Ornamental Pest Control

Category 3A

K-STATE Research and Extension

IPM INTEGRATED PEST MANAGEMENT & PESTICIDE SAFETY EDUCATION

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

Ornamental Pest Control

Category 3A

K-STATE Research and Extension

IPM INTEGRATED PEST MANAGEMENT & PESTICIDE SAFETY EDUCATION

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

Table of Contents

Using this Manual

This is a self-teaching manual. At the end of each major section is a list of study questions to check your understanding of the subject matter. These questions represent the type that are on the certification examination. By studying this manual and answering the study questions, you should be able to gain sufficient knowledge to pass the Kansas Commercial Pesticide Applicators Certification examination. Correct answers appear on page 73.

Introduction

Because ornamental plants are grown for aesthetic reasons, a particular plant may be more valuable to one person than to another. Pests include various diseases, weeds, insects, mites, and vertebrate animals. When populations are high enough, all of these can cause considerable damage. Plant problems may be related to soil or fertility, mechanical or pesticide injury, improper planting or pruning, or natural decline due to aging. Unless the cause is apparent, all of these factors should be considered before implementing control.

Take time to study the plant and site, particularly if considering the use of pesticides. Applied improperly, pesticdes may be more harmful than the pest. This self-teaching study manual provides information on common pests and problems associated with ornamental plants. It is used to formulate tests for pesticide applicators seeking certification and recertification. Because pesticides change continuously, specific chemicals are mentioned only as a guide. Recommendations are updated annually to reflect current regulations.

Insects and Mites

Trees and shrubs are susceptible to many different kinds of insects and mites. The more diverse the landscape, the greater the number of potential pests. Some plants are relatively insect and mite free, while others require constant attention. Pest presence does not indicate a problem that warrants control with an insecticide or miticide.

Prevention. The best way to prevent problems is to regularly inspect plants for pest damage or infestations on (and under) leaves, branches, buds, flowers, stems, crowns, and roots. In a large area with many plants, monitor a small, representative sample.

Natural control. Most years, parasitoids and predators such as ladybird beetles and some insect diseases are enough to keep insect and mite pest populations in check. But natural controls are susceptible to pesticides and may not always be present in sufficient numbers. When natural enemies cannot keep up with the number of individuals, pesticide applications may be needed to regulate pests with high reproductive capacity.

Cultural controls. Nonchemical control should be used whenever possible. Sanitation, pruning, planting tolerant species and varieties, and removing pests by hand are efficient and flexible methods of regulating insect and mite pest populations.

Effective Pesticide Use

Proper timing and thorough coverage. Apply miticides and insecticides when vulnerable life stages of pests are present. Most insect and mite pests are easier to control when they are young. Spray bagworms in late May and early June immediately after the eggs hatch, and spray scale insects when they are in the "crawler" stage before they develop a protective, waxy covering. Thoroughly cover all plant parts, including branches and undersides of leaves.

Dormant oils are effective in controlling some scale insects and mite pests and may be less disruptive to the environment than pesticides applied during the growing season.

Pest life cycle. Some insect and mite pests produce more than one generation per year. Unless a significant percentage of the population is killed by natural enemies or pesticides early in the season, numbers may increase to a damaging level. Most insecticides require direct contact with the pest and remain active for only a short time. Frequent applications are needed, especially when targeting species with multiple generations.

Factors to Consider

Chemical injury to plants. Some ornamental trees and shrubs may be injured by certain pesticides. It is important to read the label to determine which plant species or varieties are sensitive. When in doubt, test on a few plants to determine sensitivity.

Protection of pollinators. To minimize their impact on honey bees and other pollinators, do not apply pesticides when plants are in bloom (flower). Certain pesticides, such as carbaryl (Sevin), are extremely toxic to pollinators and should be avoided entirely. Choose the least toxic products instead.

Pest Detection

Insects or mites may not be visible when their damage is discovered. Watch for these signs that may indicate a problem.

- **Silk shelters.** Made from silk, they usually do not enclose foliage, except for an occasional leaf. Caterpillars feed from outside the shelter, using it for protection from natural enemies and weather.
- **Web-enclosed foliage.** Silk webs enclose foliage to hide caterpillars feeding inside.
- **Waxy covering.** Most scales and certain aphids excrete a protective, waxy covering.
- **Remains.** These may include egg castings, molting skins, pupal cases, cocoons, frass, and silk trails.

