites: widely used as biological control organisms. They are the same size or larger than spider mites and move rapidly. The colour may be white, tan, orange or reddish. Predatory mites are commercially available and the supplier can suggest the species and quantity to buy.

Other naturally occurring predators, including assassin bugs, predatory bugs, aphid midges, dragon and damselflies, lightning bugs/ fireflies, predatory wasps and spiders are busy during the growing season controlling pests in your landscape.

SOME COMMON INSECT PARASITES

Aphid parasites: adults are about the size of aphids. They are tiny black or brown wasps. The adult female inserts her eggs into aphids. The larvae hatch out, feed, and eventually kill the aphid. The parasitized aphid remains attached to the plant, and eventually turns into a "mummy". It is swollen, brown and papery in appearance. Close examination may reveal a small exit hole chewed in the mummy's back from which the adult wasp emerged. Several species are available commercially, but are usually not needed in the home garden. Naturally occurring parasites will find an aphid infestation on their own.

Parasitic wasps: a large group of small to large wasps that parasitize a variety of caterpillars, beetle larvae, flies, aphids and other insects. They are slender and black or yellowish to brown. They have a pinched waist and clear wings. Some females may have very long ovipositors or "stingers", but they cannot sting people. The female inserts her eggs into host insects. When the larvae complete their development, they spin cocoons on or near a dead or dying host, and then pupate. Parasitized hornworms are often seen with many white, silken cocoons attached to their bodies. Egg and larval parasites are available commercially.

Parasitic nematodes: are tiny, parasitic worms that are not harmful to humans, animals or plants. These occur naturally, mainly in soils, and can be purchased to control clear-wing borers and cutworms. There are two types available - *Steinernema* (Sc) and *Heterorhabditis* (Hb).

Sc nematodes work on insects that feed near the soil surface or inside plants while Hb nematodes can move through the soil profile to attack certain beetle grubs. Follow package directions for appropriate storage and application techniques.

ATTRACTING AND CONSERVING BENEFICIAL ORGANISMS INTO YOUR LANDSCAPE

To conserve and protect beneficial organisms in your garden or landscape, provide water, food, cover, and nesting places and a diversity of flowering plants. Instead of pesticide use, switch to careful timing of biorational, non-residual pesticides such as insecticidal soaps, horticultural oils, and B.t. products. Soaps, oils and botanical pesticides have short term effects on populations of beneficials compared to typical synthetic pesticides. In addition, try to maintain a diverse habitat. Provide pollen and nectar sources for adult beneficials by growing a wide variety of annual and perennial flowers so that some plants are blooming at all times during the growing season. Check the box below for some good choices. Provide water by leaving shallow, open containers or basins of fresh water on the ground in shade for birds, toads, frogs, turtles, snakes, spiders and insects. A diverse habitat of trees, shrubs and other plants also provides shelter, hiding places and overwintering sites. Straw mulch is especially attractive to spiders.

NON-CHEMICAL CONTROL STRATEGIES FOR PESTS AND DISEASES

There are a variety of non-chemical strategies that are available within an integrated pest management system. Generally, they can be described as mechanical, cultural or biological methods. In many instances the potential for damage and the cost/benefits of treatment indicate that no intervention should occur. An essential element of IPM is the definition of an acceptable level of pest damage.

Learn to tolerate some damage: Most healthy herbaceous and woody plants can tolerate 20-30% leaf defoliation without suffering long-term damage or yield reduction.

Wait for the "good guys": Aphid feeding in the spring alarms many gardeners. Natural predators and parasites usually clean up local infestations in a month or so.

Mechanical Controls

Water stream: A strong hose spray may temporarily dislodge mites, aphids and other pests. Be careful not to damage plants.

Hand picking: Pick off adult and immature insects and egg masses. Pests can be squashed or dropped into a jar of soapy water.

Plants to Attract and Feed Beneficial Insects	
Umbelliferae family	Carrot, yarrow, Queen Anne's lace, dill, anise, fennel, coriander, parsley
Compositae family	Zinnia, marigold, aster, daisies, mums, black-eyed Susan, cone flower, coreopsis
Mint family and perennial herbs	Mints, thyme, sage, oregano, bee balm, basil
Other plants	Salvias, wallflowers, nasturtiums, poppies

Barriers: A floating row cover is an excellent material for excluding insect pests. Other examples are paper collars for cut-worms, diatomaceous earth for slugs and tar paper covering the soil around crucifer seedlings to prevent cabbage maggots.

Cultural Controls

Remove plant or plant parts: Simply removing and disposing of badly damaged plants may minimize the problem on adjacent plants and prevent recurrence.

Timing of seeding and planting: Some pests can be circumvented by growing vulnerable plants when damage is least likely. For example, late summer squash crops are less troubled by squash vine borer. This requires knowledge of pest life cycles.

Late fall or early spring tillage: Many pests over-winter in the crop debris of host plants or in the soil around host plants. Tilling can disrupt pest habitats. Sanitation can remove overwintering sites.

Grow pest resistant or tolerant plants: Check with the nursery or gardening catalogue when selecting plants for those with resistance or tolerance to pests and diseases. Many native plants are good choices.

Do not over-fertilize: Aphids and spider mites will produce more young on over-fertilized plants.

Rotation: Rotate crops that are prone to pests and diseases. However, it is often very difficult to physically separate disease prone crops in small gardens, particularly when diseases or insects over-winter in soil or garden debris.

Set traps: Many garden pests can be trapped and disposed of with homemade or commercial devices. Slugs can be lured into low containers with beer, molasses or yeast-sugar mixtures. Earwigs can be trapped in layers of newspaper and squashed. Commercial traps are available for whiteflies (yellow sticky boards), gypsy moths (pheromone lures in cardboard tents) and many other insect pests.

Encourage diversity: By increasing the number of species grown in the garden you will increase not only the range of habitat available to beneficial organisms but also reduce the possibility of a pest causing a complete crop failure.

Provide optimum growing conditions: Healthy, strong plants are better able to withstand insect or disease infestation than weakened plants such as those growing in poor soil, under moisture stress or in crowded conditions.

Soil moisture, nutrition, light quantity and quality and air circulation are all important factors.

Biological Controls

Encourage beneficial organisms: A diverse landscape will help to attract beneficial organisms to your garden. Indigenous biological predators or parasitoids live on plants, in the soil and around the garden. They include mites, spiders, many wasps, birds, snakes and toads.

Biological pesticides: Many new biological pesticides are becoming available to the home gardener, e.g., B.t. (*Bacillus thuringiensis*) for various caterpillars and larvae. Some caution should be exercised when using B.t. as not all species of caterpillar larvae should be targeted.

SUMMARY OF WEED IPM METHODS

1. DESIGN/REDESIGN SITES TO AVOID WEED PROBLEMS

- Select species that are well adapted to local climate and soil conditions.
- Group together plants that require similar cultural care, such as like requirements for water and sun.
- Separate plants with incompatible growth characteristics.
- Select plants that develop an overlapping canopy to shade out weeds.

2. PREPARE THE SITE BEFORE PLANTING AND PLANT PROPERLY

- Eliminate any established weeds, especially perennial species.
- Grade and prepare the site for good drainage.
- Loosen and amend or add topsoil if needed.
- Provide for any needed irrigation.
- Plant trees and shrubs properly.
- Choose appropriate mulch and apply it correctly.

3. PROPERLY CARE FOR ESTABLISHED LANDSCAPES

- Provide desirable species with proper cultural care.
- Monitor regularly and frequently for weeds and keep written records of when different species appear.
- Determine which weeds can be tolerated and when control is warranted.
- Hand-pull or hoe weeds while they are seedlings.
- Correctly maintain mulch.
- Minimize any disturbance to the soil.
- Use spot applications of an allowed contact herbicide where appropriate.
- Consider redesigning and replanting problem-prone landscapes.

DEVELOPING DIAGNOSTIC AND DECISION MAKING SKILLS

The ability to accurately diagnose a wide range of plant problems can be developed over time by patient observation and consulting reliable reference materials. Timely diagnosis of plant problems can help you keep your landscape and gardens beautiful and productive. It can also prevent expensive removal and replacement of damaged plants.

HOW TO BEGIN

1. Keep an open mind. Do not jump to conclusions.
2. Avoid assigning "guilt by association". The insect, animal or disease observed may not be the cause of the problem or the symptoms.
3. Know what your plant should look like. Knowledge of general growth rates, leaf size and colouration may help alert you to early signs of trouble.
4. There is a great variation in the expected life-span of landscape plants. All plants go through periods of growth, maturity and decline. Plants grown in urban conditions generally have shorter lives.
5. Record the history of the problem plant. Extreme weather, site alteration, grade changes, fertilizer, pesticide and herbicide use as well as cultural practices, all influence a plant's relative health over time. Once mature trees begin to decline, there is often no way to reverse the process. White pines and oaks are common examples of plants which are difficult to rejuvenate after decline symptoms begin.
6. Consider all the factors that influence the plant's growth and health. Take the time to look under leaves, and when possible at the roots, for potential causal factors.
7. At least one half of all observed landscape problems are not caused by insects or diseases. Try to eliminate other causal factors first.
8. A particular problem may be caused by several factors: soil drainage, extreme weather during previous years, air pollution, pests, diseases, herbicide drift.
9. The symptom may indicate a problem in a different part of the plant. For example, leaf yellowing and scorching may be caused by root damage.
10. Many pests and diseases are plant-specific. Symptoms affecting more than one plant species may indicate cultural and environmental problems.
11. There is no substitute for "hands on" training, particularly with an experienced individual.

EXAMINING THE PLANT

1. Look at the area surrounding the problem plant. Consider factors such as: exposure to elements, proximity to roads or buildings, lighting conditions and drainage.
2. Look for physical evidence of a problem: injury, changes in site conditions, soil compaction, construction injury, lawnmower injury, insects or diseases.
3. Examine all parts of the plant closely and carefully; including roots, shoots, trunk and leaf undersides (use a hand lens if necessary). Look for a pattern to the injury.
4. Physical evidence of a pest includes: the pest itself; shed skins, droppings or frass, webbing, honeydew, sooty mold, pitch, gummosis, galls, slime trails, etc. Evidence of diseases includes: mushrooms; fungal growths; galls; white, orange or black powdery substances; leaf spots; water-soaked areas; cankers; discoloured stem and root tissue; stunting and wilting.
5. Identify the pest, disease or problem. This is critical to making a control decision. Identification of the plant is also critical to control decisions. Some plants can tolerate more damage than others.

HOW TO DECIDE WHEN TO TAKE ACTION AGAINST A PEST, DISEASE, OR ENVIRONMENTAL PROBLEM

When developing a management strategy for a particular pest problem, there are a number of criteria that must be considered when evaluating alternatives. The following list of questions will help you to select the optimal control strategy.

Will the treatment...

- reduce (not eliminate) the pest problem to a tolerable level?
- leave small areas untreated to ensure a food supply for natural enemies?
- be specific to the pest problem and be applied directly to the affected area?
- cause minimal disruption to natural controls?
- be acceptably safe for humans and other organisms in the landscape?
- be cost effective?
- be effective alone or in combination with other methods?
- be the least toxic alternative?

1. In general you have less time to make a control decision on seedlings, transplants, and newly planted trees and shrubs. Many pests and diseases do not need to be controlled on older or mature plants. For environmental problems, the site and/or cultural conditions may need to be modified to correct the problem.
2. Judgments may be based on aesthetics, or economic (yield) loss. Realistic thresholds should be set for insects and diseases. Pest or disease progression should be monitored carefully. **It is very important to identify the pest or disease and become familiar with its life cycle.** Some pests and diseases may not require control, while others may. For example, gypsy moth should be controlled, because oaks suffer from early defoliation, and use up energy reserves to re-foliate. Eastern tent caterpillar occurs early enough in the season for cherry trees to re-foliate without causing harm to the tree. **Often by the time disease or insect damage is observed, it is too late to do anything about the problem until next season.**
3. Treatment decisions depend on the type of plant that has a problem. If a plant is easy to replace, such as an annual, just pull the problem plant and replace it. Plants that continue to grow throughout the season will often outgrow the pest or disease damage, examples include locust leafminer on locust, and anthracnose on sycamore.
4. Once you have identified the problem and determine that it requires corrective action, select a control strategy. Always select the least toxic solutions first such as physical (hand removal, change watering practices, pruning out damage, etc.) and biological (encourage beneficials, release predatory mites, etc.). Allowed pesticides (B.t., insecticidal soaps, horticultural oils, etc.) should be used selectively (spot treatments).
5. Continue to monitor the plant's health after treating a problem to determine if further action is needed.

DIAGNOSTIC KEY FOR ABIOTIC (CULTURAL/ENVIRONMENTAL) PROBLEMS OF HERBACEOUS ORNAMENTALS AND VEGETABLES

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
LEAVES/STEMS		
Leaf Yellowing	Older leaf drop Excessive moisture Insufficient sunlight Nutrient deficiency Air pollution	Normal for bottom leaves to yellow and drop as plant ages. Poorly drained soil. Shoots long and spindly. Interveinal yellowing - potassium, iron, magnesium, manganese On older leaves first, then newer leaves: nitrogen. Speckled upper leaf surfaces. Undersides may appear silver.
Leaf Spots/blotches	Frost or freeze damage Herbicide or pesticide drift: white or light-coloured spots.	Water-soaked blotches that turn black or beige Random pattern. Damage on adjacent plants of different species.
Small blisters on lower leaf surfaces	Edema: on a variety of plants, especially cabbage. Occurs on wet soils when warm days are followed by cool nights.	Maintain even soil moisture and increase air circulation around plants.
Curling distortion	2, 4-D damage: grapes, tomatoes, squash and beans are especially sensitive. General herbicide damage: (including glyphosate, dicamba, etc.), from drift or contaminated sprayer. Water stress Heat stress	Damage on new growth. Leaves become narrow, twisted, crinkled and finely divided. Leaf yellowing, mottling, curling and cupping. Damage may follow leaf veins. Lower leaves curl first Lower leaf curling during hot, dry weather.
Leaf scorch, tipburn	Drought stress Pesticide burn, including soaps and oils Fertilizer burn, salt spray Calcium deficiency: especially on lettuce, cabbage and Brussels sprouts. Chloride toxicity: leaves yellow and brown at the tips. Typically from swimming pool drainage and de-icing salts.	Leaf margins are affected first. Random, irregular spots up to entire leaf burn Leaf margin burn from excessive salt uptake by roots. Grayish spots from direct foliar contact with fertilizer. Determine soil pH and adjust accordingly. Where problem persists, mix a small handful of dolomitic limestone with soil under the plant at planting time. Divert swimming pool water and ice melt runoff away from root zones. Irrigate to reduce salt levels.
Entire Plant Wilts	Walnut wilt: affects many types of herbaceous plants in the vicinity of walnut trees.	Walnut (<i>Juglans</i> spp.) roots contain a chemical (Juglone) that kills the roots and stunts the growth of many other plants that come in contact with the walnut roots. Newer growth wilts first. Poorly drained soils cause root diseases.
Plants fall over/branches break/stems split	Species characteristic Wind, rain and hail damage Mature plants, heavy fruit load (peppers are especially prone to branch-breaking). Excessive water, sudden changes in soil moisture	Tall, unsupported plants may fall over. Keep plants pruned, picked and supported. Excessive growth due to sudden water availability. Use mulches to maintain even soil moisture

FLOWERS AND FRUITS		
Flower stalk forms/plant "goes to seed"	Drought stress Cold or hot temperatures: exposure of spring-planted biennials (broccoli, lettuce, parsley) to environmental stress. Excessive sunlight: short day plants (spinach) "bolt" when days get longer.	Use mulches to maintain even soil moisture. Fall-planted broccoli often yields better results. Use a floating row cover over early biennial crops. Select short season, stress tolerant cultivars. Use "slow bolting" varieties. Plant earlier in the spring. Use a shade cloth.
Failure to flower, blossom drop	Winter damage to perennials Planted too late: season insufficiently long. High and low temperatures: continuous cloudy weather. Drought stress, excessive water Insufficient sunlight: plants spaced too closely. Excessive nitrogen Insufficient pollination: due to lack of insect pollinators (especially on plants with separate male and female flowers).	Protect overwintering crowns with thick mulch. Plant earlier to ensure establishment. Overhead watering, shading may help on very hot days. Maintain proper plant spacing. Unusually tall, lush plants Avoid spraying any kind of insecticide, particularly in the morning when bees are active.
Failure to fruit, fruit drop	High and low temperatures: kills pollen, inhibits fertilization, and causes flowers to abort. Drought stress, excessive water Insufficient sunlight: plants spaced too closely. Excessive nitrogen Insufficient pollination: due to lack of insect pollinators (especially on plants with separate male and female flowers).	Overhead watering, shading may help on very hot days. Water evenly, use mulch to conserve soil moisture. Unusually tall, lush plants Avoid spraying any kind of insecticide, particularly when plants are blooming.
Spots/rots on fruit	Frost or freeze damage: fruit becomes soft.	Also due to high summer temperatures during fruit growth and harvest.
Large discoloured areas on fruit skin	Blossom-end rot: dark, leathery, sunken areas on blossom-end of peppers, tomatoes, squash, etc. caused by a temporary calcium deficiency, and uneven soil moisture. Sunscald: yellow or pale, wrinkled, sunken areas on areas of fruit exposed to full sun.	Keep plants well-watered and mulched. Check soil pH and amend accordingly. Mix a handful of dolomitic limestone into each planting hole in spring. Avoid high N fertilizers. Occurs when plants become defoliated
Internal discolouration of edible plant parts	Calcium, magnesium and boron deficiencies: promotes graywall in tomato, hollow heart of celery and head breakdown of broccoli and cauliflower. Wet soil, cool and cloudy weather during ripening.	Have soil tested for these nutrients and amend accordingly. Boron is less available in sandy, acidic soils. Amend soil to maintain proper pH. Incorporate 90-105ml of borax each year per 100m² of garden area. Occurs more frequently on light soils. Physiological response to unfavourable weather.
Green areas on edible plant parts	Green shoulder on tomato Green shoulder of carrot, potato and onion: due to sun exposure (chlorophyll production).	Varietal problem that occurs on large-fruited varieties in dense plantings. Keep soil hilled over edible plant parts.
Failure to ripen, uneven ripening	Cold temperatures, insufficient ripening time, varietal characteristic	Late season problem. Associated with short days, low sunlight, and crowded plants. More severe on large-fruited tomato varieties.

FLOWERS AND FRUITS		
Seeds germinating inside fruit	Precocious germination: breakdown or absence of germination inhibitors in fleshy fruits.	May occur in late season fruit.
Cracking	Excessive nitrogen Excessive moisture: causes head splitting in cabbage, and radial and concentric cracking of tomatoes and other vegetables. Varietal characteristic Herbicide exposure	Avoid high nitrogen fertilizers; maintain even growth rate. Use mulches to maintain even soil moisture. Large-fruited tomato fruits more susceptible. Resulting in unusual growth characteristics.
Misshapen/hollow fruits	Cold temperatures: before and during bloom, causes "catfacing" in tomatoes. Poor pollination: causes puffiness of tomatoes and malformed cucurbit fruits. Boron deficiency: in celery (hollow heart) and cabbage.	Harden-off tomato plants and set them out after frost-free date. Exacerbated by very high or low temperatures insufficient sunlight and spraying of broad spectrum insecticides. Boron is less available in sandy, acidic soils. Amend soil to maintain proper pH. Incorporate 90-105ml of borax each year per 100m ² of garden area.
Misshapen/hollowed/forked tubers and roots	Alternate wet and dry conditions: causes knobiness, cracking and cavities in potatoes, turnips, etc. Rocky or heavy clay soils Herbicide damage Fresh manure applied to soil Over-crowded seedlings	Use mulches to maintain even soil moisture. Prepare deep, friable seedbed. Causes distorted growth. Use fully rotted, composted manure. Thin to appropriate spacing.
Woody or tough edible plant parts	Hot, dry weather, over-maturity	Brassicas and leafy greens need a continuous source of water and nutrients for optimum growth and succulence. Select varieties appropriate for the particular season.
Off-flavours, hot flavours	Cold weather, excessive moisture: causes fruits to be watery and tasteless. Hot, dry weather: makes radishes hot and cucumbers bitter and increases chili pepper pungency. Acidic soil, excessive nitrogen Over-mature or immature fruits Varietal characteristic Overcrowding, weed competition	October-harvested tomatoes and muskmelons grown under wet conditions are often poorly flavoured. Maintain adequate irrigation Adjust pH and avoid high-nitrogen fertilizers. Harvest at proper time. May also result from mislabeled varieties. Thin to appropriate spacing and keep plants mulched.

DIAGNOSTIC KEY FOR ABIOTIC (CULTURAL/ENVIRONMENTAL) PROBLEMS OF WOODY ORNAMENTS, SMALL FRUIT PLANTS AND FRUIT TREES

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
FOLIAGE/WOODY PARTS		
Plant dies suddenly	Root rots Severe drought damage Construction equipment injury	Monitor plant health for early stages root diseases. Maintain proper irrigation. Use mulch. Avoid soil compaction.
Mature tree declining	Natural senescence Compacted soil: from construction equipment. Severed or damaged roots White pine decline: needle browning, weak foliage and wrinkling of bark.	All plants have an expected life span. Don't allow heavy equipment near root zone. Associated with compacted or heavy clay soils and high soil pH.
Poor growth, failure to establish	Species or variety not adapted to area Poor plant material: pot bound, weak plants, dead roots. Poor site conditions: heavy clay, poorly drained, low soil fertility. Low or excessive light exposure. Poor planting techniques: too deep, poor soil preparation. Lack of proper care and maintenance: watering, mulching.	See Woody Ornamentals Chapter. Inspect nursery material carefully. Modify site conditions and situate plantings for proper light exposure. Deep planting is often a problem of pines, cedar, azalea, dogwood and boxwood. Maintain proper irrigation during establishment.
Leaf yellowing/mottling	Air pollution damage: flecking may be seen. Foliage is thin or stunted with premature needle or leaf drop and is most severe on conifers. Iron, magnesium and manganese deficiency: on "acid-loving" plants and conifers. Excessive water: leaves uniformly yellow and drop. Nitrogen deficiency: older leaves or needles uniformly yellow. Low light conditions: spindly growth. Fall colouration: on pines and other evergreens. Inner needles turn yellow and drop. Winter damage: leaves will eventually brown and die. Cat or dog urine: leaves and needles eventually brown. Injury relatively low on plant/tree. Herbicide damage	Damage may appear as brown, dead areas or as chlorotic bands on conifers. Occurs on high pH soils. Follow soil test recommendations. Newer growth may be undersized and sparse. May also cause slow growth and premature leaf drop. Modify soil for better drainage Shoots long and spindly. Relocate plant to suitable site. This is a natural occurrence. Usually worse on windward side. Install windbreaks. Irrigate to reduce salt levels. Similar symptoms may be seen on adjacent plants and of different species.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Early fall colouration, premature leaf drop	Drought and heat stress, poor site conditions, winter damage to crowns and roots	Modify site conditions or adjust cultural practices to reduce stress
Leaf/needle browning	Drought stress: first observed on newer growth. Natural gas leak: newer leaves affected first. Foliage turns brown and crispy. Winter burn (evergreens): damage on windward side. Fertilizer or salt damage: tips of conifer needles brown first.	Keep trees well-watered during extreme drought. Roots appear black. Install wind breaks. Boxwoods are particularly sensitive to salt damage. Damage often observed next to streets and sidewalks. Salt damage to deciduous trees may be seen when new growth resumes.
Leaf scorching/ Marginal burning	Pesticide burn: including soaps and oils. Stressed plants are more likely to be burned; and emulsifiable concentrates are more likely to burn than wettable powders. Spruce, maple and cedar are more sensitive to oil sprays. Fertilizer burn, salt spray Damage from lawn herbicides (including glyphosate) drainage and de-icing salts. Drought stress Very high temperatures Sunburn: yellow, brown or white areas develop on upper sides of leaves. Chloride toxicity: leaves yellow and brown at the tips. Typically from swimming pool drainage and de-icing salts.	Leaf margins are affected first. Leaves are particularly susceptible to burn when temperatures exceed 25-30°C. Copper, sulfur and Captan® fungicides may cause leaf burn on various fruit trees and small fruit plants. Random, irregular spots or entire leaf burn. Marginal leaf burn from roots contacting excessive salts. Symptoms from fall-applied herbicides may not appear until spring. Scorch appears first near branch tips. Damage due to excessive sunlight, ultra violet light, heat and insufficient water Divert swimming pool water and ice melt runoff away from root zones. Irrigate to reduce salt levels.
Leaf spots/ blotches	Burning from herbicide, pesticide, fertilizer or salt: light-coloured spots from direct contact. Sunburn: yellow, brown, white or silver areas develop on leaves.	Random or regular pattern (as from a spreader). Damage due to excessive sunlight, ultra violet light, heat and insufficient water.
Wilting of foliage	Drought stress: foliage wilts, droops and drops prematurely. Root damage: freeze, drought or mechanical injury. Poorly drained or wet soil: roots become oxygen-starved. Heavy clay soils: impede root growth and limit water uptake. Dry sites and insufficient watering on newly transplanted trees and shrubs. Walnut wilt: affects many types of woody plants in the vicinity of walnut trees especially rhododendrons and azaleas.	May lead to twig and limb dieback. Provide adequate water during summer and fall months. Lay down a thick organic mulch in late fall. Keep mulch away from stems and trunks. Select suitable, well drained planting sites. Modify site conditions. Keep young and newly transplanted plant materials well-watered. Walnut (<i>Juglans</i> spp.) roots contain a chemical (Juglone) that kills the roots and stunts the growth of many other plants that come in contact with the walnut roots.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Twig/branch dieback	Root damage, freeze, drought or mechanical injury Wet, poorly drained soil Herbicide damage De-icing salts Freeze injury	Prune out affected areas and keep plants well-watered. Lay down a thick organic mulch in late fall. Keep mulch away from stems and trunks. Select suitable, well drained planting sites. Divert ice melt runoff away from root zones.
Foliage/twigs/limbs broken or injured	Ice, wind or hail damage: cankers may develop. Small twigs may be pruned by squirrels for nest-building.	Prune out affected parts.
Bark is cracked longitudinally, usually on south or west side.	Frost/freeze cracks, sunscald: due to differential freezing and thawing of water in tree trunk.	Consider wrapping the trunks of young or vulnerable trees (e.g., those with smooth thin bark) or paint with interior white latex paint.
Trunk bark/wood is gouged or scarred	Lawn mower or string trimmer injury Imbedded wires or collars from tree support apparatus. Construction equipment	Mulch to avoid necessity for trimming. Remove supports after first season. Don't allow heavy equipment near root zone.
Sap oozing from trunk or branches	Natural gummosis Drought or waterlogging	Occurs on <i>Prunus</i> spp. (peach, cherry, plum) from any damage. Modify site conditions.
Water sprouts, suckers	Environmental stress Removal of large branches and limbs	In all cases promptly pull or cut all water sprouts at point of attachment.
Bulging or deformity of trunk at graft union	Normal on grafted trees for scion wood to over-grow or under-grow the rootstock	Remove all suckers that arise below the graft union. If graft union is damaged or killed, sucker growth may outgrow desired scion stock.
Top of young tree breaks off at or near ground level	Failure of graft union: incompatibility between scion wood and rootstock.	Determine the degree of compatibility prior to planting.
Roots at tree base wrapped partly or completely around trunk	Girdling roots: more likely with container grown stock planted in heavy, clay soil.	Occurs when roots are deflected from normal growth. Can sometimes be removed with chisel and mallet.
Flowers/Fruits		
Newly planted flowering trees and shrubs fail to bloom	Plants have not matured sufficiently: perennials must become well-established before they can reproduce sexually. Environmental stress: poor site conditions, excessive shading.	Check references and nurseries to determine typical or average requirement of plant. Consider transplanting to better location.
Failure to bloom on trees or shrubs over 5 years old	Trees growing too vegetatively: fruiting delayed. Stress: drought, wet soil, insect and disease damage, low light conditions. Fall pruning will often cause removal of flower buds.	Minimize dormant pruning. Stop applications of high N fertilizers. Spread scaffold branches at wider angles to induce fruit bud formation. Proper site selection, care and maintenance. Spring-flowering ornamental shrubs and trees should be pruned immediately after bloom period.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Blasted or damaged blooms	Winter-kill of buds Spring frost damage to buds and flowers Low temperature damage: trees may leaf out without flowering (leaf buds are hardier than flower buds). Leaf and flower buds may be killed or damaged by misuse of dormant oil sprays or pesticide sprays: spraying with temperatures below 5°C. Spraying dormant oil or lime-sulfur on open blooms. Water stress	Avoid planting in low areas or frost pockets. If possible, apply overhead irrigation to reduce freeze damage. Over-spraying of dormant oil, lime-sulfur and other fungicides and insecticides may damage buds and blooms. Follow label directions. Follow recommended spray schedule guidelines.
Blossom drop	Stressful conditions: drought, wind, low temperatures. Lack of pollinator trees (a second variety): examples include apple, pear, and nut trees. Poor pollination/fertilization: bee activity is low during cool, wet weather. Spraying insecticides during bloom period. Over-use of nitrogen fertilizers prior to bloom period.	Determine the pollination requirements of trees before planting. Especially a problem on cross-pollinated species (apple, pear, walnut). Avoid broad spectrum pesticides that kill pollinators. Reduce applications of high nitrogen fertilizers.
Failure to fruit, minimal fruit set	Winter-kill of buds Spring frost damage to buds and flowers Low light conditions Low temperature damage: trees may leaf out without flowering (leaf buds are hardier than flower buds). Lack of pollinator trees (a second variety): examples include apple, pear, and nut trees. Poor pollination/fertilization: bee activity is low during cool, wet weather. Spraying insecticides during bloom period may kill pollinating insects. Spraying dormant oil or lime-sulfur on open blooms. Over-use of nitrogen fertilizers prior to bloom period. Biennial bearing pattern: failure to prune after a heavy crop, particularly on certain apple cultivars like Golden Delicious. Severe pruning: will reduce number of blooms. Male plant: dioecious species, both male and female plants required for pollination.	Avoid planting in low areas or frost pockets. If possible, apply overhead irrigation to reduce freeze damage. Follow proper thinning and pruning guidelines. Situate plantings for optimum light exposure. Determine the pollination requirements of trees before planting. Especially a problem on cross-pollinated species (apple, pear). Avoid spraying insecticides during bloom. Leaf and flower buds may be killed or damaged by misuse or overuse of dormant oil sprays, including spraying when temperatures below are 5°C. Follow recommended pruning guidelines Do not prune out fruit bearing wood during the dormant season. Follow recommended pruning guidelines. Including hollies, ginkgo and some hardy kiwis.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Fruit drop	Natural thinning Spring frost Poor pollination/fertilization Drought, cold or hot temperatures Spraying Sevin® (insecticide) during bloom	Many trees over-produce fruit and thin themselves naturally. May damage or kill buds and developing fruits. Lack of pollinator tree or insufficient bee visits. Avoid spraying insecticides during bloom. Used by commercial growers to thin tree fruit crops.
Small or undersized fruits	Failure to thin or prune properly Low soil fertility Drought	Thin to reduce number of fruit or blossoms. Follow soil test recommendations. Irrigate during critical periods such as fruit set and enlargement.
Malformed fruit	"Catfacing": from poor pollination. Hail damage: scars can be observed.	Remove immediately from tree or ground. Damage is cosmetic.
Cracking/splitting	Excessive moisture during ripening.	Pick ripened fruit promptly and use mulches to maintain even soil moisture.
Gummosis, fruits exude sap	Mainly on peaches during rapid fruit enlargement: not a problem.	Use mulches to maintain even soil moisture.
External damage	Pesticide burn Hail: small, roughened areas on fruit. Mechanical damage Sunscald: white, tan or brown sunken areas on exposed surfaces. High temperatures: cause individual bramble fruit drupelets to turn white.	Captan®, sulfur and oil sprays may produce russetting on sensitive varieties. From contact with branches or rough handling. May alter fruit flavour. Remove and discard affected fruit.
Internal damage, corky areas, browning	Environmental stress: drought, waterlogging, and high and low temperatures during ripening, harvesting and handling. Deficiencies of calcium, magnesium, or boron. Over-mature fruit. Freeze damage.	Associated with a wide range of fruit disorders. More likely to occur on light soils. Have soil tested for these micronutrients and amend accordingly. Pick ripened fruit promptly.

DIAGNOSTIC KEY FOR SEEDING AND TRANSPLANT PROBLEMS

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Poor germination	Cold soil: seeds (especially corn and bean) rot in cold, wet soil. Clay soil: seedlings can't penetrate crusted surface easily. Seeds planted too deeply Low germination vigour: seeds not viable. Species characteristic: e.g., spinach. Fungal disease: seedlings fail to reach soil surface.	Determine germination requirements of crop (use a soil thermometer). Pre-sprout seed where appropriate. Amend furrow with organic matter or cover seeds with vermiculite. Create raised beds and pre-sprout seeds. Rule of thumb for seeding depth: 2-3x seed diameter. Buy seed packed for current year. Pre-test germination rates of questionable seeds. Seeds that germinate slowly can be pre-sprouted. Use a well-drained, sterile growing media. Allow surface to dry between waterings.
White-tipped leaves	Frost damage	Plants seeded or set-out too early or insufficiently hardened
Leaf yellowing	Spider mites: fine stippling, especially in warm weather. Whitefly: tiny, white insects fly up when plant is disturbed.	If necessary, use insecticidal soap or pyrethrum spray. Be careful on tender transplants. Predatory mites are another control option. Usually from greenhouse where plants were grown. Control with insecticidal soap or pyrethrum based insecticide. Be careful on tender transplants
White-tan spots, leaves turn brown and papery	Sunburn, cold damage, wind whipping	Protect seedlings and transplants. Harden plants off prior to transplanting. Protect transplants in extreme weather conditions.
Stunted growth	Cold soil, cool air temperatures	Avoid planting too early. Try warming the soil with clear or black plastic. Harden plants off prior to transplanting.
Pale green leaves	Lack of nitrogen Low light conditions, cloudy weather	Cool soils contribute to poor nutrient uptake.
Purple leaves	Cold damage, phosphorous deficiency	Low soil temperatures prevent phosphorous uptake by plant roots.
Weak plants, whole plant wilts	Desiccation Water stress: excessive or deficient soil moisture. Seed corn maggots: small, white grubs feed on germinating seeds and chew on young plants below soil level. May introduce rot organisms. Problem on many different types of vegetables. Corn rootworm (cucumber beetle larvae): 1 cm long, whitish body, brown head. Larvae tunnel into roots and stems of corn, bean, cucurbit seedlings.	Leaves become dry and pale in cool wind. Plant in loose, well-drained soil. Do not plant too early or deeply. Slow germination in cold soils encourages problem. Use a floating row cover, other plant protectors or place paper collars around individual plants. Incorporate organic materials in fall rather than spring. Select resistant varieties. Plant extra seed or transplants. Use a floating row cover.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Seedlings fall over and die	Damping-off disease: roots and lower stems shrivel and darken. Cutworms: variously patterned, night feeding caterpillars that cut plants off at soil line.	Use a sterile, well drained media and allow surface to dry between waterings. Place paper plant collars around individual plants. Early spring tillage may reduce populations.
Plants cut off at soil line	Cutworms (see above) Slugs: night feeders. Slime trails may be seen. Birds, voles, squirrels, rabbits, chipmunks: newly emerged seedlings eaten.	Plants seem to "disappear" (dragged into underground burrows). Most common in April-June. (see above) Hand pick at night. Lay down abrasive barriers (diatomaceous earth, coarse sand, egg, oyster or crab shell). Use a floating row cover, fencing, or hot pepper flakes sprinkled around vulnerable plants.
Leaves and stems chewed	Deer, rabbits, groundhogs, birds, earwigs, slugs	See section above and Chapter 9 - Wildlife Management.
Small holes in leaves	Flea beetles: small, dark shiny beetles that jump when disturbed and produce a shotgun feeding pattern.	Use a floating row cover.
TIPS Pre-germination: Seeds of vegetable crops that are difficult to germinate can be pre-germinated. Simply place seeds between moist paper towels in a plastic bag at 20-25°C. Check daily for signs of germination and plant when roots are extended but before leaves unfold. Hardening off: Vegetable, herb and flower transplants are easily shocked when planted out in early spring weather. Plants that undergo a "hardening off" process can better withstand these changes. Two weeks prior to planting, progressively expose plants to outdoor conditions by placing on a sheltered back porch or patio. Bring plants in at night. Pesticides: Many pesticides can damage tender transplants. Use care when spraying transplants that have been damaged by spider mites or whiteflies.		