- **Honeydew.** Clear sticky liquid excreted by soft scales and aphids. A black, sooty, mold fungus may develop on the honeydew.
- **Sawdust, wood chips, and pitch masses.** Found on or below the host plant, as a result of feeding by wood-boring insects (beetles and caterpillars).
- **Galls.** Distorted growth present on leaves, petioles, branches, and flowers. A number of insects and mites create galls on plants including aphids, psyllids, flies, midges, and small cynipid wasps.

General Considerations

When dealing with insect and mite problems, an understanding of pest biology and conditions that favor development and reproduction is beneficial. Follow this procedure to determine the best treatment options.

1. ***Evaluate the situation.*** Know what normal or healthy plant growth looks like. If plant growth does not look normal, evaluate plants to determine what is causing the problem.

2. ***Identification and assessment.*** If insects, mite pests, or damage is apparent, determine what pest is responsible. Not all insects and mites are pests. In fact, a substantial number of insects or mites are considered beneficial (natural enemies). In addition, certain insect or mite pests cause minimal damage to plants and populations may be regulated by natural enemies. Even plants that appear healthy may be attacked. Check plants regularly to prevent populations from building up.

3. ***Management.*** The situation may call for preventive action, curative action, or no action at all. Prevention strategies include proper watering, fertilizing, pruning, and mulching to maintain plant health. Proper site selection to minimize plant stress and susceptibility to insect and mite pests and sanitation practices such weed and debris (leaves and branches) removal also alleviate problems.

   Curative action typically involves insecticide and miticide applications to prevent pest populations from reaching outbreak proportions. When using contact pesticides, spray plants thoroughly to cover leaves, branches, and stems. Reapply, if necessary, at intervals noted on the pesticide label. Before treating with an insecticide or miticide ask:
   - Does the insect or mite pest damage affect plant survival?
   - Is the aesthetic value of the plant compromised enough to warrant treatment?
   - Is the damage permanent or temporary?

   In some situations no action is warranted; for example, when the application might increase problems by killing the insect or mite's natural enemies, or when no practical control method exists for a particular stage of development. Waiting to treat until the insect or mite pest reaches a susceptible life stage, makes it possible to kill a higher percentage of individuals and reduces problems with future generations.

   Considerations in selection and use of insecticides and miticides:
   - Is the pesticide harmful to humans, pollinators, wildlife, and natural enemies?
   - Will the pesticide harm plants?
   - Are the pesticide label directions specific in regards to what plants the product should not be applied?
   - Does the pesticide label state environmental conditions (temperature, relative humidity, and sunlight) required for product application?
   - Does the pesticide label state the intended target insect or mite pest?

4. ***Application.*** Before use, read the label to avoid these common problems:
   - Errors in mixing pesticides in the correct proportion.
   - Inadequate spray coverage. Thorough coverage of all plant parts is necessary, especially leaf undersides where most insect and mite pests are located.
   - Improper agitation, which leaves pesticide to settle in the spray tank and results in either insufficient or excess amounts of material applied.
   - Improper timing of applications. If an insecticide is applied too early insufficient residues may be present to affect the pest population. If applied too late, insect or mite pests may be in

non-susceptible life stages (pupa) or located in areas of plants that may be difficult to reach such as leaf junctures or inside plant tissues.
- Environmental influences that reduce effectiveness. Avoid applying pesticides within 24 hours of rain and when temperatures exceed 80°F, which may reduce residual activity.

5. ***Evaluation.*** Was the management strategy effective based on considerations discussed under management?

In the context of ornamentals, a number of insect and mite pests are of particular concern. They can be grouped by the part of the plant they consume (leaves or shoots, twigs, branches, trunks and roots) and feeding behavior (chewing or sucking).

Leaf Feeders (Chewing Insects)

Deciduous trees and shrubs will tolerate some defoliation without harming tree health. On the other hand, evergreens can be seriously affected by heavy defoliation because they only replace a portion of their leaves (needles) each year. For example, pines may only replace ⅓ of the growth consumed by chewing insects such as the European pine sawfly. In addition, evergreen leaves (needles) store food reserves for the following year.

Insect feeding affects the amount of food plants can store. New leaves produce plant food more efficiently. If leaves are consumed early in the season, food production may be reduced considerably for the following year. Late season defoliation of deciduous trees and shrubs has less of an impact than early season defoliation because food has already been stored.