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF LANDSCAPE SHADE TREES

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Leaves eaten or chewed	Early and late season caterpillars, sawflies, or leaf feeding beetles: Gypsy moth: is an early to mid-season caterpillar that should be controlled on oaks. Other early season caterpillars include Eastern tent caterpillar and cankerworms. Mid to late season caterpillars: such as fall webworm; red humped, yellow necked, mimosa webworm; orange striped oakworm generally do not require control except on young trees or if heavy defoliation is occurring. Leaf feeding beetles: include Japanese beetles, chafers, locust leafminer, elm leaf beetle. Sawflies include dusky birch, ash, dogwood sawflies on deciduous plants and redheaded pine sawfly on conifers.	Early season caterpillars such as gypsy moth should be controlled when larvae are small and before damage is extensive. The biological insecticide B.t. is effective on small caterpillars. Hand picking caterpillars and sawfly larvae can give adequate control of small populations on young trees. Large caterpillars, sawflies and beetles may require a residual insecticide spray if populations are causing significant damage. Control may be difficult on large trees unless spray coverage is thorough.
Webbed or tented foliage	Tent caterpillars, webworms, leafrollers and leaf tiers: various caterpillars found within webbed leaves or silken tents.	If numerous caterpillars are present, use B.t. when the caterpillars are small. Knock down or prune out webs on terminal branches and destroy caterpillars.
Leaf distortion	Leafhoppers: pale green to white wedge shaped insects that cause curling and stunting of terminal leaves. Look for coarse white stippling between veins. Whitish cast skins usually present on lower leaf surfaces. Plant bugs: (0.5 cm long green or brown), cause distortion of leaves in spring, especially on sycamore and honey locust. Spider mites and aphids: cupped leaves on some plants.	Treat as needed with a registered insecticide. Use caution when spraying Japanese maples since they are sensitive to certain pesticides. Trees generally outgrow the damage. Generally impractical to spray large trees for mites and aphids. When control is needed, use insecticidal soap or horticultural oils to minimize adverse effects on natural enemies.
Bags constructed of plant material attached to branches	Bagworms: caterpillars feed on foliage and construct protective silk bags covered with host plant material.	Spray with B.t. when bags are small from mid-June to mid-July. Handpick and destroy bags during the fall and winter.
Whitish frothy material on foliage	Spittlebugs: small sucking insects, covered with spittle that feed on terminal twigs of host plants.	Control is generally not warranted.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Leaf stippling (pin-point yellow spots)	Spider mites: very tiny, "period-sized". Present on lower leaf surfaces. Leaves yellow, eventually turn brown and drop prematurely. Webbing may be visible with high populations in protected sites. Lacebugs: (0.5 cm long, lacy wings) feed on lower leaf surface. Stippling on upper leaf surface is white. Black fecal spots on lower leaf surface.	Generally impractical to spray large trees for spider mites. On small trees, if control is needed, use insecticidal soap or horticultural oils to minimize adverse effects on natural predators. Direct sprays toward the lower leaf surfaces. Releasing predatory mites to control spider mites is another option on small trees. Insecticidal soap sprays should be directed to lower leaf surfaces.
Serpentine trails or blotches in leaves	Various leafminers (maggots, small caterpillars, sawflies or grubs): feed between the upper and lower leaf surfaces.	Control is difficult on large trees. Note host plant to determine identity of pest and if damage is significant control may be warranted. "Heritage" birch is resistant to birch leafminer. Locust leafminer usually only a problem on black locust. Does not require control.
Growths on leaves, may be raised nodules, some may be fuzzy.	Galls: produced by eriophyid mites (very tiny, generally not visible to naked eye), gall midges and gall wasps. Galls may be various colours and shapes. Galls may also be caused by various plant pathogens.	Control is generally not needed. If needed, pull off and destroy leaf galls while they are still green. Horticultural oil, dormant season sprays may help reduce overwintering mite populations.
Spots on leaves	Leaf spotting diseases: isolated, minor damage. During wet weather may blight entire leaves and cause extensive defoliation. Eyespot gall on maple: yellow slightly raised area ringed in red on upper leaf surface, eventually turns brown. Tulip tree spot gall: purplish spots, 3 mm in diameter.	Registered fungicides may be warranted when disease conditions are severe on young trees. Prune out dead twigs and branches in dry weather and rake up and remove fallen leaves in the fall. Control is impractical on large trees. Consider replacement with resistant varieties. Control not necessary. Control not necessary.
Leaf blights	Anthracnose diseases: leaf spots or blotches that run together and cover leaf surface. Defoliation can occur under severe conditions. Twigs and branches may also be killed by anthracnose diseases.	Registered fungicides may be warranted when disease conditions are severe on young trees. Prune out dead twigs and branches in dry weather and rake up and remove fallen leaves in the fall. Control is impractical on large trees. Consider replacement with resistant varieties.
Leaf scorch	Bacterial leaf scorch: affects interior leaves and those near the base of the tree first. Scorched areas are surrounded by a yellow border.	When symptoms are first noticed, promptly prune out infected branches well below the last scorched leaf. Trees with extensive dieback should be removed.
White coating on leaves	Powdery mildew: white surface growth on leaves that may cause distortion.	Controls are generally not needed except on crabapples and dogwoods. Leaves should be raked up in the fall. Check horticultural oil labels for powdery mildew control listings

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Sooty mold/ sticky honey dew	Aphids: small, soft bodied insects on young shoots, leaves and bark (giant bark aphids). Soft scales: appear as raised bumps on twigs and branches. Leafhoppers: pale green to white wedge shaped insects that cause curling and stunting of terminal leaves. Look for coarse white stippling between veins. Whitish cast skins usually present on lower leaf surfaces. They also transmit fastidious xylem-limited bacteria that cause "Scorch" on several tree species.	Healthy plants can tolerate moderate population of aphids and scales. Conserve natural enemies. If high populations are present, spray when plants are dormant with horticultural oil at the dormant rate. Treat as needed with a registered insecticide. Use caution when spraying Japanese maples since they are sensitive to certain pesticides.
Leaf yellowing, foliage fades, yellows, browns or wilts, often scattered throughout the canopy.	Armored scales: encrustations on branches. Scales can be scraped off. Soft scales: appear as raised bumps on twigs and branches. Can be scraped off. Honeydew and sooty mold may be present. Spider mites: very tiny, "period-sized". Present on lower leaf surfaces. Leaves yellow and eventually turn brown and drop prematurely. Webbing may be visible with high populations. Borers: holes and tunnels in branches Verticillium wilt: scrape twigs and branches to look for evidence of vascular browning that would indicate Verticillium wilt. Cankers: caused by various fungi. Common genera include <i>Cytospora</i>, <i>Botryosphaeria</i>, <i>Nectria</i> and <i>Phytophthora</i>. Cause dark, elongated lesions with roughened bark Root/wood rots: numerous fungi that cause wood decay and form fruiting bodies such as mushrooms on branches or trunk	For either armored or soft scale infestations, prune out branches with severe symptoms. Spray tree with a dormant rate of horticultural oil during the dormant season to control overwintering scale insects. Generally impractical to spray large trees for mites. When control is needed, use insecticidal soap or horticultural oils to conserve predators or consider releasing predatory mites. Prevent borer infestations by keeping trees healthy. No sprays are effective. Prune out wilted and dead branches and irrigate during dry weather. Avoid root damage from salt or cultivation. In problem sites, select resistant alternative trees. Trunk injections may be considered for old specimen trees. However, if damage is severe, they will not prevent dieback. Fertilization can encourage new growth if enough healthy roots are available to take up nutrients. No chemical control. Maintain adequate irrigation during drought. Prune out affected branches where practical. Although infected trees may take several years to die they pose a hazard and should be removed. Single infected branches should be removed promptly.
Orange or yellow pustules on leaves	Rust diseases: upper leaf surfaces turn yellow or brown and infected leaves may drop prematurely. Rusty coloured spores are usually on lower leaf surfaces.	Controls are not usually practical. Replace with resistant varieties.
Early leaf drop and early fall colour	Various insects and diseases: often an early sign of stress due to pests, diseases, and abiotic or cultural problems.	No chemical controls are usually needed. See key on abiotic problems of woody ornamentals.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Shoots chewed and girdled , bark stripped from trunk or branches	Deer feeding: worse during very cold winters. Antler rubbing from bucks.	Where appropriate, electric fences are very effective. Repel deer by hanging one or more of the following from mesh bags on trees: small bars of soap, human hair, blood meal or mothballs (see Chapter 12 on Woody Ornamentals).
Scattered twig and branch dieback	Armored scales: encrustations on branches, especially oak. Borers: holes and tunnels in branches. Twig girdlers and twig pruners: fallen twigs with chewed ends. Cicadas: deep slits made in bark during egg laying activity causing twigs to break easily in windy weather. Verticillium wilt: cankers and split bark. Foliage fades, yellows, browns or wilts. Damage often scattered throughout the canopy. May also see scattered dieback in canopy. Cankers: caused by various fungi. Common genera include <i>Cytospora</i> , <i>Botryosphaeria</i> , <i>Nectria</i> and <i>Phytophthora</i> . Causes dark, elongated lesions with roughened bark (excessive resin flow typical on conifers).	Prune out affected branches. Apply horticultural oil at the dormant rate before bud break in the spring to control scale infestations. Prevent infestations by keeping trees healthy. Rake up and dispose fallen twigs in the fall with chewed ends to control twig girdlers and pruners. In most years damage from cicadas is minor and no control is necessary. No sprays are effective. Prune out wilted and dead branches and irrigate during dry weather. Avoid root damage from salt or cultivation. In problem sites, select resistant alternative trees. Trunk injections may be considered for old specimen trees. However, if damage is severe, they will not prevent dieback. Fertilization can encourage new growth if enough healthy roots are available to take up nutrients. No chemical control. Maintain adequate irrigation during drought. Prune out affected branches where practical.
Hard growths on twigs	Twig and stem galls: caused by gall wasps. Most common on oaks. Dieback may occur.	Prune out twig galls as they form, especially on pin and willow oak.
Frass around wounds and bark cracks. Gummosis may be present on <i>Prunus</i> species.	Clearwing borers: white larvae (caterpillars) make shallow tunnels under the bark and push frass (excrement) out through holes. Frass accumulates in branch crotches, bark and base of the tree.	Keep mulch away from trunk on <i>Prunus</i> species. Beneficial nematodes can be sprayed on infested areas of branches and trunk; however, gummosis prevents entry of nematodes into borer tunnels.
Whitish cottony material on twigs and branches	Woolly aphids: honeydew may be present. Egg masses of soft scales.	Healthy plants can tolerate moderate populations of aphids and scales. Conserve natural enemies. If high populations are present, spray when plants are dormant with horticultural oil at the dormant rate.
Small twigs on the ground	Twig girdlers and twig pruners: fallen twigs with chewed ends appearing to be filed off evenly across. Squirrels: prune twigs for nest building material. Twigs are chewed roughly on an angle.	In the fall, rake up and dispose of fallen twigs with chewed ends to control twig girdlers and pruners.
Wilting	Lack of water, wood boring beetles, root rots, etc.	
Proliferation of branches or dense bushy growth (Witches Broom)	Insects, eriophyid mites, fungal, viral or mycoplasma diseases.	Prune out affected areas.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Rapid dieback of branches, blackening or browning of shoots, blossoms or fruit. Plant appears scorched.	Fireblight: a bacterial disease that infects plants in the rose family such as crabapples, flowering cherries and pears.	Prune out infected branches promptly 30 cm below visible damage. Remove root suckers and water sprouts. Select resistant plant cultivars. Reduce nitrogen fertilization. Under severe conditions, fungicides may be required.
Fungal growths or mushrooms on branches or trunk.	These structures are visible evidence of extensive interior wood decay or root rot.	Large trees should be inspected by a certified arborist to determine the extent of trunk damage. Trees with extensive damage should be removed promptly to avoid liability issues.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF EVERGREEN TREES IN THE LANDSCAPE

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Needle yellowing	Spruce spider mites: very tiny, "period-sized". Yellowing of tree from bottom up. Generally a problem in spring and fall. Soft scales: raised bumps on twigs, can be scraped off. May also see honeydew and sooty mold. Armored scale: white scale covers on needles, yellowing in heavy infestations	When control is needed, use insecticidal soap or horticultural oils to minimize adverse effects on natural predators or consider releasing predatory mites. For soft and armored scale insects apply horticultural oil at the dormant rate during the dormant season to control scale infestations.
Needle browning	Advanced symptoms of insect and disease damage. Tips of needles brown first as a result of root damage.	Controls at this stage of damage are not often effective.
Needle stippling (pin-point yellow spots)	Spruce spider mites: Tap branches on white paper to look for mites.	When control is needed, use insecticidal soap or horticultural oils to minimize adverse effects on natural predators or consider releasing predatory mites.
Spots on needles	Scale insects: look for white, brown or gray scale covers on needles. Will scrape off. Needle cast diseases: Mostly dark brown to black spots causing premature needle drop. Needle rusts: powdery orange-yellow spots.	When control is needed, use insecticidal soap or horticultural oils to minimize adverse effects on natural enemies. Needle cast diseases may be controlled with a registered fungicide on small trees. Other than pruning, no practical controls are suggested.
Needle drop	Spruce mites: advanced mite damage. Needle diseases: severe damage	Generally impractical to spray large trees for mites. On small trees, if control is needed, use insecticidal soap or horticultural oils to minimize adverse effects on natural predators. Releasing predatory mites to control spider mites is a viable option. Difficult to spray large trees. Use a registered fungicide on small trees.
Needles eaten, chewed or webbed	Sawflies: resemble caterpillars, feed in groups. Bagworms: look for bags constructed of needles, attached to branches. Pine tube moth: bundle of needles webbed together to form a tube. Pine webworm: young caterpillars initially mine needles. As they grow they make nests of silk and frass around terminal twigs.	Handpick and destroy sawfly larvae. Spray with B.t. when bags are small from mid-June to mid-July. Handpick and destroy bags during the fall and winter. Control rarely necessary. On small trees hand-pick and destroy the pine tubes. Manually remove and destroy nests on terminals as soon as they are noticed.
Shoots chewed and girdled, bark stripped from trunk or branches	Deer feeding: worse during very cold, snowy winters. Antler rubbing from bucks.	Where appropriate, electric fences are very effective. Repel deer by hanging one or more of the following from mesh bags on trees: small bars of soap, human hair, blood meal or mothballs.
Serpentine trails or blotches in leaves	Various leafminers: larvae feed between the upper and lower leaf surfaces.	Pick affected leaves, or spray with a systemic insecticide if damage is severe.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Dead terminals	Pine shoot and tip moths: tan to brown caterpillars bore into and kill terminal growth. White pine weevil: adults (brown 0.5 cm, 2 white spots) and larvae (white, 1 cm, brown heads) feed in terminal leader. Sphaeropsis tip blight: pines. Excessive pitch on terminals and pinpoint spots on needles. Cenangium twig blight: pines. Dying of terminal buds and reddening of needles.	Prune out and destroy affected terminals. In June, prune out and destroy affected terminals. Maintain adequate irrigation during droughts. Use a registered fungicide spray on new growth in spring. Remove severely damaged trees. Maintain adequate irrigation during droughts. Disease typically affects stressed pines. Prune out affected areas during dry weather.
Sooty mold, honeydew on needles	Aphids: small green insects feed on needles, honeydew may be present. Pine tortoise scale: raised bumps on twigs. Ants, honeydew and sooty mold present near branch terminals.	When control is needed, use insecticidal soap or horticultural oils to minimize adverse effects on natural predators. Scale may be controlled during the dormant season with an application of horticultural oil at the dormant rate.
Frothy mass on twigs	Pine spittlebugs: soft bodied insects under spittle masses on twigs.	Present in May and June. Light infestations cause no damage. Heavy infestations may kill Scotch pine. If necessary spray with a residual insecticide in May.
White material on bark	Pine bark adelgid: fluffy white wax on branches and trunk in spring. Hemlock woolly adelgid: fluffy white wax at bases of needles in spring.	Usually does not warrant control. Use a dormant oil spray November to early March. Spray with insecticidal soap or summer weight oil from July through October to kill immature adelgids.
Branch Dieback	Sphaeropsis tip blight: advanced stages, lower branches die first. Bark beetles and borers: look for holes of various sizes. Rust diseases: swollen areas on trunk or branches, orange-yellow blister-like or gall-like areas on bark. Cankers: caused by various fungi. Common genera include <i>Cytospora</i>, <i>Botryosphaeria</i>, <i>Nectria</i> and <i>Phytophthora</i>. Cause dark, elongated lesions with roughened bark (excessive resin flow typical on conifers).	Maintain adequate irrigation during drought. Use a registered fungicide spray on new growth in spring. Remove severely damaged trees. Bark beetles and borers are stress related pests. Insecticide applications not always effective. Remove dead and dying trees. Reduce stress on existing trees by providing adequate water. Isolate alternate hosts where practical. No chemical controls available. No chemical control. Maintain adequate irrigation during drought. Prune out affected branches where practical.
Wilting	Pine wilt nematode: sudden drying out, branches become brittle.	No chemical control. Remove dead and dying trees. Avoid planting trees on dry sites that contribute to stress conditions.
Poor Growth	White pine decline: wrinkled bark on young branches, thin weak foliage. Procera root rot: resinous flow at soil line (primarily on pines).	No chemical control. Remove dead and dying trees. Avoid planting in poorly drained soils. Do not plant trees too deeply.
Dark spots or blotches on leaves	Fungal or bacterial diseases: black rot produces yellow-brown, wedge-shaped lesions and black leaf veins.	Pull-up and dispose of badly infected plants. Select resistant varieties.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF DECIDUOUS SHRUBS IN THE LANDSCAPE