Caterpillars

Two common types of chewing insects are caterpillars and beetles.Caterpillars are the larvae of butterflies and moths. Many types of caterpillars feed on plant leaves. Some form webs or tents on branches, and may produce more than one generation per year. Major caterpillar pests in Kansas are bagworm, mimosa webworm, cankerworm, and fall webworm.

Bagworm

Bagworms attack both evergreens and deciduous trees and shrubs but prefer to consume arborvitae, cedar, juniper, and other evergreens. They live in spindle-shaped bags constructed from leaves, needles, or twigs of the host plant. As they move about feeding, they carry the bags with them for protection from weather extremes and natural enemies.

Bagworms overwinter as eggs inside the maternal bag attached to the plants. Eggs hatch in late May through early June. As small caterpillars feed, they begin to construct the bags in which they will reside and move about in search of food. The bag expands as caterpillars grow, until they gradually emerge. Caterpillars mature in late August through September, pupate, and become adults. The female is a wingless moth that remains in the bag and is fertilized by a winged male moth. After fertilization, the female lays her eggs inside the bag and dies. Each female lays 500 to 1,000 eggs, which will overwinter. The bagworm has a single generation per year.

Handpicking. On small plants, bagworm infestations may be handled by physically removing bags and placing them in soapy water. Young bagworm caterpillars spin a silken thread and "balloon" from infested plants to uninfested plants. This allows bagworms to disperse long distances to surrounding host plants.

Insecticides. As they grow, bagworm caterpillars become increasingly difficult to kill with insecticides. To maximize effectiveness, apply insecticides between early June and mid-July. Multiple applications may be required. Cover all plant parts thoroughly with spray solution and time applications when bagworm caterpillars are small.

Bagworm

Mimosa Webworm

Mimosa webworm attacks both honeylocust and mimosa. Thornless and seedless honeylocust varieties such as Sunburst, Moraine, Skyline, Shademaster, and Imperial are all susceptible. The larvae feed mainly on the upper surface of leaflets, but they also may feed on the lower leaf surface. Leaves eventually turn brown and die, giving infested trees a scorched appearance.

Mimosa webworms reside in irregular-shaped silk webs, woven together with tree leaflets. When removed from their nests, larvae create a thin strand of silk and use it to migrate downward. Caterpillars are a half-inch long when full-grown, pale gray or brown, with five longitudinal white stripes. Caterpillars have dark heads, and bodies that may be tinged with pink. Mimosa webworm adults, which are rarely seen, are gray moths approximately ⅓ inch in length with a half-inch wingspan.

Mimosa webworm overwinter as pupae inside a cocoon in the soil or protected area. Adult moths emerge in early June and mate, and females lay eggs on honeylocust leaves. There are two generations per year. Second-generation eggs are laid in July through August in the webbing of the first generation. Damage is most noticeable from August through September when second-generation larvae activity peaks.

The webbing makes it difficult to get adequate penetration and coverage of insecticide sprays. Insecticide applications should be performed immediately after eggs hatch and before leaves are webbed together by the small caterpillars. Apply insecticides routinely from mid-June through August.

Mimosa webworm larva

Fall Webworm

Fall webworm caterpillars create unsightly webbing in trees such as walnut and hickory from mid-summer through fall. This pest should not be confused with other nest-making caterpillars such as the eastern tent caterpillar, which appears in early spring when leaves emerge.

Susceptible host plants include walnut, mulberry, pecan, redbud, elm and ash. The caterpillars feed within the enclosed nest, which moves as they feed. Unlike eastern tent caterpillars, fall webworm caterpillars never leave the protective nest.

Adult moths are white, with a wingspan of 1½ to 1¾ inches. They emerge from their wintering stage (pupae) during the spring and summer, and females lay clusters of 200 to 500 eggs on the leaf surfaces of host plants. Eggs are partly covered with white hairs or scales and are typically located on leaves near the ends of branches.

In general, small caterpillars emerge from eggs in 1 to 2 weeks and immediately begin creating a webbed nest at the ends of the branches. The nest expands in size as the caterpillars consume leaves in their path. The caterpillars remain in the nest during the feeding process. Caterpillars can consume entire leaves or leave the veins intact. As the caterpillars mature and the nest becomes larger, the inside fills with dead leaves, molting cast skins, and fecal deposits.

Caterpillars are typically white to cream with two black spots on each abdominal segment, and covered with thin, white hairs. The caterpillars are approximately 1 inch long when mature, and they eventually migrate down a tree toward the soil, spin a silken cocoon, and pupate in debris or the soil. There are two generations per year, with the first occurring in June and the second in August.

Individuals from the second generation remain as pupae until the following spring when adult moths emerge to begin the cycle again.

Physically remove by pruning or disturbing the nests with either a rake or forceful water spray to create openings that allow birds to consume the caterpillars. To be effective, insecticides should be applied before caterpillars build webbed nests. Once nests have been built, it is too late.

Fall webworm nests in a tree

Fall webworms

Cankerworms

Cankerworms are also called measuring worms, inchworms or loopers. In Kansas, they attack plants in the spring as leaves emerge. They also may attack buds before leaves emerge.

Of the two types of cankerworms, the spring cankerworm is most common in Kansas. Adult females of both types are wingless moths. Fall cankerworm adults emerge from October through November, while spring cankerworm adults emerge in late February through March.

Females of both species migrate up the tree trunk to deposit eggs. Eggs of both species hatch in April or early May, and young caterpillars consume developing leaves. Dispersal occurs when the small caterpillars are blown from one tree to another. Both species have one generation per year. Defoliation may not be apparent; however, trees may look dead because they fail to leaf out. Caterpillars leave small holes, eventually consuming the entire leaf as they mature. This pest feeds on elm, hackberry, and honeylocust.

One technique is too apply a sticky substance (tanglefoot) as a band to the trunk of trees to capture wingless females as they migrate upward on the tree to lay eggs. Because large numbers of small caterpillars may be dispersed to other trees by wind, this technique should be done on a community-wide basis.

Insecticides are effective when applied in April or early May when young caterpillars are present. Monitoring populations and timing applications accordingly will result in higher mortality.

Fall cankerworm

Beetles

Elm Leaf Beetle

Elm leaf beetle is the most damaging leaf beetle in Kansas. Introduced from Europe, this pest only feeds on elm. Although most elm species are susceptible, the beetles prefer Siberian elm (commonly called Chinese elm) and hybrid elms. The true Chinese elm is seldom attacked.

Elm leaf beetle feeding may result in partial or complete defoliation. Severe infestations may result in leaves turning brown, and often dropping prematurely. In some cases, entire trees may be defoliated by mid-summer. Most of the damage is caused by the larvae feeding on the undersides of leaves. Trees that lose most of their leaves due to elm leaf beetle feeding commonly put out a new flush of growth, which may be consumed by remaining larvae.

Feeding damage by elm leaf beetle adults and larvae seldom kills elm trees. However, severe feeding may weaken trees and increase susceptibility to other insects and diseases.

Elm leaf beetles overwinter as adults in sheds, houses (where they are a nuisance pests),

and protected places outdoors such as under the bark of trees or house shingles. Adults are about ¼ inch long, yellow to olive green with a black stripe along the outer edge of each wing cover. In spring, the beetles leave their overwintering sites, fly to nearby elm trees, mate, and begin laying eggs. Adults eat small, circular holes in expanding leaves.

The lemon-yellow colored, spindle-shaped eggs are laid in groups of 5 to 25, always in parallel rows, on leaf undersides. Each female may lay between 600 and 800 eggs during her life span. Small black larvae feed on the undersurface of the leaves. The larvae feed for three weeks, and when mature are approximately a half- inch in length, dull yellow, with two black stripes.

Larvae usually feed in groups consuming the undersides of leaves only—leaving the upper leaf surface intact. After the feeding period, larvae migrate to the lower parts of elm trees, or in cracks, crevices, or crotches of the trunk or larger branches. Adults emerge in midsummer. There are two to three generations in Kansas.

Insecticide applications should be timed to kill the first-generation larvae and later the second generation larvae after hatching from eggs. Check leaves for the presence of dark-colored larvae. Apply insecticides in mid-May for the first generation and early to mid-July for the second brood. Specific application times may vary with the season and different areas of the state.

Elm leaf beetle adult

Leafminers

Leafminers are a group of insect pests that includes flies, wasps, moths, and beetles. The larva is the damaging life stage that feeds inside the leaf tissue. Damage appears as brown or discolored blotches or winding serpentine mines on the leaf. There may be more than one generation per year. Damage is usually not sufficient to warrant insecticide application.