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Leaf yellowing, foliage fades, yellows, browns or wilts, often scattered throughout the canopy.	Spider mites: very tiny, "period-sized". Present on lower leaf surfaces. Leaves yellow, eventually turn brown, and drop prematurely. Webbing may be visible with high populations in protected sites. Armored scales: encrustations on branches. Scales can be scraped off. Soft scales: appear as raised bumps on twigs and branches. Can be scraped off. Honeydew and sooty mold may be present. Whiteflies: small, transparent oval insects on leaf undersides. Tiny, white insects fly up when plant is disturbed. Borers: holes and tunnels in branches. Stem galls: enlarged growths on stems or branches. Root rots: general decline of plant, scattered dieback. Verticillium wilt: scrape twigs and branches to look for evidence of vascular browning.	When control is needed, use insecticidal soap or horticultural oils to minimize adverse effects on natural predators or consider releasing predatory mites. For either armored or soft scale infestations, prune out branches with severe symptoms. Spray tree with a dormant rate of horticultural oil during the dormant season to control overwintering scale insects. Generally controlled by parasites and predators. If control is needed, spray undersides of leaves with insecticidal soap. Prune out infested branches. Beneficial nematodes may be sprayed on infested areas of branches and stem, for lilac or rhododendron borers (clear wing borers). Prune out affected stems or branches. Remove plant. Improve soil drainage if replanting in same area. No sprays are effective. Prune out wilted and dead branches and irrigate during dry weather. Avoid root damage from salt or cultivation. In problem sites, select resistant alternative shrubs. Fertilization can encourage new growth if enough healthy roots are available to take up nutrients.
Leaf stippling (pinpoint yellow spots)	Spider mites: mites present on lower leaf surfaces. Leaves yellow, eventually turn brown, and drop prematurely. Webbing may be visible with high populations in protected sites. Lacebugs: stippling on upper leaf surface is white. Black fecal spots present on lower leaf surface.	When control is needed for spider mites, use insecticidal soap or horticultural oils to minimize adverse effects on natural predators. Consider releasing predatory mites. Insecticidal soap may be used to control lacebugs. Sprays should be directed towards the lower leaf surfaces.
Leaves eaten or chewed	Early and late season caterpillars, sawflies, or leaf feeding beetles	Early season caterpillars should be controlled when larvae are small and before damage is extensive. The biological insecticide B.t. is effective on small caterpillars. Handpick large caterpillars, sawflies and beetles. If necessary, use a residual insecticide spray.
Webbed or tented foliage	Euonymus caterpillar: on <i>Euonymus americana</i> . Also Gypsy Moth and Eastern Bent Caterpillar .	If numerous caterpillars are present, use B. t. when the caterpillars are small.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Leaf distortion, curling downward	Privet rust mite: leaves curl down and turn olive green.	Treat as needed with horticultural oil at the dormant rate in late winter to reduce overwintering populations.
Bags constructed of plant material attached to branches	Bagworms: caterpillars feed on foliage and construct protective silk bags covered with host plant material for protection.	Spray with B.t. when bags are small from mid-June to mid-July. Handpick and destroy bags during the fall and winter.
Whitish frothy material on foliage	Spittlebugs: small sucking insects that feed on terminal twigs of host plants.	Remove manually or spray with insecticidal soap.
Spots on leaves	Leaf spotting diseases: may be minor or in wet weather may blight entire leaves and cause extensive defoliation. Black spot on roses is a serious problem.	Generally not a serious problem, but may need to be controlled with registered fungicides in wet weather. Black spot can often be controlled with cultural practices.
Leaf mottling	Viruses: leaves have a mottled green and yellow colouration. Distortion may also be evident.	No chemical controls are available. Prune out affected branches or remove entire plant.
Serpentine trails or blotches in leaves	Various leafminers: larvae feed between the upper and lower leaf surfaces, Dogwood can be seriously injured.	Pick off affected leaves, dispose of infected plants when necessary.
Leaf blight	Bacterial leaf blights: tends to affect young leaves turning them black.	Prune out infected branches promptly when symptoms are first noticed.
White coating on leaves	Powdery mildew: a white surface growth on leaves and may cause distortion.	Controls are generally not needed. Leaves should be raked up in the fall. Check horticultural oil labels for powdery mildew control listings.
Sooty mold/ sticky honeydew	Aphids and various soft scales: Aphids are small, soft bodied insects. Soft scales appear as raised bumps on twigs and branches, and are easily scraped off.	Healthy plants can tolerate moderate populations of aphids and scales. Conserve natural enemies. If needed, spray when plants are dormant with horticultural oil at the dormant rate.
Shoots chewed and girdled, bark stripped	Deer feeding: worse during very cold winters	Where appropriate, electric fences are very effective. Repel deer by hanging one or more of the following from mesh bags on trees: small bars of soap, human hair, blood meal or mothballs.
Bark stripping or girdling	European hornets: large hornets with dark brown and orange markings. They will take strips of bark off branches for nesting material.	Usually no controls are necessary.
Scattered twig and branch dieback	Armored scales: small encrustations on branches. Can be scraped off. Borers: holes and tunnels in branches. Cicadas: deep slits made in bark during egg laying activity causes twigs to break easily in windy weather. Verticillium wilt, cankers and root rots: foliage fades, yellows, browns or wilts, often scattered throughout the canopy. Scattered dieback may also be present.	Prune out affected branches. Apply horticultural oil at the dormant rate before bud break in the spring to control scale infestations. Prevent borer infestations by keeping trees healthy. In most years damage from cicadas is minor and no control is necessary. Verticillium wilt is primarily a problem on lilacs. No sprays are effective. Prune out wilted and dead branches and irrigate during dry weather. Avoid root damage from salt or cultivation. In problem sites, select resistant alternative shrubs. Fertilization can encourage new growth if enough healthy roots are available to take up nutrients.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Stem galls	Crown gall: causes growths of abnormal tissue along stem.	Prune out affected areas or remove plant.
Fungal growths or mushrooms on branches or trunk	Decay fungi: reproductive structures are visible evidence of extensive interior wood decay or root rot.	Remove affected branches or plants.
Whitish cottony material on twigs and branches	Woolly aphids: honeydew may be present. Egg masses: of soft scales.	Healthy plants can tolerate moderate populations of aphids and scales. Conserve natural enemies. If high populations are present, spray when plants are dormant with horticultural oil at the dormant rate.
Frass around wounds and bark cracks	Clearwing borers: white larvae make shallow tunnels under the bark and push frass out through holes. Frass accumulates in branch crotches, bark and base of shrub.	Prune out infested branches. Beneficial nematodes may be sprayed on infested areas of branches and stems.
Wilting	Lack of water, wood boring beetles, root rots or extensive trunk damage.	No chemical controls are available. Prune out affected branches or stems.
Proliferation of branches or dense bushy growth (Witches Broom)	Possible causes include insects, eriophyid mites, fungal, viral or mycoplasma diseases.	Prune out affected areas.
Flowers affected	Thrips: cause white or brown streaks and blotches on blossoms. Japanese and chaffer beetles and rose slugs: feed on buds and flower petals. Botrytis petal blight: small discoloured spots enlarge and cause browning of entire flower.	Hand pick insects where possible and, if serious, use a residual insecticide to control insects. Dead head old blossoms promptly and avoid overhead watering.
TIP Consider replacing problem plants with shrubs better adapted to your site conditions and needs.		

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF EVERGREEN SHRUBS IN THE LANDSCAPE

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Leaf/needle yellowing, foliage fades, yellows browns or wilts, often scattered throughout the canopy.	Spider mites, scale insects, whiteflies, borers, root rots, fall colouration: Examine lower leaf/needle surfaces for presence of spider mites or whiteflies. Examine needles, twigs and branches for scale covers or borer holes.	To control spider mites or whiteflies, use insecticidal soap or horticultural oils to minimize adverse effects on natural predators. Sprays should be directed towards the lower leaf/needle surfaces. For either armored or soft scale infestations, prune out branches with severe symptoms. Spray shrub with a dormant rate of horticultural oil during the dormant season to control overwintering scale insects. Prevent borer infestations by keeping shrubs healthy. For root rots, prune out affected areas. Fertilization can encourage new growth if enough healthy roots are available to take up nutrients.
Leaf/needle stippling (pinpoint yellow spots)	Spider mites: mites present on lower leaf/needle surfaces. Leaves or needles yellow, eventually turn brown, and drop prematurely. Webbing may be visible with high populations. Lacebugs (broadleafed evergreens): stippling on upper leaf surface is white. Black fecal spots are present on lower leaf surface.	When control is needed, use insecticidal soap or horticultural oils to minimize adverse effects on natural predators. Sprays should be directed towards the lower leaf/needle surfaces. Consider releasing predatory mites to control spider mites. Insecticidal soap may be used to control lacebugs. Sprays should be directed towards the lower leaf surfaces.
Leaves/needles eaten or chewed	Early and late season caterpillars, sawflies, leaf feeding beetles or leaf notching weevils.	Early season caterpillars should be controlled when larvae are small and before damage is extensive. The biological insecticide B.t. is effective on small caterpillars. Handpick large caterpillars, sawflies and beetles. If necessary, use a residual insecticide spray.
Shoots chewed and girdled, bark stripped	Deer feeding: worse during very cold snowy winters.	Where appropriate, electric fences are very effective. Repel deer by hanging one or more of the following from mesh bags on trees: small bars of soap, human hair, blood meal or mothballs.
Cupping or leaf distortion	Boxwood psyllid: causes cupping of terminal leaves in the spring.	Control is only necessary for heavy infestations. Spray with horticultural oil or insecticidal soap in April and May.
Leaf galls	Exobasidium gall: swollen or puffy portions on newly expanded leaves.	No chemical controls are effective. Prune out infected leaves.
Webbed or tented foliage	Ugly nest caterpillar: caterpillars are yellowish or greenish with black heads. They construct dense nests by webbing twigs and leaves together. Juniper webworm: caterpillars are tan with brown stripes and black heads. Damage initially appears as yellowing needles. Larvae web branches together and feed inside the webbing.	If numerous caterpillars are present, use B.t. when the caterpillars are small. Prune out dead branches. Pull open webbed branches and look for active caterpillars. Use B.t. if caterpillars are small. A residual insecticide may be needed if damage is heavy and caterpillars are large. Treat only if necessary.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Bags constructed of plant material attached to branches.	Bagworms: caterpillars feed on foliage and construct protective silk bags covered with host plant material for protection.	Spray with B.t. when bags are small from mid-June to mid-July. Handpick and destroy bags during the fall and winter.
Whitish frothy material on foliage	Spittlebugs: small sucking insects that feed on terminal twigs of host plants.	Remove manually or spray with an insecticidal soap.
Spots on leaves/needles	Leaf spotting diseases: may be minor or in wet weather may blight entire leaves and cause extensive defoliation. Scale insects: yellow spots on needles. Light coloured scale covers will scrape off.	Leaf spotting diseases are generally not a serious problem, but may need to be controlled with registered fungicides in wet weather. When control is needed for scales, use insecticidal soap or horticultural oils to minimize adverse effects on natural predators. A dormant rate of horticultural oil applied when plants are dormant is effective.
Leaf mottling	Viruses: leaves have a mottled green and yellow colouration. Distortion may also be evident.	No chemical controls are available. Prune out affected branches or remove entire plant
Serpentine trails or blotches in leaves	Various leafminers: larvae feed between the upper and lower leaf surfaces. Especially boxwood and holly.	Pick affected leaves. For heavy infestations, use a registered systemic insecticide.
White coating on leaves	Powdery mildew: a white surface growth on leaves may cause distortion.	Controls are generally not needed. Leaves should be raked up in the fall. Check horticultural oil labels for powdery mildew control listings.
Sooty mold/sticky honey dew	Aphids and various soft scales: Aphids are small, soft bodied insects. Soft scales appear as raised bumps on twigs and branches.	Healthy plants can tolerate moderate populations of aphids and scales. Conserve natural enemies. If high populations of scale insects are present, spray when plants are dormant with horticultural oil at the dormant rate.
Discolouration of berries or fruit	Holly berry midge: berries remain green in the fall. Pyracantha scab: berries turn black.	Controls are not available for holly berry midge. Use a registered fungicide for scab.
Tip dieback	Juniper twig blights: caused by Phomopsis and Kabatina. Juniper tip midge and leaflet miners: tips mined out. Small caterpillars or midges may be present.	Use a registered fungicide on Phomopsis tip blight. Choose resistant varieties for Kabatina tip blight. Removal of severely diseased plants or replacement with resistant varieties may be the best remedy. For tip midge and leaflet miners, prune off and destroy infested tips in the dormant season. For heavy infestations on large trees, use a systemic insecticide in late June or September.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Scattered twig and branch dieback	Armored and soft scales: encrustations on branches can be scraped off. Borers: holes and tunnels in branches. Cicadas: deep slits made in bark during egg laying activity causing twigs to break easily in windy weather. Phytophthora root rot and dieback and Botryosphaeria cankers: foliage fades, yellows, browns or wilts. Damage and dieback are often scattered throughout the canopy. Verticillium wilt: can occur on magnolias.	Prune out affected branches, apply horticultural oil at the dormant rate before bud break in the spring to control scale infestations. Prevent borer infestations by keeping trees healthy. In most years damage from cicadas is minor and no control is necessary. Phytophthora and Botryosphaeria are primarily a problem on rhododendrons and azaleas. No sprays are effective. There are no controls for canker or wilt diseases. Prune out infected branches promptly. No sprays are effective. Prune out wilted and dead branches and irrigate during dry weather. Avoid root damage from salt or cultivation. In problem sites, select resistant alternative shrubs. Fertilization can encourage new growth if enough healthy roots are available to take up nutrients.
Rapid dieback of branch tips or leaves	Bacterial leaf blight: primarily occurs on American holly. Bacterial leaf blight tends to affect young leaves, turning them black. Fire blight: kills terminals quickly and turns them black. Leaves remain attached.	Prune out infected branches promptly when symptoms are first noticed. When symptoms are severe use a copper fungicide. Plant resistant varieties. Prune out infected parts using the ugly stub pruning method (see tip at end of Pome Fruit section). Otherwise dormant pruning of cankers is recommended. Reduce or eliminate nitrogen applications
Stem galls	Crown gall: causes growths of abnormal tissue along stem.	Prune out affected areas or remove plant.
Bark stripping or girdling	European hornets: large hornets with dark brown and orange markings. They will take strips of bark off branches for nesting material. Voies or meadow mice: will also chew on bark and roots of shrubs, especially boxwoods, junipers and Rhododendron.	Usually no controls are necessary traps can be used for rodents.
Fungal growths or mushrooms on branches or trunk	These structures are visible evidence of extensive interior wood decay or root rot.	Remove affected branches or plants.
Whitish cottony material on twigs and branches	Woolly aphids and mealybugs: honeydew may be present. Egg masses: of soft scales.	Healthy plants can tolerate moderate populations of aphids and scales. Conserve natural enemies. For heavy scale infestations, spray when plants are dormant with a horticultural oil at the dormant rate.
Frass around wounds and bark cracks	Clearwing borers: white larvae make shallow tunnels under the bark and push frass out through holes. Frass accumulates in branch crotches, bark and at the base of the shrub.	Prune out infested branches. Beneficial nematodes may be sprayed on infested areas of branches and stems
Wilting	Lack of water, wood boring beetles, root rots or extensive trunk damage.	No chemical controls are available. Prune out affected branches or stems.
Flowers affected (Rhododendrons and Azaleas)	Ovulinia petal blight: small, water soaked spots enlarge rapidly, cause flowers to collapse and feel slimy. Exobasidium flower gall: swollen areas on buds, flowers and petals.	Use a registered fungicide. Handpick and remove galls.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF ANNUALS AND PERENNIALS

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Plant wilting	Various root rots, stem cankers, borers, aphids, plant hoppers, root feeding insects: rule out abiotic causes (see abiotic problem key). Examine plants carefully for signs of boring activity such as frass and holes in the stem. Carefully dig up a specimen to observe root symptoms. Healthy plants can be replanted.	Remove diseased plants from the garden, cut out infested (rotten) portions of perennials and replant remaining healthy sections.
Leaves eaten or chewed	Caterpillars, leaf feeding beetles and weevils, grasshoppers, sawflies, slugs, earwigs	Caterpillars should be controlled when larvae are small and before damage is extensive. The biological insecticide B.t. is effective on small caterpillars. Large caterpillars, sawflies and beetles can be handpicked. Heavy insect infestations may require a residual insecticide spray. Treat only if necessary. Slugs may be controlled with diatomaceous earth, baits or by removing cover, such as excess mulch.
Leaf yellowing, foliage fades, yellows, browns or wilts	Aphids, spider mites, mealybugs, whiteflies, borers, stem galls, root rots, Verticillium wilt: examine lower leaf surfaces for presence of spider mites or whiteflies. Examine twigs and branches for scale covers or borer holes. Scrape base of stem near soil line to look for evidence of vascular browning.	Light insect infestations do not require control. Plants damaged by heavy insect or mite feeding can be injured by insecticidal sprays during hot, dry weather. For heavy to moderate mite infestations consider releasing predatory mites for biological control. Remove diseased plants from the garden. Prune or cut back affected sections
Leaf stippling	Leafhoppers, plant bugs (especially 4-lined): nymphs and adults feed on lush spring growth causing yellow stippling that may become necrotic black blotches. Stunting may occur.	Most plants will outgrow the damage later in the season. If necessary, replace heavily damaged annuals.
Leaf spots and leaf blotches	Various fungi, bacteria, foliar nematodes, Plant bugs i.e., four lined plant bug: yellowish green, black stripes, 0.75 cm long. Nymphs are bright orange. Feeding causes perfectly circular spots. Harlequin bugs: red and black, shield shaped. Feeding causes white and yellow blotches on leaves.	Remove spotted leaves. Improve air circulation to prevent leaf diseases. Plants can tolerate heavy plant bug feeding.
Blights	Southern blight, Rhizoctonia web blight: foliage collapses and turns brown or black. Plants may be killed.	Improve soil drainage and air circulation. Pull mulch back away from stems. Use a registered fungicide for severe outbreaks.
Leaf scorch	Abiotic stresses, heavy spider mite, whitefly and thrips feeding: symptoms can occur along leaf margins or between veins.	Plants damaged by heavy insect or mite feeding can be injured by insecticidal sprays during hot dry weather. For heavy to moderate mite infestations consider releasing predatory mites for biological control.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Twisted and distorted plant growth	Aphids: small, soft bodied insects on young growth, stems and leaves. Treehoppers: common, small jumping insects, vary in shape. Some appear humpbacked or resemble thorns. Viruses: foliage appears mottled green and yellow. Plants may be stunted.	Aphids are usually controlled by beneficial insects. Reduce heavy infestations of aphids, and treehoppers with sprays of insecticidal soaps to conserve beneficials. There are no controls for viruses. Remove infected plants.
Leaf mottling	Viruses: foliage appears mottled green and yellow. Plants may be stunted.	Remove infected plants.
Light coloured tunnels or blotches (mines) in leaves	Leafminers: larvae feed between the upper and lower leaf surfaces.	Pick off and dispose of infested leaves.
White powdery coating on leaves	Powdery mildew fungi: grow on the leaf surface.	Spray with registered fungicides if disease is severe. Check horticultural oil labels for powdery mildew control listings.
Orange yellow spots on leaves and stems	Rust fungi: cause orange coloured spots on leaves and stems.	Spray with registered fungicides if disease is severe.
TIP It is often easier and cheaper to replace annuals and perennials than to go through a lot of trouble and expense to control a problem.		

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF HOUSEPLANTS

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Plant wilting	Overwatering or lack of water: overwatering can cause root rots. Healthy roots should be light coloured and firm. Various root rots: pull plant out of the pot and observe roots for discolouration. Diseased roots will appear dark and soft. Stem cankers: discoloured areas on stem.	Use a well-drained, peat based potting media. Severely damaged plants should be discarded. Remove diseased plants from their pots, cut out infested portions (rotten), and replant remaining healthy sections. Take cuttings and root them in sterile potting mix. Prune out affected areas.
Leaf yellowing, foliage fades, yellows browns or wilts	Aphids: small soft bodied insects found on leaves, stems and flower buds. Spider mites: minute pests that feed on lower leaf surfaces, webbing may be visible. Mealybugs: white cottony insects. Whiteflies: adults are tiny white insects that fly from the plants when disturbed. Immature stages found on lower leaf surfaces. Brown soft scale and hemispherical scale: raised black or brown bumps on leaves and stems. Root rots: discoloured and softened roots.	Regularly rinse plants with water to keep down pest problems. Use a registered houseplant spray to control pests. Plants damaged by heavy insect or mite feeding can be injured by insecticidal sprays. Severely damaged plants should be discarded. Remove diseased plants from their pots, cut out rotten portions, and replant remaining healthy sections. Take cuttings and root them in sterile potting mix
Fine stippling	Spider mites: minute pests that feed on lower leaf surfaces, webbing may be visible.	Regularly rinse plants with water to keep down spider mite problems. Use a registered houseplant spray to control mites. Plants damaged by heavy mite feeding can be injured by insecticidal sprays. Severely damaged plants should be discarded.
Leaf spots and leaf blotches	Water spots, sunburn, various fungi, bacteria.	Remove spotted leaves and improve air circulation for leaf diseases. Keep water off foliage of sensitive plants.
Leaf scorch	Abiotic stresses such as over-fertilization, lack of water: scorching symptoms can occur along leaf margins or between veins.	Leach excessive fertilizer from potting mix by flushing with water or repot with fresh potting media.
Stunted, twisted and distorted plant growth	Aphids: small soft bodied sucking insects. Cyclamen mites: predominately a pest of flowering plants. New growth is affected first. Viruses: foliage appears mottled green and yellow. Plants may be stunted.	Aphids can be controlled with a stream of water or with a registered insecticide. Cyclamen mite infested plants and virus infected plants cannot be easily cured and should be discarded.
Leaf mottling	Viruses: foliage appears mottled green and yellow. Plants may be stunted.	Discard infected plants.
White powdery coating on leaves	Powdery mildew fungi: grows on the leaf surface.	Provide better air circulation and pick off infected leaves. Spray with a registered fungicide if disease is severe. Check horticultural oil labels for powdery mildew control listings.
Fluffy white wax	Mealybugs: white cottony insects may occur on foliage, in leaf axles, leaf sheaths, roots and bud scales.	Use a registered houseplant spray to control mealybugs.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Leaves eaten or chewed	Check plants that have been outside for the summer for pests such as caterpillars, leaf feeding beetles, weevils, grasshoppers, crickets, slugs, and earwigs.	Hand pick pests and repot plants before moving plants inside.
Few or no flowers	Low light levels, excessive fertilizer, cyclamen mites.	Increase light levels by relocating plants closer to a light source or add additional artificial light sources. Cyclamen mite infested plants should be discarded.
Spindly growth	Low light levels or excessive fertilizer	Increase light levels by relocating plants closer to a light source or add additional artificial light sources. Reduce fertilizer applications during winter. Irrigate thoroughly from the top of the pot to leach out excess fertilizer salts.
Poor growth	Poor culture, insects and diseases	
Flying insects	Whiteflies: tiny white insects flying around plants. Fungus gnats: tiny black flies flying near plants or near light sources.	Use a registered insecticide for whiteflies. Allow potting media to dry between waterings.
Insects in potting media	Ants, sowbugs, springtails, slugs: often brought in from outside when relocating plants from summering outdoors.	Repot plants with fresh potting media. Beneficial nematodes may be used to control fungus gnat larvae.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF TURF

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Leaf spots	Most common fungi are: Helminthosporium leaf spot: leaf spots with tan centres. Lesions are round or elongate. Turf thins out. Common in wet spring weather and affects primarily bluegrass and ryegrass. Dollar spot: leaf lesions with a dark border and hour glass shaped spots. Affects all turfgrass species. Common in late spring on turf under low fertility. Brown patch: elongated lesions with chocolate brown margins. Entire leaves may turn brown and thinning may occur. Occurs in mid-summer.	Avoid drought stress and light or frequent watering. Reduce thatch build-up and avoid spring fertilization with soluble nitrogen sources. Reseed with improved turf cultivars. Avoid drought stress. Prevent thatch buildup and soil compaction. Maintain adequate nitrogen fertility and reseed with improved turf cultivars. Tall fescue turf maintained at proper mowing heights and fertility rates will recover in the fall.
Pink/reddish colour on leaf blades	Red thread: red, thread-like growths extending beyond leaf blades. Appears in patches and occurs in spring and fall on fine fescue and perennial ryegrass species.	Maintain adequate nitrogen fertility levels.
Gray to black streaks in leaf blades	Striped smut: leaves split into ribbons and curl. Appears in irregular patches and infects primarily bluegrass in spring and fall.	Avoid drought stress and excessive thatch. Reseed with improved turf cultivars.
Blades covered with red, orange or yellow powdery material	Rust diseases: turf may appear yellow or reddish from a distance. Occurs primarily on bluegrass, ryegrass, and zoysia.	Maintain adequate nitrogen fertility levels and reseed with improved turf cultivars.
Blade covered with a white coating	Powdery mildew: white coating, typically occurs in shady areas in the fall on bluegrass.	Reduce shade and improve air movement. Avoid excessive nitrogen and drought stress. Increase mowing height and reseed with improved disease resistant cultivars.
Blades covered with black sooty-like material	Sooty mold: not harmful. It is easily wiped off or removed. Blades remain green underneath. Occurs primarily in spring or fall after rain.	Wash off sooty material with a hose or remove material by mowing.
Rings or arcs of dead or green grass, mushrooms may be present	Fairy rings: rings or arcs of dead or green grass bordered by zones of darker green grass. More common on droughty sites and poorly nourished turf. Occurs on all turf cultivars throughout the growing season.	Aerate turf frequently; maintain adequate nitrogen fertility and adequate water during dry spells.
Circular straw coloured patches	Summer patch: circular patches that range from 7-30 cm in diameter. Occurs in bluegrass and fine fescue lawns 2 years or older, July to September.	Avoid excessive nitrogen especially in spring. Use slow release nitrogen sources. Increase mowing height, avoid light frequent watering and reduce thatch build-up.
Turf comes up easily, obvious lack of roots	White grubs: turf can sometimes be rolled up like a carpet. C-shaped grubs found in soil from June through September. Can be severe on bluegrass, rye grass and fine fescues.	Reseed the lawn in the fall with a tolerant fall species such as tall fescue.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Turf blades can be pulled easily from sod	Billbugs: light tan sawdust-like frass in areas of heavy feeding. Small legless grubs found near crowns and roots from June through August.	Water and fertilize grass to stimulate regrowth. Reseed with endophyte containing tall fescues. If necessary, use a registered insecticide April to mid-May.
Irregular brown patches with white moths flying over the turf	Sod webworm: brown caterpillars may be found at the base of the blades and in the thatch. Active from June through July.	Reseed with grasses with high levels of endophyte such as tall fescue, or spray with B.t. insecticide.
Localized yellow or brown areas	Chinch bugs: tiny black insects with shiny white wings found on crowns and stems. Damage usually occurs in sunny well drained locations.	Reseed with grasses with high levels of endophyte such as tall fescue. Often controlled by natural predators such as big-eyed bugs.
Straw coloured patches surrounded by a ring of dark green turf.	Dog urine: symptoms may resemble some diseases. May kill the crown tissue	Heavy irrigation will promote recovery of spots.
Banded streaks or irregular patterns	Fertilizer or chemical injury: grass may be stimulated at the margins. May kill the crown tissue.	Calibrate spreaders and sprayers for uniform and accurate application of materials.
Black or dark spots or patches on lawn	Oil or gasoline damage: from leaking lawnmower.	Severe oil leak or spill requires removal of affected soil. Small gasoline leaks or spills volatilize quickly. Soil should be replaced if saturated.
Large yellow area near pool	Chlorine damage from pool water.	Leach chlorine through soil with water. Replant.
Grass over high spots looks scalped	Mower injury: crowns of plants exposed	Adjust terrain, raise mower blade or change mowing direction.
Shredded blade tips	Dull mower injury: tips appear gray and then turn tan.	Sharpen mower blades.
Patches of dead or dormant grass	Buried debris, shallow soil, insect injury or thick thatch: often follows a dry period.	Check for causes.
Pale green to golden yellow turf	Chlorosis: iron or nitrogen deficiency. Yellow streaks may form parallel to leaf veins	Maintain adequate fertilizer levels.
Black or greenish crust on soil	Algae growth: on bare soil or in thin turf. Occurs in poorly drained or compacted areas, usually more severe in shade.	Increase drainage and establish a thicker stand of turf. Aerate compacted areas and increase sunlight in shaded areas.
Small green plants growing with turf	Moss: on bare soil or in thin turf. Occurs in poorly drained or compacted areas, usually more severe in shade.	Increase drainage and establish a thicker stand of turf. Aerate compacted areas and increase sunlight in shaded areas.
Turf appears dry and bluish green in colour.	Drought: foot prints remain after walking on turf. Grass wilts.	Irrigate turf.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF SOLANACEOUS CROPS (Tomato, Pepper, Eggplant, Potato)

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
FOLIAGE		
Leaf yellowing	Various wilt diseases (internal stem tissue discoloured). Verticillium and Fusarium are common. Spider mites: fine yellow stippling (leaf undersides may appear dirty). Mites can be seen on leaf undersides with naked eye or hand lens. Leafhoppers: small, green, wedge-shaped insects that can spread virus diseases.	Use resistant varieties. Resistant varieties are indicated by the letter V and/or F following the cultivar name. Plants with severe mite damage are further injured by insecticidal sprays (including soaps and oils). Consider releasing predatory mites. Cover vulnerable plants with a floating row cover.
Leaf spots (small, dark lesions)	Various fungal diseases: early blight very common on tomatoes. A "bulls-eye" pattern may be observed. Bacterial diseases: bacterial spot on peppers appears as water-soaked blotches.	Increase distance between plants. Spread mulch around plants and avoid overhead watering. Use a registered fungicide if disease becomes severe. Early blight resistant varieties of tomatoes are followed by the letter A. Control with fixed copper sprays. Increase distance between plants. Spread mulch around plants and avoid overhead watering.
Leaf/stem blotches and blights	Advanced symptoms of various fungal and bacterial diseases. Late blight on potato and tomato: dark brown blotches on leaf tips and margins that enlarge rapidly producing a water-soaked appearance. Blackleg on potato: blackening of plant above and below soil-line. Southern Blight (tomato and pepper): brown-black cankers on lower stem.	See above. Use fixed copper sprays or other registered fungicides. Avoid overhead watering. Use certified disease free seed stock. Discard severely diseased plants. Pull out and dispose of infected plants. Use certified disease free seed pieces. Remove and dispose of infected plants. Work in organic matter and rotate plants to new area.
Leaf curling/distortion	Aphids, leafhoppers: soft, pink or green insects on young growth. Viruses: mottled, deformed leaves (most common on peppers and potatoes). Bacterial diseases of potato.	Naturally-occurring predators and parasites control aphids. Pull out and discard virus-infected plants. Discard infected tubers. Plant certified seed stock.
Entire plant wilts	Fungal and bacterial diseases: fusarium most common on tomatoes. Plant wilts from bottom up and recovers at night. Bacterial wilt causes a more rapid top-down wilt. Discoloured stem tissue observed with all wilt diseases. Potato tuberworm: Small, pinkish-white caterpillar with brown head that tunnels in stems, leaves and tubers of potatoes. Other solanaceous crops may be damaged if planted near infested potatoes.	Pull out and discard infected plants. Use resistant varieties. Where fusarium is a problem, use varieties resistant to all three races or strains of the disease. Cover vulnerable plants with a floating row cover. Keep tubers covered with soil and mulch around plants. Discard infested plants and tubers.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Chewed and mined leaves	Pin worm: folded, webbed and mined leaves. Small dark caterpillars may be seen. Various caterpillars: especially tomato hornworm on tomato. Flea beetles: tiny holes in shotgun pattern usually on eggplant and tomatillo. Small, dark beetles jump when disturbed. Colorado potato beetles: adults and larvae chew entire leaves, usually on eggplant, potato and tomato. Potato tuberworm: tunnels into leaves.	Destroy larvae and dispose of infested fruit and plant residues. Caterpillars are generally not serious pests. Pick-off and destroy. Prevent damage by covering plants with a floating row covers. Where pest pressure is severe, row cover may be required for entire season (remove for pollination). Prevent damage by mulching plants, covering plants with a floating row cover or hand picking pests. For heavy infestations, spray young larvae with B.t. product. Prune out.
FRUITS		
Holes or chewing damage in fruit	Various caterpillars, crickets, grasshoppers, Colorado potato beetles, or slugs.	Handpick pests. Pick-off and discard damaged or infested fruits.
Spots on fruits	Various fungal and bacterial diseases Stink bugs: brown or green, shield-shaped bugs that suck fruit sap leaving hard, yellow spots beneath fruit skin on pepper and tomato.	Pick-off and discard fruit. Remove all infected fruits from garden. Damage is typically superficial (cut-out infected area). Remove affected fruits from garden.
Large, discoloured areas	Late blight, buckeye rot (concentric rings) Anthraxnose (eggplant): dark, sunken spots.	Pick-off and discard fruit. Remove all infected fruits from garden.
Soft rots	Various fungal and bacterial diseases	Pick-off and discard fruit. Remove all infected fruits from garden.
TUBERS		
Tunnels bored into tubers	Potato tuberworm: small, pinkish-white caterpillar with brown head that tunnels in tubers of potatoes. Other solanaceous crops may be damaged if planted near infested potatoes.	Cover vulnerable plants with a floating row cover. Keep tubers covered with soil, mulch plants and discard infested plants and tubers.
Skin discolouration (brown or purplish), internal corkiness, symptoms may appear in storage	Early Blight: "bulls-eye pattern" on surface lesions. Late blight: dark, corky area just below skin. Scab: sunken or raised rough patches may extend shallowly into tubers. Rhizoctonia canker (black scurf): small, dark specks or spots that do not rub off easily.	Dispose of infected tubers. Dispose of infected tubers. Plant resistant varieties. Maintain pH at or below 5.2. Skin-deep only. Peel off affected skin. Do not re-plant tubers.
Internal browning (symptoms may appear in storage)	Bacterial or viral diseases: brown rings may be observed in cut tubers.	Discard infected tubers. Plant certified, disease free seed pieces.
Soft rots	Bacterial diseases (blackleg): slimy and smelly tubers.	Plant in well-drained soil. Hill soil up around plants when full grown. Harvest immediately after vines die. Only plant certified, disease free seed pieces.
TIP Letters after variety names on seed packets or in catalogues indicate resistance or tolerance to diseases and nematodes. As an example, following is a list for tomatoes: V or VI - Verticillium wilt, F- Fusarium wilt, FF or F1, F2 race 1 and race 2 Fusarium wilt, N - nematodes (root knot), T or TMV - tobacco mosaic virus, A - <i>Alternaria alternata</i> (crown wilt), L or SLS - leafspot (Septaria), St - <i>Stemphyllium</i> (gray leaf spot).		

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF CUCURBITS (Cucumber, Squash, Melons, etc.)

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
FOLIAGE		
Leaf yellowing	Spider mites: fine, yellow stippling. Leaf undersides may appear dirty. Mites can be seen on leaf undersides with naked eye or hand lens. Squash bugs: eggs are golden ovals laid in clusters on and under leaves. Adults and nymphs suck sap producing a pale yellow-green spotting on leaves.	Plants with severe mite damage are further injured by insecticidal sprays (including soaps and oils). Consider releasing predatory mites. Handpick eggs. Cover plants with a floating row cover (remove during bloom to ensure pollination).
Leaf scorching	Advanced symptoms of fungal and bacterial diseases, spider mites and squash bugs.	Pull-up and dispose of badly infected plants.
White powdery growth on leaves, may be on both surfaces	Powdery mildew: starts mid-summer on older leaves. Can spread rapidly causing plants to yellow and die.	Use resistant varieties and dispose of infected plants. Check horticultural oil labels for powdery mildew control listings.
Yellow spots on leaf surface, downy, grayish spots on undersides	Downy mildew: mostly on cucumber and muskmelon. Starts on older leaves in August with cooler night temperatures.	Use resistant varieties and dispose of infected plants.
Circular or irregular dark spots on leaves/stems	Fungal or bacterial diseases. Gummy stem blight: blackening of stem at soil-line, primarily on muskmelon and watermelon.	Use resistant varieties and dispose of infected plants. Plant resistant varieties and dispose of infected plants.
Leaf curling/cupping	Aphids: leaves curl downward, turn brown and die. Aphids transmit viral diseases.	Naturally-occurring parasites and predators usually keep aphid populations in check.
Yellow or green mottling of leaves, leaves may be distorted	Virus diseases: leaves may curl upward or downward.	Pull out and dispose of infected plants. Control weeds, aphids and cucumber beetles, and plant resistant varieties.
Wilted vines	Squash vine borer: small, cream-coloured caterpillar with brown head. Adult female is large, reddish and wasp-like, that lays eggs on plant stems and leaf stalks. Piles of sawdust-like frass (excrement) may be observed. Feeding usually occurs at base of a large stem. Bacterial wilt: mainly on cucumber and muskmelon. Spread by cucumber beetle feeding. Vines recover at night but eventually die. To confirm diagnosis: cut a wilted stem close to plant base. Cut the stem in half and rejoin the cut surfaces. Upon drawing the sections apart you will see threads of bacterial ooze.	Use a razor to slit stems and remove borers. Mound soil over the wound. Cover plants with a floating row cover. Remove during bloom to ensure pollination. Do not spray insecticides when bees are active. Plant varieties with some purported resistance to cucumber beetles, and control cucumber beetles early in the season. Cover transplants with a floating row cover. Remove during bloom to ensure pollination. If necessary, use a registered insecticide. Do not spray insecticides when bees are active.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Holes chewed in leaves, flowers and stalks	Cucumber beetles: yellow-green beetles with black stripes or spots.	Protect young plants. Feeding damage is severe after bloom period. Cover with a floating row cover. Remove during bloom to ensure pollination or use a registered insecticide after transplanting or seedling emergence. Discard all plant debris at season end. Fall tillage may interrupt overwintering sites.
FRUITS		
Holes tunneled in fruit	Pickleworm (late season problem), squash vine borers (especially pumpkin).	Remove and dispose of infected fruit.
Fuzzy, gray and black growth on squash and pumpkin blossoms and young fruits	Choanephora wet rot: a problem in wet weather.	Remove blossoms that stick to young fruit and remove and discard infected blossoms and fruits
Watersoaked or dry, sunken, black or brown spots on fruit	Fungal and bacterial diseases.	Plant resistant varieties. Keep plants mulched and remove and discard infected fruits.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF BRASSICAS (Broccoli, Cabbage, Collards, etc.)