Study Questions

1. Natural enemies play an important part in keeping insects and mites under control. These natural enemies include:
   a. wasps and lady beetles
   b. wind
   c. rain
   d. none of these

2. What are some common signs of insect or mite presence?
   a. galls
   b. web-enclosed foliage
   c. pupal cases
   d. all of the above

3. Sawdust, wood chips, and pitch are usually present on or below the plant when which of the following insect pests is/was present:
   a. aphids
   b. wood borers
   c. leafhoppers
   d. mites

4. Not all insects on plants are pests. Examples of non-pests include:
   a. aphids
   b. lady beetles
   c. leafhoppers
   d. scales

5. When applying insecticides, it is important to time sprays to coincide with the vulnerable life stage of a given pest.
   a. T
   b. F

6. Deciduous trees can tolerate more defoliation than evergreens.
   a. T
   b. F

7. How do bagworms overwinter?
   a. adults hidden in soil duff
   b. eggs within the female's bag
   c. caterpillars in the bag
   d. pupae within the soil

8. How many generations of bagworms are there in Kansas?
   a. 1
   b. 2
   c. 3
   d. 4

9. How many generations of the mimosa webworm are there in Kansas?
   a. 4
   b. 3
   c. 2
   d. 1

10. Fall webworms eat only the:
    a. flowers and seeds
    b. small twigs
    c. leaf veins
    d. tender portions of the leaves

11. How are cankerworms most readily spread to other trees?
    a. as eggs on lawn mowers
    b. as small larvae blown by the wind
    c. as pupae on the feet of birds
    d. as adult females flying to trees to lay eggs

12. Which life stage of the elm leaf beetle causes most of the damage?
    a. adult
    b. larva
    c. pupa
    d. none of the life stages

13. How many generations of elm leaf beetle are there in Kansas?
    a. 1
    b. 4
    c. 2–3
    d. 6–8

14. When is the best time to spray for elm leaf beetle?
    a. just after larvae hatch from the eggs
    b. as larvae are crawling down the tree to pupate
    c. there is no best time to spray
    d. in the fall as adults are looking for hibernation sites

Leaf Feeders (Sucking Insects)

Aphids

Most ornamental plants are susceptible to one or more aphid species. Aphids, like scale insects and true plant bugs, withdraw plant fluids with their piercing-sucking mouthparts. Some aphid species feed on foliage, others on twigs, branches, flowers or fruit. In addition, there are aphids that feed on plant roots. Aphids prefer certain host plants, spending part of their development time on one host and sometimes the remainder on another host.

Appearance and damage. Aphids are small (approximately ⅛ inch in length), soft-bodied, pear-shaped insects varying in color from green, black, gray, to red. They can be distinguished from other insects by the presence of cornicles (tailpipes). Cornicles may be long or narrow, and short or broad depending upon the species.

Most aphids attack in massive groups and prefer feeding on young shoots or leaves. Aphid feeding may cause both direct and indirect plant damage. Direct damage includes plant stunting, leaf yellowing, leaf curling, and deformity of leaves and flowers. In addition, aphids can create galls on leaves, stems, and roots. Indirect damage is associated with aphids vectoring plant viruses.

Many aphid species also excrete a sticky liquid called "honeydew." This material falls onto leaves, branches, and fruit, and is an excellent growing medium for black sooty mold fungi. The presence of this fungus inhibits the ability of plants to manufacture food (photosynthesis). Honeydew attracts ants and is a nuisance on cars, chairs, tables, and other objects located under aphid infested trees.

Aphid biology. Although there is variation in aphid biology, there are certain general biological characteristics that may be applied to aphids as a group. Aphids can reproduce without mating, and give birth to living young (parthenogenesis). Aphids tend to feed on specific host plants, or feed as a group on plants. Some aphids have alternate hosts on which they are found at different times of year.

Aphid damage

Aphid populations are usually regulated by environmental factors such as rain, temperature, fungal diseases, and natural enemies. The natural enemies of aphids include ladybird beetles, syrphid fly larvae, lacewing larvae and small wasp-like parasitoids.

Woolly Aphids

Woolly aphids vary in color from brown to purple. However, they all possess a white, woolly, wax-like covering. Generally, the cornicles are reduced or absent, the sexual forms lack mouthparts, and the ovipositing female produces only one egg.

Nearly all woolly aphids alternate between host plants, with the primary host, in which the overwintering eggs are laid, being a tree or shrub, and the secondary host a herbaceous plant. These aphids may breed either on the roots of the host plant or on aboveground parts. Feeding damage is characterized by prematurely opened leaf buds, distorted leaf edges curled or rolled similar to a gall, "clustered" leaves or enlarged growth on twigs and branches.