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
FOLIAGE		
Leaf yellowing	Spider mites: fine, yellow stippling. Leaf undersides may appear dirty. Mites can be seen on leaf undersides with naked eye or hand lens. Harlequin bug: red and black shield-shaped adults and nymphs suck plant sap. Eggs are black and white and barrel-shaped. Fusarium yellows (mostly on cabbage): plants are stunted with purple leaf margins.	Plants with severe mite damage are further injured by insecticidal sprays (including soaps and oils). Consider releasing predatory mites. Handpick eggs and adults. Cover plants with a floating row cover. Remove all crop debris where infestations are severe. Pull out and discard badly infected plants. Select resistant varieties.
Light coloured spots on leaves	Downy mildew: yellow-green spots on leaf surfaces. White-gray, fuzzy mold develops on lower leaf surfaces in moist weather.	Pull out and discard infected plants. Use resistant varieties.
Dark spots or blotches on leaves	Fungal or bacterial diseases: black rot produces yellow-brown, wedge-shaped lesions and black leaf veins.	Pull-up and dispose of badly infected plants. Select resistant varieties.
Leaves curled, clusters of gray or green insects	Aphids: suck on plant sap causing leaves to lose colour.	Naturally-occurring parasites and predators usually keep aphid populations in check.
Wilted plants	Fungal and bacterial diseases: cabbage maggots are more common in radishes and turnips and roots are tunneled and slimy. Club-root: infected plants have large swellings on roots.	Pull out and discard infected plants. Rotate crops, and plant resistant varieties. Use a floating row cover for cabbage maggot. Adjust soil pH to 7.2 with hydrated lime. Pull out and discard infected plants and rotate crops.
Holes chewed in leaves	Various caterpillars: chew ragged holes. Flea beetles: small holes in scatter-shot pattern. Small dark, shiny beetles that jump when disturbed.	Cover plants with a floating row cover, hand pick eggs and larvae or spray B.t. products when larvae are young. Cover plants with a floating row cover. Chinese cabbage more severely affected.
HEADS/FLORETS		
Soft rots	Fungal and bacterial diseases (more likely on over-mature plants).	Remove infected plant parts. Grow brassicas in well-drained soil and rotate crops.
Holes chewed	Various caterpillars (feed on foliage first)	Cover plants with a floating row cover. Handpick eggs and larvae or spray B. t. products when larvae are young.
ROOTS		
Holes or tunnels	Cabbage maggots: most common on turnips and radishes. Brown grooves may be observed on surface. Tunnels are slimy. Maggots can spread blackleg and soft rots.	Discard infested roots and dispose of plant debris. Use a floating row cover over seedbed or transplants.
Large swellings, club-like malformations	Club-root, fungal diseases	Pull out and discard infected plants. Rotate crops and plant resistant varieties. Adjust soil pH to 7.2 with hydrated lime.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF LEGUMES (Beans, Peas)

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
LEAVES/STEMS		
Leaf yellowing, entire plant declines	Root aphids: small white insects that feed in clusters on plant roots.	Pull out and dispose of plants. Till soil and re-plant with crops of a different vegetable family.
Discolouration of roots and lower stems	Various soil-borne fungal root rots: more likely to occur on slow-growing, stressed plants.	Pull out and discard infected plants. Plant on ridges or raised beds in well-drained soil and rotate crops.
Wilting	Various fungal root rots, fusarium wilt: persistent, soil-borne fungus. Accompanied by lower leaf yellowing, stunting and internal stem discolouration.	Pull out and discard infected plants. Plant on ridges in well-drained soil and rotate crops. If caused by fusarium, plant resistant varieties.
Dark spots and blotches	Various fungal and bacterial leaf blights.	Remove all plant debris at season's end. Plant resistant varieties in well-drained soil. Space plants out for improved air circulation.
Yellow spots, red-brown pustules	Rust: rust-coloured spots surrounded by yellow halos form on leaves, stems and pods.	Remove all plant debris at season's end. Select resistant varieties.
White moldy growth on leaves, stems and pods	Various fungal diseases: downy mildew produces more of a dry rot while white mold and pod blight are accompanied by water soaked spots. More severe in wet seasons with plants eventually dying.	Remove and discard infected plant debris. Select resistant varieties where available. Rotate crops and provide good air circulation
White, powdery growth on leaves and pods	Powdery mildew: pods may become distorted. A late season problem favoured by cool, dry weather.	Plant resistant varieties. Some bean varieties are sensitive to sulfur fungicidal sprays. Check horticultural oil labels for powdery mildew control listings.
Leaf and stem distortion	Aphids: small soft-bodied insects feed in clusters and are light-green to black in colour. Their feeding causes cupping, yellowing and distortion of young leaves. Aphids may also spread viral diseases. Potato leafhopper: on beans, damage appears as leaf margin curling, browning and eventual wilting. Viral diseases: leaves may be yellowed or mottled. Plants may be stunted or wilted.	Natural predators and parasites are usually sufficient to control pest populations. Other options include insecticidal soap and a floating row cover. Use a floating row cover. Pull out and discard infected plants. Use resistant varieties.
Leaf stippling	Spider mites: pale yellow or bronze discolouration. Leaves and entire plants eventually turn brown and die.	With moderate-severe infestations consider purchasing and releasing predatory mites.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Chewed leaves and stems	Mexican bean beetle: adults and nymphs skeletonize leaves. Yellow, oval-shaped eggs are laid on leaf undersides. Bean leaf beetle: rounded holes in leaves. European corn borer: feed on leaves and bore into stems. Flea beetles: chew tiny, round holes in leaves. Small, dark, shiny beetles that jump when disturbed. Grasshoppers: large ragged holes chewed in leaves (mid-late summer problem).	Handpick eggs, larvae and adults. Use a floating row cover. Remove and discard infested plants. Use a floating row cover. Use a floating row cover.
PODS		
Holes chewed in pods	Various caterpillars (corn earworm, corn borer and gray hairstreak).	Handpick pests. Use a floating row cover or registered B.t. insecticide product.
Tiny grubs inside seed	Bean and pea weevil or cowpea curculio (on limas and cowpeas). Sometimes noticed when bean seed is saved and stored.	Discard all plant trash at season's end. Use a floating row cover.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF SWEET CORN

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
LEAVES/STEMS		
Dark spots, blotches and streaks	Various fungal diseases.	Remove and dispose of infected plant debris and plant resistant varieties.
Small rust-coloured pustules	Rust: favoured by cool, humid weather. Oxalis is alternate host for this disease.	Remove and dispose of infected plant debris and plant resistant varieties. Eliminate Oxalis from immediate garden area.
Stunted/wilted plants	Stewart's bacterial wilt: leaves develop yellow streaks. Leaf margins have irregular brown areas. Disease is transmitted by flea beetles and tends to be more severe on young plants.	Remove infected plants and plant debris. Till soil in late fall to disrupt flea beetle habitat, and plant resistant varieties.
Holes chewed in leaves	Flea beetles: small, round holes and small, dark, shiny beetles that jump when disturbed. Spreads bacterial wilt disease. Holes bored in stalk. Various caterpillars: corn earworm and fall armyworm produce irregular holes and notching in leaf margins. European corn borer makes shot holes in unfolding whorl leaves. Grasshoppers and various beetles will also feed on leaves.	Ignore damage. Small losses of plant tissue will not reduce yields.
Holes bored in stalk	European corn borer: pale-pink or brownish caterpillars with dark brown heads, 2.5 cm long.	Remove and dispose of plant debris and hand pick cream-coloured egg masses on leaf undersides. Control with registered insecticides is rarely required in home gardens
EAR DAMAGE		
Fleshy galls on ears, leaves, stalks and tassels	Smut: soil-borne fungus produces white, fleshy growths that turn brown with dark powdery spores. More severe in dry seasons. Considered a gourmet item when young.	Remove and destroy growths when noticed to prevent galls and powder from reaching the soil surface. Plant resistant varieties.
Silks chewed	Japanese and cucumber beetle damage: pollination may be prevented if feeding occurs early in silking. Various caterpillars: en route to ear.	For serious beetle problems spray with a registered insecticide. Handpick insect pests. Use B.t. products on silks to control young caterpillars.
Ear and kernel feeding	Various caterpillars: corn earworms feed on the tips of ripening ears. Armyworms and corn borers may enter the ear at base, side or tip. Sap beetles are small, round and black and feed on exposed and damaged kernels. Birds, rats, raccoons and deer are some wildlife pests.	Harvest sweet corn when the silks turn brown and kernels are plump. Tip damage can be cut away from healthy ears. Pull and discard badly damaged ears. Insecticides are ineffective once ear damage is observed.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF ALLIUMS (Garlic, Onions, Leeks, etc.)

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
LEAVES/STALKS		
White flecking or streaking	Thrips: produce long white streaks. Botrytis leaf blight: white specks expand and leave dieback from tips and turn brown. Downy mildew: starts on older leaves. White or purplish mold develops in cool, moist weather.	Use a floating row cover. Pull out and discard infected plants. Plant resistant varieties where available and rotate crops. Increase plant spacing. Same as above.
Water-soaked spots that turn brown. Enlarging lesions turn purple with yellow halos.	Purple blotch: fungus disease that overwinters in plant debris. More severe in wet weather.	Pull out and discard infected plants. Plant in raised beds and rotate crops.
Yellowing and dieback of leaf tips, wilting	Various fungal or bacterial diseases (white mold). Onion root maggot: small, white maggots tunnel into plant base (more likely on shallot and onion).	Pull out and discard infected plants. Rotate crops. Use a floating row cover. Space plants farther apart, remove all plant debris at season's end and till soil in late fall to disrupt over-wintering sites. Do not apply fresh manure to garden soil.
BULB DAMAGE		
Necks and bulbs become soft, slimy and smelly, typically in storage	Various fungal and bacterial diseases.	Discard infected bulbs. Avoid late nitrogen feeding. Allow plant tops to dry prior to harvest. Avoid injuring bulbs during harvest, and remove and discard all plant debris. Rotating crops may be helpful.
Tunnelling in bulb	Onion root maggot: 0.75 cm long, creamy-white larvae (especially on shallots and onions). Pupae overwinter in soil.	Use a floating row cover. Space plants farther apart, remove all plant debris at season's end and till soil in late fall to disrupt over-wintering sites. Do not apply fresh manure to garden soil.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF SWEET POTATO

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
FOLIAGE		
Holes chewed in leaves	Sweet potato flea beetle: chews narrow grooves along leaf veins.	Not a serious problem. Plants outgrow damage.
Spots and blotches	Various fungal diseases: minor damage.	No controls necessary.
ROOTS		
Black or brown spots on skin, discolouration extends beneath surface	Various fungal diseases.	Select resistant varieties and purchase certified, disease free seed stock. Do not attempt to store infected roots.
Irregular, brown skin blotches on skin, does not extend beneath surface	Scurf (a fungal disease)	Peel off affected skin. Plant certified, disease free slips.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF ASPARAGUS

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
FOLIAGE/STEMS		
Low plant vigour	Over-harvesting, deep cultivation, weed competition, low soil fertility, old planting, poor vigour.	See Vegetable Chapter.
Tops turn yellow, brown and dieback	Rust (fungal disease): reddish-brown, orange or black pustules on stems and leaves.	Cut tops close to ground in fall. Plant resistant or hybrid varieties.
Foliage chewed	Asparagus beetle: adults and larvae feed on foliage throughout season. Adults are 0.5 cm, blue-black beetles with red area behind head. Larvae are gray-green grubs 1 cm long.	Handpick larvae and adults.
Stunting and resetting of ferns	Asparagus aphids: small, green insects feed in clusters in leaf axils.	Remove and destroy all ferns in the fall.
SPEAR PROBLEMS		
Weak, spindly spears	Fusarium wilt and crown rot: internal discolouration of stem and shoot tissue. Crowns buried too deeply, heavy clay soil	Remove infected plants (including crown). Plant resistant hybrid varieties. See Chapter 13 - The Vegetable Garden.
Tough or deformed spears	Harvested too late, low soil fertility Damage to crown, underground buds	Side-dress plants with fertilizer in early spring. Pull weeds and avoid cultivation with tools. Pull rather than cut spears.
Red/brown discolouration	Rust (fungal disease)	Cut-out and remove infected spears. Plant resistant or hybrid varieties.
Feeding on spear surface, brown scarring	Asparagus beetle: adults and larvae begin feeding with spear emergence in early spring (see description above). Slugs, snails: newly emerged spears chewed. Look for slime trails.	Wash off elongated, dark-brown eggs inserted into spears. Handpick adults and larvae. Hand pick at night. Lay down coarse barriers of sand, crushed oyster or crab shell or diatomaceous earth.
Spears, bent and shriveled, white or light green	Phytophthora root or crown rot: more common in wet seasons. Frost injury.	Plant certified, disease free crowns in well-drained soil. Plant away from diseased areas.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF OTHER VEGETABLE CROPS

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
LETTUCE, SPINACH, BEETS, CHARD		
Leaves chewed	Various caterpillars, leaf-feeding beetles and slugs. Flea beetles: (on spinach) chew small, round holes, producing a scatter-shot pattern. Larvae may mine leaf undersides. Rabbits and other wildlife pests.	Hand pick pests or use a floating row cover where pest pressure is severe. Use a floating row cover. Fence out large pests. Sprinkle bloodmeal or crushed hot pepper flakes around plants to deter rabbits.
Brown spots, blotches or trails on leaves	Leaf miners: tiny white maggots produce serpentine or blotch mines by feeding between leaf surfaces.	Use a floating row cover. Remove damaged leaves/plants.
Yellowing and browning of older leaves	Various fungal diseases (soil-borne): some of these diseases cause "damping-off" in seedlings. Wet rots may develop. Leafhoppers: small, wedge-shaped insects that can transmit virus diseases.	Pull out and discard infected plants. Select resistant varieties and plant in well-drained soil or raised beds. Use a floating row cover.
Stunted plants, leaves curled and yellowed	Virus diseases Aphids (usually green in colour): can transmit viruses. Tarnished plant bug: 0.5 cm brownish shield-shaped insect.	Pull out infected plants. Select resistant varieties. Remove badly damaged plants. Use a floating row cover.
CARROTS, PARSNIPS, PARSLEY AND RELATED CROPS		
FOLIAGE		
Yellow/stippled leaves	Leafhoppers: small, wedge-shaped insects that suck sap and transmit viruses.	Use a floating row cover.
Tan to dark spots on leaves	Plant bugs: suck sap and inject a toxin that produces small spots of dead tissue. Fungal and bacterial diseases.	Use a floating row cover. Pull out and discard infected plants. Select resistant varieties. Increase plant spacing and avoid overhead watering.
Stunted plants, leaf yellowing	Leafhoppers, tarnished plant bug Virus diseases Root-knot nematode	Use a floating row cover. Select resistant varieties. Select varieties that make short storage roots.
Foliage chewed	Parsleyworms, other caterpillars and carrot weevil adults.	Hand pick pests or use a floating row cover.
ROOT DAMAGE		
Misshapen, forked, small knots on fibrous roots, hairy roots	Root-knot nematode Carrot rust fly	Discard infested roots. Select varieties that make short storage roots. Sow in raised beds filled with amended soil. Use a floating row cover. Control weeds in and around garden.
Tunneling in roots	Carrot weevils: zigzag tunnels in upper and outer part of root. Creamy-white grubs with reddish-brown heads. Carrot rust fly: surface tunnels with rotted, rust-coloured tissue. Maggots are white.	Use a floating row cover. Rotate crops, control garden weeds and don't allow carrots to overwinter in the ground. Avoid contact with foliage while tending or harvesting plants. Same as above.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF POME FRUITS (Apples and Pears)

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
FOLIAGE		
Leaf spots	Apple and pear scab (fungal diseases): olive-brown velvety spots on leaves. Cedar apple rust (fungal disease): bright yellow spots with orange or black centre. Black rot, also called "frog-eye" leaf spot (fungal disease): small purple leaf spots become light tan with brown borders. Pear leaf blister mite (apple and pear): small, green or yellow pimples turn into reddish-brown blisters. Tiny white or light-red mites can be seen on leaf undersides with a hand lens. Various other fungal and bacterial diseases	Plant resistant varieties. Rake up and discard all leaves, fruits and debris. Plant resistant varieties. Do not plant <i>Juniperis virginiana</i>, the alternate host of the disease. Remove the galls, which range in size from the diameter of a nickel to a quarter in the spring. In wet periods these galls may produce orange "horns". Often associated with fruit mummies which are shriveled fruit which remain on the tree from the previous season. "Frog-eye" leaf spots will often occur below fruit mummies. Dormant oil spray.
White-gray powder on leaves and buds	Powdery mildew	Select resistant varieties. Remove damaged shoots and prune for improved air circulation. If powdery mildew was a problem the previous year, spray with wettable sulfur at bloom. Another option is to check horticultural oil labels for powdery mildew control listings.
Leaf yellowing or browning	Spider mites: "period-sized" pest feeds mostly on leaf undersides, causing stippling and bronzing. Damage is more severe during hot weather. San Jose scale: tiny, yellow crawlers feed on leaf surfaces. Fireblight: entire leaves on individual branches brown but do not fall off.	Spray with dormant oil during pre-bloom period. Broad-spectrum insecticides kill off mite predators and often worsen the problem. Spray with dormant oil during pre-bloom period. Plant resistant varieties. Prune out infected parts using the ugly stub pruning method (see tip at end of this section). Otherwise dormant pruning of cankers is recommended. Spray Bordeaux or fixed copper spray at silver-tip for severe infections. Reduce or eliminate nitrogen applications.
Leaves curled, twisted or rolled	Green apple aphid, rosy apple aphid : also feeds on buds. Black sooty mold growing on honeydew excretions may be observed.	Early season problem. Aphids spread fireblight. A hard water spray will dislodge aphids. Reduce or eliminate nitrogen applications.
Leaves with black splotches	Sooty mold : from aphid, scale or pear psylla feeding.	Spray dormant oil at bud swell. Remove water sprouts throughout growing season.
Leaves chewed	Gypsy moth larvae , other caterpillars	Inspect trees May through June. Handpick or spray young larvae with B.t. product.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
SHOOTS, TWIGS, BRANCHES		
Shoots wilt and bend at ends ("shepherd's crook"). Sunken, black or wine coloured cankers	Fireblight (bacterial disease)	Plant resistant varieties. Prune out infected parts using the ugly-stub pruning method (see tip at end of this section). Otherwise dormant pruning of cankers is recommended. Spray Bordeaux or fixed copper spray at silver-tip for severe infections. Reduce or eliminate nitrogen applications.
Roughened bark, clusters of hard, gray-coloured specks	San Jose scale: usually on young wood. Red halos may be observed around scale covers. Lecanium scale: reddish-brown to black bumps usually found on young wood.	Spray with dormant oil and prune out damaged wood.
Shoots chewed, trunk girdled, bark stripped from trunks and branches	Deer feeding: worse during very cold snowy winters. Antler rubbing by bucks.	Where appropriate, electric fences are very effective. Repel deer by hanging one or more of the following from mesh bags on trees: small soap bars, human hair, blood meal or mothballs.
Roots and base of young trees chewed	Voles (meadow mice), rabbits: nest in mulch, weeds and plant debris around trunk. More serious problem during very cold winters.	Keep orchard mowed and mulch pulled back from trunk. Place tree guards (50 cm high circles fanned from hardware cloth) around trees and 5-8 cm below soil line. Use traps to reduce population levels of voles.
FRUITS		
Apples dimpled, brown trails or streaks in flesh	Apple maggot: small, white maggot tunnels through fruit.	Worse on thin-skinned and early varieties. Pick up and discard all drops. Where pest pressure is severe hang 4-5 sticky red spheres on outer branches to trap out adult flies.
Holes chewed Shallow, pin prick-sized holes	Fruitworms and other caterpillars. Codling moth "stings": caused by larvae that punctures fruit and die. Plum curculio: adult feeding. Very active during bloom and early fruit set. Adults drop to ground when disturbed.	Discard all infested fruit.
Small holes at blossom-end, dark frass (excrement) kicked out	Codling moth: 1-2.5 cm long larvae are cream-pink coloured with brown head. Begin feeding 2-4 weeks after full-bloom.	Pick up and discard all drops and damaged fruit still on the tree. Wrap 15 cm wide strips of cardboard or burlap around trunk and large limbs in August. Check wrapping in December, discarding trapped larvae/pupae.
Tan-brown, crescent-shaped scars, larvae tunnel into core	Plum curculio: 6 mm long yellow-white grub with brown head. Adult is small black beetle with long snout. Eggs laid directly in fruit under scar.	Cool, wet weather at petal fall makes control more difficult. Monitor adult population by striking branches with padded paddle and collecting curculios on a light-coloured tarp.
Circular clusters of tiny black specks and small sooty smudges	Fly speck and sooty blotch: common, late season fungal diseases. Sooty mold on pear from pear psylla feeding.	Symptoms can be rubbed or peeled off. Fruit may be dipped in a 10% bleach solution to remove fly speck, sooty blotch and sooty mold.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Spots on fruits	Various fungal and bacterial diseases. Bitter rot: sunken, brown-black spots that enlarge. Scab: velvety, olive-brown spots. Lesions become corky. Fireblight: brown spots. Fruit eventually shrivels. San Jose scale: small, red-purple spots with light-coloured centre. Small black dots (scale covers) may be observed.	For all fruit problems, promptly remove and dispose of all infected fruit. (Remove from the vicinity of the orchard). Prune out dead wood in the trees and remove brush from the orchard. Associated with fireblight infection. Remove infected fruit. Plant resistant varieties. Plant resistant varieties. Discard fruit. Use dormant oil spray.
Premature drop	Various insect pests	Open and inspect drops to identify pest(s). Promptly discard all drops.
Deformed fruits	Early disease infection of fruit buds Aphid feeding on buds Tarnished plant bug and various other insect pests	Control damaging insect and disease pests. Remove all affected fruit.
Flying insects hovering around ripe fruit	Yellow jackets and hornets Sap beetles: small, black beetles feed on over-ripe fruit	Do not allow fruit to become over-mature. Pick up drops.

When Fighting Fireblight, Leave an "Ugly Stub".

The fireblight bacterium is a systemic pathogen that can move rapidly into healthy tree tissue. Backyard orchardists are often unaware that pruning out infected shoots and limbs during the growing season can further spread the disease. Follow these pruning guidelines to improve fireblight control:

- Use very sharp pruning tools to remove infected limbs 20-30 cm below visible symptoms.
- Do not make the cut back to a healthy limb or spur, but leave a naked ("ugly") stub. (The bacterium will colonize the ends of these pruning cuts and produce cankers which serve as a source of inoculum for continued infection).
- Mark the stubs to make it easier to locate them. Remove and dispose of the "ugly stubs" during dormant pruning (November-January).

Adapted from: Steiner, P.W. "Ugly Stub" Procedure for Removing Fireblight Symptoms. Extension Fruit Pathology Mimeo. University of Maryland.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF STONE FRUITS (Peach, Cherry, Plum, Apricot)

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
FOLIAGE		
Leaf yellowing	Green peach aphid: leaves curl, yellow and drop. Aphids secrete honeydew which may lead to sooty mold on foliage. Spider mites: white flecking or stippling. Leaves brown and die. Cankers, Phytophthora and Verticillium Wilt.	Primarily an early-season problem. Hard water spray directed at aphids. Apply a dormant oil spray at bud swell. Apply a dormant oil spray at bud swell. Problem more severe in hot, dry weather. See tips at the end of this section.
Leaf spots	Bacterial spot (peaches): small, angular spots between veins. Spots are green, then turn purple and finally brown. Scab (peaches): small, olive-green spots. Cherry leaf spot: small purple spots on leaf surfaces. Leaves develop holes and turn yellow. Infected leaves often drop. Plum leaf spot: similar to cherry leaf spot but smaller.	FOR ALL FOLIAR DISEASES: Promptly rake up and dispose of infected leaves. If defoliation was severe the previous season, Bordeaux mixture (copper sulfate and lime) can be applied after harvest.
White-gray powder on leaves and buds	Powdery mildew	Select resistant varieties. Remove damaged shoots and prune for improved air circulation. Spray with wettable sulfur at bloom if powdery mildew was a problem the previous year or check horticultural oil labels for powdery mildew control listings
Leaves curled and puckered	Peach leaf curl: fungal disease on un-folding leaves in spring. Leaves are thickened malformed and brightly coloured (purple, red, and orange).	Apply a pre-bloom spray of liquid-lime sulfur on all tree parts. If leaf curl was severe the previous year, apply Bordeaux mixture before buds swell in the spring.
Leaves chewed	Various caterpillars Japanese beetles: skeletonize leaves.	Handpick pests. Where feeding is severe, use a registered insecticide.
No buds, damaged buds	Plant bugs	Early season problem. Mow or remove weeds.
Peach shoots wilt and die	Oriental fruit moth: 1 cm long, gray-white larvae with black head. Bore several centimeters into new shoots. Larvae over winter in soil under tree.	Prune out and dispose of wilted tips, 15 cm below visible damage. Shallow cultivation around base of tree 2 weeks before bloom.
Dark, sunken cankers, gummosis may be observed	Various fungal and bacterial diseases (especially Cytospora canker)	Prune out and dispose of infected wood below visible damage. Prune to increase air circulation. Do not leave stubs. Avoid fertilization after June. Apply indoor white latex paint to trunk and large branches after leaf fall.
Small reddish-brown and black bumps on 1-3 year old wood	Lecanium scale: noticeable May through July. Crawlers feed on foliage after hatching in July.	Apply a dormant rate horticultural oil spray before bud break.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Shoot tips stunted, leaves yellow and curl upward, tree may break off at ground level	Stem pitting: viral disease, mainly of peach that is spread by nematodes. Symptoms occur late in season after harvest.	Plant certified, disease free nursery stock.
Black, gnarled swellings along twigs and branches	Black knot: fungal disease of plum and cherry.	Prune out and dispose of infected wood below visible damage.
Gum oozes from holes at base of trunk or lower branch crotches (sawdust-like frass may be observed)	Peach tree borer: primarily on peach and nectarine. 2.5-3.5 cm long white larva with brown head. Female adult is a large, blue and orange, clear-wing moth. Larvae feed in tunnels below bark and overwinter, renewing activity in early spring.	Larvae can be speared with thin wire inserted into holes. It takes only one or two borers to kill a tree.
Numerous small round holes in twigs and branches (gum may be evident)	Shothole borers	Remove and dispose of infested wood promptly.
Shoots chewed, trunk girdled, bark stripped from trunks and branches	Deer feeding: more severe during very snowy, cold winters. Antler rubbing of bucks.	Where appropriate, electric fences are very effective. Repel deer by hanging one or more of the following from mesh bags on trees: small soap bars, human hair, blood meal.
Roots and base of young trees chewed	Voles (meadow mice) rabbits: nest in mulch, weeds and plant debris around trunk. Damage is more severe during very cold winters.	Keep orchard mowed and mulch pulled back from trunk. Place tree guards (50 cm high circles formed from hardware cloth) around trees and 5-8 cm below soil line. Use traps to reduce population levels of voles
FRUITS		
Spots on fruit	Brown rot: small, circular light brown lesions that expand on ripening fruit. Tufts of gray spores can be observed under moist conditions. Peach scab: numerous small, greenish circular spots on fruit surface that turn brown-black and velvety. Powdery mildew: white, powdery lesions that becomes rust-coloured. Bacterial spot: small, circular, depressed lesions with water-soaked margins. Rhizopus rot: fungal disease that develops after harvest and is similar to brown rot. Fruit become soft and covered with "whisker-like" growth.	Do not allow fruit to become over-mature. Pick fruit when entire background turns yellow. Promptly remove and dispose of all infected fruits and "mummies" on tree and on the ground. A post-harvest 1-2 minute dip of fruits in a 10% chlorine bleach solution will kill surface spores. For the following diseases promptly remove and dispose of all infected fruits on tree and on the ground. Remove infected fruit immediately. Pick peaches prior to full-ripeness. Do not allow fruit to become over-mature.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Fruits exude gum	Oriental fruit moth: larvae bore in at stem end. Plant bugs: begin feeding 5-10 weeks after bloom.	Remove and dispose of all infested fruit. Shallow cultivation around base of tree 2 weeks before bloom. Control weeds around planting.
Fruits chewed or scarred	Plant bug feeding: young fruits affected. Hail damage.	Pull off and dispose of fruits. Control weeds around planting.
Deformed fruits	Plant bug feeding. Hail or frost damage. Plum pockets: fungal disease causes plums to become elongated and misshapen.	Pull off and dispose of fruits. Control weeds around planting. Bordeaux mixture or liquid lime-sulfur spray at bud swell.
Premature drop	Feeding damage by various insect pests.	Promptly pick up and dispose of all drops.
Flying insects hovering around ripe fruit	Yellow jackets, other wasps and hornets. Sap beetles: small, black beetles feed on over-ripe fruit.	Do not allow fruit to become over-mature. Pick up drops. No chemical controls available.

TIPS FOR BACKYARD ORCHARDISTS

Troubleshooting the Causes of Tree Decline in Stone Fruits

Stone fruits tend to have shorter lives than pome fruits. The useful life of a peach tree, for example, is 12 to 15 years, although well managed trees may be productive for 15-20 or more years. Gardeners with stone fruits often observe a general decline in tree vigour, reduced yields, undersized leaves that yellow and drop prematurely, wilting of shoots and branch dieback. **When troubleshooting a declining tree examine the 15-20 cm area just above and below the soil line and look for the following:**

1. **Is there evidence of vole feeding?** Voles or meadow mice can girdle and kill a tree. Damage is more likely during a cold winter with deep snow cover.
2. **Are heavy gum deposits present?** Peach tree borers are likely to enter the tree in this area. The gum is produced by the tree as an attack response.
3. Scrape away some of the tree bark (especially on the most symptomatic side of the tree). **Do you notice cankers and browning of the tissue under the bark?** This indicates Phytophthora root rot or Verticillium wilt. These soil-borne fungal diseases are more prevalent on wet soils. The foliage of infected trees tends to yellow gradually and drop during the summer.
4. **With the bark scraped away, can you see white, fan-shaped fungal mats between bark and wood?** This is Armillaria root rot. Infected trees tend to collapse in mid-summer.
5. **Is the bark spongy and thickened?** With the bark scraped away can you see small pits or grooves. This indicates stem pitting (tomato ringspot) virus which is spread by weeds and nematodes.

Over-fertilization Creates Problems - Tree fruits receiving excessive nutrients, especially nitrogen will remain vegetative (fruiting is delayed) and fail to harden off properly. They are also more susceptible to feeding by pests such as scales, mites and aphids.

Brown Rot Control - Recent research has shown that yard waste compost applied around peach trees reduces the incidence of brown rot disease. It is thought that benign fungal spores from the compost are blown up to the fruits where they colonize the surfaces preventing brown rot infection.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF NUT TREES

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
FOLIAGE/WOOD		
Holes chewed in leaves	Various caterpillars: walnut caterpillars are hairy and feed in clusters in mid-summer on walnut trees.	No control necessary.
Spots/blotches on leaves	Various insects and diseases: pecan scab produces dark olive to black spots.	Rake and dispose of fallen leaves.
Wilted, water soaked foliage	Walnut curculio: larvae bore into shoots causing dieback.	Promptly prune out wilted shoots.
Branch dieback	Canker diseases.	Remove diseased and damaged twigs, branches and limbs during dormancy period.
Warty growths on exposed roots and lower trunk	Crown gall (bacterial disease).	Tree will decline and die prematurely. No controls available. Avoid mechanical injury to tree trunk and roots.
NUTS		
Failure to bear	Immature tree: most nut trees require 6-10 years of growth before producing nuts. Biennial bearing pattern: heavy crops followed by crop failure. Lack of cross-pollination. Over-fertilization: tree stays vegetative. Poor soil drainage, low soil fertility. Spring freezes. Defoliation.	Check with nurseries and catalogs to determine bearing age. Selective pruning. Reduce fertilization. All nut trees must be cross-pollinated. Always plant two or more compatible varieties of the same species. Reduce or eliminate fertilizer use, especially nitrogen. Nut trees need deep, well-drained soil. Identify and control serious insect or disease problems.
Nuts are empty or poorly filled	Poor pollination Spring frost/freeze Growing season too short or cool Micronutrient deficiency Drought	Cool, rainy conditions during bloom period. Short bloom period and low bee activity. Check varieties for specifics. Boron, zinc, iron and copper are all essential elements in nut formation. Take a soil test and follow recommendations. Calcium is also very important. Keep trees well-watered during drought.
Premature drop	Poor pollination Insect and disease damage Environmental stress (drought, cold temperature)	Pick up and examine drops for insects. Dispose of diseased and infested nuts.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Nutmeats are discoloured or chewed	Walnut husk fly: larvae feed on green husks and may discolour shell and nutmeats. Females lay eggs on husks in mid-summer. Walnut curculios: two species of dark brown, long-snouted weevils. Females lay eggs under crescent-shaped punctures on twigs and young nuts. Larvae bore into nutmeats. Pecan weevil: adult females lay eggs in nuts, August-September. Larvae feed on nutmeats. Chestnut weevils: two species of dark brown, long-snouted weevils. Adults emerge from soil under trees beginning in May. Adult females lay eggs in nuts late August-September. Larvae feed on nutmeats.	Remove and dispose of all fallen nuts. <u>FOR ALL CURCULIOS (WEEVILS):</u> Where problem exists, try tapping branches with a padded broom. Adult curculios will drop down on to tarp laid under the tree. Do not leave nuts on the ground if a curculio problem exists.