Woolly aphids

Foliage-Feeding Aphids

These aphids are small, soft-bodied and frequently found in abundance withdrawing sap plant fluids from stems or leaves. Aphid colonies include individuals in all stages of development. They are serious pests of cultivated plants. Many species affect certain plants, but a few feed on many different plant types. These aphids cause curling or wilting of plant foliage, and may also vector a number of important plant diseases.

Aphid management. Beneficial insects or natural enemies are important in regulating aphid populations. Plant inspections may help assess the presence of beneficial insects, population levels, ability to regulate aphid populations, and degree of parasitization. Beneficial insects respond to high aphid numbers and may provide sufficient regulation of aphid populations if insecticides are not used. Insecticide applications kill beneficial insects as well as pests, which may result in pest resurgence or outbreaks occurring. If feasible, and if high aphid populations are present, a forceful spray of water is effective in quickly removing aphids from the plants. Performed regularly (twice a week), this may reduce the use of insecticides. However, if this procedure is not an option contact or systemic insecticides may be applied. When using contact insecticides, thorough coverage of all plant parts is important.

Spider Mites

Several spider mite species attack and feed on plants causing leaves to appear specked or bronzed. Severely infested plants lose their aesthetic appearance, and may even be killed. The most important mites are the twospotted spider mite and the spruce spider mite.

Twospotted spider mite. This is a warm-season mite that feeds on a wide range of ornamental plants. Mites feed on the leaf undersides, and remove chlorophyll (green pigment) from leaves. Infested leaves become stippled or speckled and may be covered with silken webbing.

Twospotted spider mites overwinter as adult females in protected places, not on trees or shrubs. The overwintering mites are bright orange, whereas in summer they are cream to green in color with two dark spots on the abdomen. The life cycle from egg to adult takes about two weeks, but this depends on temperature. It can take 7 to 10 days to complete the life cycle when temperatures are above 80°F. This is why two spotted spider mite populations can build up rapidly.

Twospotted spider mite adult

Spruce spider mite. Spruce spider mite attacks all species of spruce, arborvitae, juniper, and pine. Mites use their stylet-like mouthparts to remove plant fluids resulting in foliage (needles) appearing light-brown to bronze in color, especially the older growth.

Spruce spider mite overwinters as an orange-colored egg on the needles and twigs of the host plant. Eggs hatch early in spring and the mites, in summer, are dark-green to dark-brown in color. Spruce spider mite is a cool-season mite with activity occurring when temperatures are below 80°F. They are mostly active in spring and late fall.

Scouting for mites. The best way to scout for mites is to hold a piece of white paper under a branch suspected of having mites or exhibiting symptoms, and striking the branch against the paper. The mites are about 1/50 of an inch long. If mites are present, examine 10 leaves per plant. If there is an average of three to five mites per leaf, continue scouting every two days. If mite numbers increase, or there are

10 or more mites per leaf, a miticide should be applied.

Management. Environmental conditions such as temperature, humidity, and moisture (rain) may regulate mite populations, keeping them below damaging levels. Natural populations of predatory mites and other predators also may help. If necessary, miticides may be applied to suppress mite populations. Miticides may be harmful to natural enemies, and lead to outbreaks if miticides are applied regularly. Continual reliance on miticides may result in mite populations developing resistance.

Plant Galls

Plant galls attract attention because of their unusual shapes and color. Homeowners who prefer damage-free landscape plants may consider them unsightly. Gall numbers vary from year to year. There maybe a large number one year and only a few the next, or they may be abundant on the same plant year after year. The number of galls is associated with populations of insects or mites that cause them and the presence of susceptible host plants.

Gall formation. Insects or mites initiate the formation of galls during feeding. Certain chemicals produced by insects or mites cause plant cells to increase rapidly, resulting in gall formation. The gall protects the developing larva from environmental conditions, natural enemies, and insecticides. The plant and gall location — leaves, branches, or stems — may be used to identify the cause. Galls are primarily created by aphids, midges, wasps, psyllids, mites, and adelgids, but they also may be produced by nematodes, fungi, bacteria, and viruses.

Gall types. Various types of galls exist, including leaf and bud galls. Leaf galls may be present on edges, surfaces, and petioles. Many appear as wart-like projections, which vary in color or shape depending on the gall-forming organism. On buds, galls may appear deformed, or assume various shapes. An abundance of galls can detract from the plant's appearance.