DIAGNOSTIC KEY FOR PESTS AND DISEASES OF SMALL FRUITS (Blueberries, Brambles, Grapes, Strawberries)

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
PROBLEMS COMMON TO MANY SMALL FRUITS		
Low plant vigour and fruit yield	Plants crowded, weed competition, "wet" feet, winter damage, low soil fertility, low light conditions.	See Chapter 14 - Small Fruits.
Gray-white, powdery or moldy growth on leaves	Powdery mildew (fungal disease).	Check horticultural oil labels for powdery mildew control listings.
Leaf yellowing	Aphids: leaves curl, yellow and drop. Sooty mold (black splotches) may develop. Spider mites: white or yellow flecking. Leaves bronze, then brown and die. Leafhoppers: very small, fast-moving plant sap suckers. Cause white-yellow blotching of leaf margins. Can spread diseases.	Natural predators usually keep pest populations under control. Hard water spray may be used to dislodge aphids. Use a floating row cover. Where problem is severe each year, buy and release predatory mites or use a floating row cover. Use a floating row cover.
Leaf spots	Various fungal leaf spot diseases.	Rake up and discard infected leaves.
Leaves chewed	Various caterpillars. Japanese beetles: skeletonize leaves, especially brambles.	Hand pick pests or use a floating row cover.
Green and yellow mottling of leaves, plants stunted	Various viral diseases: spread by sucking pests, like aphids.	Purchase certified virus-free plants. Prune out infected canes. If more than 20% of canes are infected, remove entire plant. Dig up and remove infected wild plants (brambles). Control aphids.
Leaves rolled or tied together, small caterpillars feeding inside	Leafrollers.	Prune out and dispose of damaged foliage and pests.
Plants wilt, leaves may yellow	Various root rot and wilt diseases (Verticillium) Root knot nematodes: root system stunted and gall-like growths on roots.	Remove infected plants. Plant certified, virus-free nursery stock, in well-drained soil. Remove affected plants and do not replant in same area.
Galls at base of plant, on roots and on canes, plants stunted	Crown and cane gall (bacterial disease): galls are spongy, rough swellings that become dark and woody with age.	Remove and dispose of plant.
Dark lesions along canes and branches, followed by dieback	Various fungal diseases.	Prune out and dispose of infected plant parts.
Shoots chewed and girdled, bark stripped	Deer feeding: more severe during very cold winters.	Where appropriate, electric fences are very effective. Repel deer by hanging one or more of the following from mesh bags on plants: small soap bars, human hair, blood meal or mothballs.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Roots, crowns and lower stems chewed	Voles (meadow mice), rabbits: nest in mulch, weeds and plant debris around plants. Damage is more severe during very cold winters.	Keep planting mowed and mulch pulled back from crowns. Use traps to reduce vole population levels.
Ripe fruit rots, gray, fuzzy mold develops	Botrytis (gray mold): this fungal disease is more pronounced during humid, wet weather.	Do not allow fruit to become over-mature. Remove and dispose of all infected fruit. Prune to increase air circulation and avoid overhead watering.
Fruits pecked, torn or removed	Bird and squirrel damage	Netting should be placed over plants 2-3 weeks prior to ripening. Iridescent silver and red "streamers" can be purchased and draped over plants.
Flying insects hovering around ripe fruit	Yellow jackets, other wasps and hornets. Sap beetles: small, black beetles feed on over-ripe fruit.	Do not allow fruit to become over-mature.
BLUEBERRIES		
Dieback of shoot tips and blooms	Botrytis: fungal disease. More severe in cool, wet springs. Brown discolouration spreads down shoots and twigs. Blossoms look water-soaked.	Reduce nitrogen feeding in spring and prune to increase air circulation. Prune out and remove all infected plant parts.
Berries turn red or tan as they ripen, become hard and shriveled. Buds, blossoms, shoot tips and leaves brown and wither.	Mummy berry: more severe during cool, wet springs. Powdery mass of spores may be observed on infected parts.	Pick up and dispose of all infected plant parts especially fallen fruit "mummies". Plant resistant varieties.
BRAMBLES		
White or tan spots with purple borders on canes, followed by cane dieback	Anthrachnose (fungal disease).	Plant red raspberries far away from black raspberry plants. Prune out badly infected canes. Apply a dormant spray of liquid lime-sulfur.
Blister-like, red-orange pustules form on lower leaf surfaces	Rust: a group of several fungal diseases. Mainly found on blackberries and black raspberries.	Promptly remove and dispose of affected plant parts. Remove wild brambles in vicinity. Plant resistant varieties from certified, disease free stock.
Primocanes (new canes) and floricanes (fruiting canes) develop brown - purple lesions, wilt and dieback	Cane and spur blight (fungal disease): infects recently pruned canes. More prevalent on black raspberries.	Prune during dry weather for increased air circulation. Promptly remove dead canes after fruiting. Apply a dormant spray of liquid lime-sulfur when buds are half-green at the tips.
Stunted shoots become yellow, wilt and die	Verticillium wilt: soil-borne fungal disease, primarily on black raspberries. Most severe on wet soils -with cool, moist spring weather.	Remove and dispose of infected plants. Plant certified, disease free stock, in well-drained soil.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Plant becomes weak , individual canes wilt and die	Crown and cane borers: larvae feed inside canes and crowns. Raspberry cane borers: slender 1 cm long black beetles begin feeding in shoot tips in June and may reach the crown by fall.	Remove and dispose of old and damaged canes below where damage is observed. Remove wilted shoot tips in mid-summer. Remove and dispose of old and damaged canes below where damage is observed.
GRAPES		
Brown spots with dark borders on leaves. Grapes turn black, shrivel and remain attached to stems	Black rot (fungal disease): probably the most serious problem for backyard growers. Can affect all green plant parts. Fruit is most susceptible to infection when pea-sized, but infections can continue until fruit begins to ripen.	Remove and dispose of all affected plant parts, especially “mummies”. Prune to increase air circulation.
Rotting of ripe grapes on the vine	Botrytis (bunch rot) (fungal disease): enters breaks in grape skins.	Remove all affected clusters. Prune to increase air circulation. Maintain even soil moisture.
Small, yellow spots on upper leaf surfaces. White, cottony growth forms on undersides of spots.	Downy mildew (fungal disease).	Use resistant varieties.
White flecking of leaves	Grape leafhoppers.	Control weeds around planting.
Small rough galls on leaf undersides, swellings on roots	Grape phylloxera: small aphid-like insect. Other innocuous galls may appear on leaf surfaces.	Plant varieties grafted onto resistant rootstock.
Small holes chewed in buds and leaves	Grape flea beetle: small blue-black beetle. Adults and larvae are damaging.	Control weeds around planting. Use a floating row cover.
Canes are scarred, girdled	Grapevine girdler: 0.3 cm long black weevil. Chews holes in cane ends. Overwinters in canes.	Prune out 15 cm below the damage and dispose of infested canes.
Individual berries are webbed together by silk threads. Entrance holes can be observed.	Grape berry moth: 2-3 generations per year.	Remove and discard infested fruit.
STRAWBERRIES		
Leaf Spots	Strawberries are susceptible to wide range of foliar diseases.	Remove and discard affected plant parts. Plant resistant varieties.
Small, white, frothy masses on stems and leaves	Spittlebug: small orange-green nymphs can be found under the spittle. They suck plant sap in early spring.	No control necessary.
Small holes chewed in leaves	Flea beetles: small, dark insect that jumps when disturbed. Larvae and adults feed on flowers, leaves and young fruit.	Use a floating row cover.

SYMPTOMS	POSSIBLE CAUSES	CONTROLS/COMMENTS
Stunted, weak plants	Various root and crown feeding insects. Virus diseases.	Do not plant into newly tilled grass or sod. Avoid poorly drained soil. Plant on raised beds. Use a floating row cover. Inspect the roots and crowns of affected plants. Remove infected plants and replace with virus-indexed plants. Control leaf feeding insects (e.g., leafhoppers, aphids) that spread virus diseases.
Damaged fruits	Slugs: slime trails may be observed. Cutworms: make large, clean holes. Sap beetles: small, black beetles feed on over-ripe fruit. Tarnished plant bug: causes "button berry". Berries are small, woody and knobbed.	Remove breeding and hibernating habitat. Use a floating row cover. Use clean straw to raise berries off soil Use a floating row cover. Use a floating row cover.
TIPS Thick organic mulch (straw, shredded leaves) will help to keep fruit clean, prevent fruit rots and suppress weeds. Always purchase healthy, certified disease free plants (see Chapter 11). For brambles and strawberries, select tissue cultured (virus indexed) plants.		

IDENTIFICATION KEY FOR INDOOR PESTS

HABIT	PEST DESCRIPTION	CONTROL
Flying	Clothes Moths: 1 cm wingspan, buff-coloured moth, in closets, bedroom, etc. Indian Meal Moth: more than 1 cm, moth, back part of wings dark, in kitchen, pantry. Drain Flies: tiny, gray, fuzzy, moth-like insect, in bathrooms, near sinks. Fungus Gnats: tiny, black, gnat-like fly, around houseplants, standing water. Fruit Flies: small, tan coloured fly; red eyes, in kitchen.	Locate infested fabric, carpeting, etc. underneath wool rugs for larvae. Vacuum and shampoo or dry clean. Store cleaned fabrics in sealed bags or cedar chests. Locate infestation and dispose of infested material. Store food in airtight plastic or glass containers or in the freezer. Check stored bird seed, pet food and dried foods. Clean drains with enzyme cleaner, manually clean traps. Keep plant saucers dry, allow plants to dry between waterings. If necessary repot plants with fresh potting media. When possible store fruit or vegetables in the refrigerator. Do not keep fruit or vegetables on counters for extended periods. Rinse cans and bottles for recycling.
Jumping	Fleas: very small, dark brown, bite. Cave or Camel Crickets: large, over 2.5 cm, hump-backed, wingless, brown, with long antennae and legs, usually in basement. House or Field Crickets: large, over 2.5 cm, winged, black or brown, cricket-like, usually in basement or ground floor. Springtails: tiny, 3 mm or less, gray to white insects, jump, in bathrooms, around flower pots, or areas of high humidity.	Thoroughly vacuum carpeting, upholstery, under furniture and along baseboards. Dispose of bag when finished. Use product containing the insect growth regulator methoprene to control flea larvae. Control fleas on pets. Follow all label directions, contact veterinarian for best control on pets. If there are no pets in the home, raccoons or squirrels may be nesting in chimney or attic. Prevent entry by tightening screens, weather-stripping doors and windows. Dehumidify basements. Keep pet foods and dry food products in tight containers. See above. Dehumidify area. Clean mold and mildew. Allow media in potted plants to dry out between waterings or repot with fresh media.
Running, Walking or Crawling	Millipedes: 2.5 cm or longer, dark brown, many short legs, curl up and die indoors, usually found in basement or near outside entry door. House Centipedes: over 2.5 cm, many long legs, run fast. Spiders: size variable, 8 legs, colour variable, yellowish to black, smooth or hairy, may or may not have web.	Prevent entry to home. Weather-strip doors, install new thresholds, caulk around basement window frames. Dehumidify damp basements. Predatory, feed on insects, such as cockroaches. Escort outdoors. Predators, feed on insects and other spiders. Check for other insects in house that may be source of food for spiders. Many enter house in fall. Caulk and seal cracks around doors and windows.

HABIT	PEST DESCRIPTION	CONTROL
	Silverfish or Firebrats: flattened, about 1 cm with 3 tails, gray or tan, found in boxes, cabinets, bathrooms, near furnace, other warm areas etc. Earwigs: brown, 2.5 cm, with pincers on rear. Carpet and Cigarette Beetle larvae: 0.5 cm or less, carrot shaped, furry, in closets, bathrooms, kitchens, etc. Carpet and Cigarette Beetles: 0.5 cm or less, oval to round beetles, brown, multi-coloured or black, in any room. Pillbugs and Sowbugs: 1-1.5 cm, gray, oval some roll up into a ball. Cockroaches: 1 cm or larger, brown to black, long antennae, flattened, kitchen and or bathroom, often seen at night. Booklice: very tiny, tan insects, in or around stored papers and books. Ants: small to large, brown to black, pinched waist, six legs, usually in kitchen, occasionally in other rooms. Bird Mites: very tiny, mite-like, bite, come into house through window, vents, etc. Boxelder Bugs: red and black insects on south side of house, come indoors. Ladybird Beetles: colour variable, orange to red, some with spots, 0.5 cm, round beetle, around windows, screen porches, side of house on sunny day in fall. Clover Mites: very tiny mites, large numbers on sunny exposure, often come in windows, stain red when crushed.	Dehumidify area, store books and papers in sealed containers. Occasionally enter home, swat or escort outdoors. Keep debris, mulch, and other hiding places away from house. Vacuum all areas thoroughly. Put clean woolens away in sealed containers. Check stored food products and spices for infestations and dispose of infested material. Store all herbs, spices and dried food products in airtight containers. Check for dead mice, old bee or hornet nests, etc., in wall voids or attic. These beetles feed on dead insects and dead animals. See above. Prevent entry to home. Weather strip doors, new thresholds. Need moist environments, die quickly indoors. Have species identified. Sanitation primary control. Use baits containing hydroprene (growth regulator). Dehumidify area, store books and papers in sealed containers. Identify ants. Block entry from outdoors. Use bait stations to control indoors. Granular bait and bait stations available for outdoor use. Remove bird nests from gutters, vents, air conditioners, etc. Vacuum mites indoors. Tighten window screens, seal cracks, screen vents, control outdoors with a mild soap solution (test on small area to make sure it won't damage siding and plants). Vacuum indoors. Sweep up indoors and release outside, harmless predators of aphids. Seal up entry points on outside of house. Seal cracks and holes, vacuum indoors.

HABIT	PEST DESCRIPTION	CONTROL
Maggot or Caterpillar-like	Fly Maggots (larvae of House or Blow Flies): whitish, 1 cm or slightly longer, no visible head, in trash, crawling across floor, possible from fireplace or vent.	Locate source of infestation, possibly dead bird or squirrel in chimney, attic, etc. and remove. Dispose of maggots in home.
	Indian Meal Moth larva: whitish, 1 cm, brown head, in stored products, crawling up walls, etc.	Locate infestation and dispose of infested material. Feed on various stored products including cereals, grain products, bird seed, etc. Store food in plastic or glass containers with tight lids.

IDENTIFICATION KEY FOR BEES AND WASPS

DESCRIPTION	PROBABLE INSECT	CONTROL
Large, brown, orange markings, may fly at night, strips bark from trees and shrubs, especially lilacs.	European Hornets: nest in hollow logs, trees, outbuildings, etc.	Control difficult, nest location may be difficult if near a wooded area.
1 cm, black and yellow, not fuzzy, aggressive, may nest in ground or in a gray papery sphere attached to house tree or shrub.	Yellowjackets: tend to be a problem late summer into early fall.	Locate nest during the day. If nesting in a wall void, do not seal opening to outside, as they may chew through interior walls.
2.5 cm, black with white or yellow markings, long legs, narrow waist, nests in gray, papery sphere in tree or shrub.	Bald-faced Hornets	Locate nest during the day.
2.5 cm, brown with various markings, long, thin legs, narrow waist, nest in papery exposed nest attached to eaves or porch.	Paper Wasps: generally not aggressive.	Control usually not necessary.
Medium to large, hairy, black and yellow, common at flowers, nests in ground.	Bumble Bees	Control usually not necessary.
Large bees, shiny black abdomen, bore 1 cm round holes in wood. Males have spot on face and no stinger. Males fly around and establish mating territory, only appear threatening.	Carpenter Bees: feed on pollen and nectar, do not eat wood, only nest in it.	Freshly painted surfaces tend to deter them. They prefer weathered or unpainted wood.
1 cm, brown, fuzzy bee, common on flowers, nests in trees, commercial hives and occasionally in structures.	Honey Bees	To remove swarms, contact a local bee keeper. If nesting in a wall in a home, contact a professional pest control company. After bees are killed, comb and honey should be removed promptly from wall voids to avoid attracting other insects and mice. There will also be a strong odour from the honey and dead bees. The honey may also seep through plaster walls.
Small, fuzzy bees, nest in loose soil in lawns, banks, etc.	Ground Bees	Not aggressive. Males have no stinger. They establish a mating territory and only appear threatening. They are only around for a few weeks. No control necessary.
Large, black with yellow markings on abdomen, hover above the lawn, non-aggressive, nest in loose soil.	Cicada Killers: feed on cicadas.	Control generally not necessary.

DESCRIPTION	PROBABLE INSECT	CONTROL
1.5 cm long, blue-black wasp, yellow stripe on each side of abdomen, fly over lawn during the day.	Scoliid Wasps: not aggressive.	Parasites of white grubs Do not attack people. Control not necessary. Adults are often seen visiting golden rod flowers in late summer.

IDENTIFICATION KEY FOR WOOD DESTROYING PESTS

DESCRIPTION	PROBABLE INSECT	CONTROL
Mud tunnels from ground to wood, white, ant-like insects in wood, wood soft.	Subterranean Termites	Contact professional pest control company.
Dark brown, 0.5 cm, 4 long wings of equal length, fluttery flight habit, indoors or outdoors.	Termite Swarmers: reproductive form of subterranean termites, usually emerge from area of infestation.	Contact professional pest control company.
Large brown to black ants, 0.5-2.5 cm, winged or wingless, in house, outdoors, or on trees, often near damaged wood, coarse sawdust.	Carpenter Ants: do not eat wood, only nest in it.	Locate nest and treat, repair or replace damaged wood. Repair any water problem.
Oval holes in wood, may be powdery sawdust, may hear chewing noise, generally in structural timbers or log homes.	Old House Borers	Determine if infestation is active. Contact a professional pest control company.
0.3 cm or smaller, round holes, possible fine sawdust, often in soft woods, structural timbers, pine flooring, imported furniture, bamboo fences, etc.	Powder Post Beetles	Determine if infestation is active. Replace damaged wood if possible. Contact a professional pest control company.
1 cm round holes in wood, large bees with shiny black abdomen seen flying in area or boring into wood.	Carpenter Bees: feed on pollen and nectar, do not eat wood, only nest in it	Freshly painted surfaces tend to deter them. They prefer weathered or unpainted wood.
Tips on Tick Safety • Tick bites may occur at any time of the year. • Avoid wooded areas and brushy, tall grass areas if possible. • Use a repellent containing DEET on skin not covered by clothing. • Wear light coloured clothing to make tick detection easier. • Tuck pant legs in socks or boots. • Make frequent tick checks and promptly remove ticks. • Remove attached ticks with fine pointed tweezers by grasping the tick at skin level and giving a firm, steady pull until it comes away. Save the tick in alcohol for identification. Treat the bite with an antiseptic. • Make a record of the tick attachment. Call your doctor if a flu-like illness and or a bullseye-like rash appears at the bite site.		

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Illustrations of ladybird beetle life cycle, lacewing life cycle, flower fly eggs and larva, predatory mite, predatory gall midge larva, minute pirate bug, damsel bug, aphid parasite, and parasitic nematode life cycle by John A. Davidson, Department of Entomology, University of Maryland, College Park, MD.

All other illustrations from USDA.

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<http://www.hc-sc.gc.ca/ahc-asc/branch-dirgen/pmra-arla/index-eng.php>

Ontario Ministry of Agriculture, Food and Rural Affairs

<http://www.ontario.ca/health-and-wellness/omafra-offices>

Ontario Ministry of the Environment

<http://www.ene.gov.on.ca/environment/en/index.htm>

CHAPTER 19: PESTICIDE REGULATIONS

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CHAPTER 19: PESTICIDE REGULATIONS

ONTARIO PESTICIDE LAWS

In the original manual there was a separate chapter with extensive discussion on the use of pesticides. While it promoted the Integrated Pest Management (IPM) and careful approaches to pesticide use, it is now out of date because of Ontario's Pesticide Ban and has been replaced by the following Master Gardener Policy on Pesticide Use.

The Ontario ban on the cosmetic use of pesticides took effect on April 22, 2009. Master Gardeners in Ontario have always supported the least invasive techniques in dealing with pests and diseases in the garden and are continually educating themselves on best management practices and alternatives to pesticide use.

It is a policy of Master Gardeners of Ontario Inc. that all advice given by Master Gardener volunteers when working under the authorization of the local group must be in accordance with the laws of Ontario and the principles of an IPM strategy.

For the purposes of this policy, an IPM strategy is defined as follows:

IPM is an integrated approach to pest control based on a good knowledge of the pest organism (insect, plant disease or weed), determination of tolerable levels of damage, and choosing the least aggressive control measure from the following sequence of strategies: cultural controls first, then mechanical, biological and finally, chemical controls (where allowed).

Resources:

The following websites are sources of information:

http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_085343.pdf

http://www.hc-sc.gc.ca/hl-vs/alt_formats/pacrb-dgapcr/pdf/iyh-vsv/life-vie/homemade-artisanaux-eng.pdf

http://www.ene.gov.on.ca/environment/en/category/pesticides/STDPROD_085338.html

http://www.ene.gov.on.ca/environment/en/category/pesticides/STDPROD_079355.html#2

It is against Master Gardeners of Ontario Inc. policy to recommend production or use of all homemade recipes.