Management. In general, there is no need to manage galls because they are not detrimental to plants. But certain bud galls on conifers can lead to deformed growth. Large numbers of galls on young plants may inhibit growth. For certain plants, such as roses, galls may be removed by pruning. Any pruned out galls should immediately be removed from the vicinity in order to prevent reinfestation. Removing leaves in the fall may also help in reducing the numbers of gall-forming organisms. In most cases, when galls are noticed, the gall-forming organism has left the gall and will return next year.

Insecticides, including both contact and systemic, are not very effective in preventing the formation of galls on plants, because they will not kill the gall-forming organism.

Common Galls in Kansas

Hackberry nipple gall. This gall-former is a small, mottled, psyllid (jumping plant lice). Adult females lay eggs on the undersides of the leaves. After the eggs hatch, the young nymphs initiate feeding, which results in gall formation. Mature psyllids emerge from the galls simultaneously. In fact, in late fall, large numbers of psyllids may emerge from galls, and due to their small size they can pass through window screening, where they are a nuisance to homeowners. It is important to note that the galls do not harm the trees. The installation of fine mesh screens may prevent the adult psyllids from entering homes.

Hackberry nipple gall

Petiole gall of poplar. Aphids cause this gall when feeding at the base of a newly developing leaf. This results in the leaf stem folding back on itself forming an enclosure. If the enclosure is opened in summer a large number of aphids may be observed. Cottonwood trees may lose some leaves from this gall, but there will be no detrimental effects. As such, there is no need for management.

Poplar petiole gall

Oak galls. Oak trees are susceptible to a number of gall-forming organisms including flies, mites, and wasps (cynipid wasps) that create galls on the leaves, branches, twigs, and petioles. These galls may vary in size, shape, and color depending on the gall-making organism. Most are harmless, but in some cases can detract from the tree's aesthetic appearance. Several, such as the veinpocket gall caused by a gall-making fly, may distort leaves such that, from a distance, a tree may exhibit symptoms of herbicide injury. Two common galls caused by flies are the midrib and marginal fold galls. The succulent oak gall, a common gall on pin oaks in Kansas is caused by a cynipid wasp. The galls are green and resemble grapes.

Succulent oak gall

Plant Bugs and Leaf Hoppers

Plant bugs and leafhoppers are important pests of honeylocusts in Kansas, attacking newly expanding leaves. Feeding causes leaf stunting and deformities. Heavy infestations may result in leaf or twig death, but minimal permanent damage.

The insects overwinter as eggs in the twigs, close to buds. Eggs hatch in early April and small nymphs move to feed on expanding leaves. Adults usually are present from May through June, and females lay eggs on woody tissue. There is one generation per year.

Contact insecticides should be applied when new leaves emerge to prevent damage from both plant bugs and leafhoppers. Multiple applications may be required.

Plant bug nymph

Leafhopper adult

Lacebugs

Lacebug adults are small, broad, flattened insects with clear lace-like wings. Eggs, nymphs, and adults may be present on a plant simultaneously. Both adults and nymphs feed on plant fluids with their piercing-sucking mouthparts. This causes stippling or speckling of leaves, leaf yellowing, and eventually leaf drop. Small black, varnish-like excrement present on the undersides of leaves indicates the presence of lacebugs.

In general, lacebugs do not cause severe plant damage although extensive populations may reduce aesthetic appearance. Contact insecticides may be applied; however thorough coverage of leaf undersides is important. This strategy may be impractical for large plants.

Lacebug adult

Wood-Boring Insects

Of the many insects that attack ornamental plants (trees and shrubs) wood-boring insects are the most destructive. Damage may be overlooked during the summer because the larvae feed inside twigs, shoots, branches, or trunks. Vigorous, healthy plants are less susceptible to wood-boring insects than plants that are stressed because of drought or lack of moisture. Two major groups of wood-boring insects attack trees and shrubs: beetles and moths.

Beetles

This group consists of a large number of species, which are easily identified as beetles because the adult insect body is hardened and the wing covers meet in a straight line down the middle of the back. The two types discussed here attack a wide range of trees and shrubs; these include flatheaded wood borers and roundheaded wood borers.

Flatheaded Wood Borers

Flatheaded wood borer adults are brightly colored, metallic, boat-shaped, and ⅓ to 1 inch long. They are commonly called metallic wood-boring beetles because of their their iridescent color.

Larvae are ½ to 2 inches long, yellow-white in color, legless, with a pronounced flattened enlarged area behind the head.

Adult beetles emerge from host trees during early spring through summer, and females lay eggs near cracks and crevices in the bark. The larvae hatch from the eggs and tunnel beneath the bark entering the sapwood or phloem. Tunnels are typically packed with excrement (frass) from chewing wood during tunneling. Most flathead wood borers complete their life cycle in one year, whereas others may require two to three years. The flatheaded appletree borer and the bronze birch borer are common in Kansas.

Flatheaded appletree borer. The flatheaded appletree borer attacks young or newly transplanted trees including hard and soft maple, sycamore, oak, hickory, linden, poplar, and willow. Newly planted trees, or those that have been pruned to expose the trunk to direct sunlight are highly susceptible.

Adult beetles primarily attack the side of the tree exposed to sunlight (southwest), but all parts are susceptible. Larvae are about 1 inch long when mature. The flatheaded appletree borer overwinters as a larva, with adults emerging May through July. Females deposit eggs in bark crevices in June and July. Eggs hatch over several months, and all stages of the larvae may be present in a single tree. There is one generation per year.

To prevent infestations, wrap trunks of young or newly transplanted trees with burlap or other type of protection from the base to the first branch. Insecticides can be applied to tree trunks in June and July to kill larvae that hatch from eggs.

Flatheaded appletree borer larva

Flatheaded appletree borer adult

Bronze birch borer. Bronze birch borer is a pest of white birch (*Betula alba*) trees in Kansas. Adults are slender, black, iridescent beetles, ¼ to ½ inch long. Adult beetles emerge from D-shaped exit holes in branches and trunks from late spring to early summer, usually in June and July. Females lay eggs in cracks in the bark or in holes chewed in the bark. Eggs hatch into small white larvae that tunnel into the inner bark. The larvae make crooked, crisscrossing galleries packed with dark-brown, sawdust-like excrement, or frass. Frequently, callous tissue develops around the winding larval galleries forming ridges on the bark.

The full-grown larva is about 1 inch long and accordion-like in shape with a flattened, enlarged head. Larvae tunnel into the sapwood in the fall and excavate overwintering cells. In spring, larvae pupate, and eventually adults chew D-shaped exit holes through the bark and emerge. The tunneling of larvae may girdle branches, and disrupt sap flow, which causes the tips of the branches to die back. Infested trees may die from the top down.

To alleviate infestations, prune below the infestation point and remove branches exhibiting symptoms by early May. This should kill the insects before they emerge to lay more eggs.

Properly timed insecticide applications will kill adults and newly hatched larvae. It is important to treat the entire tree, especially the top portions. Apply insecticides in May, with two follow-up applications three weeks apart. To avoid problems with bronze birch borer, plant river birch, which is less susceptible (almost resistant) than white birch.

Bronze birch borer adult

Roundheaded Wood Borers

Roundheaded wood borer adults are cylindrical, hard-shelled and may be colored with contrasting bands, spots, or stripes. Adults are commonly referred to as longhorned beetles because the antennae are at least half as long as the body. In some species, the antennae are nearly one and a half times as long as the body. The larval stages are legless, white to yellow in color, fleshy and round.

Adult beetles emerge from infested trees from late spring through early fall. Mated females seek egg-laying sites, often under the bark in crevices or tree wounds. They may cut elliptical notches in the inner bark where

eggs are laid. After hatching, larvae may feed beneath the bark before entering the wood or remain under the bark. The life cycle varies from one to four years depending on the borer species.

Cottonwood borer. This borer attacks cottonwood and other poplars. Adults are about 1½ inches long, with black and white patches and cross striping. In July, females lay eggs in the tree trunk at the soil surface. Emerging larvae tunnel beneath the bark and wood, producing a considerable amount of frass. Larvae live in trees for two years. They may girdle the base, preventing and disrupting the flow of plant fluids, eventually killing the tree. Heavily infested trees may fall over during windy conditions.

Wrap paper or burlap around the base of young trees to prevent females from laying eggs. Barriers should remain in place for several years. Maintain plant health through proper watering, fertilizing, pruning, and mulching to reduce losses due to cottonwood borer.

Apply a preventive insecticide treatment in July, thoroughly covering the base of the tree.

Cottonwood borer adult

Wood-Boring Moths

Moths may be recognized by the powdery scales on wings and coiled mouthparts. The caterpillar stage causes plant damage. Two groups will be discussed: clearwinged moths and carpenterworm moths because they are important wood-boring pests in landscapes. In general, wood-boring moths attack both healthy and stressed trees and shrubs.

Clearwinged moths. Clearwinged moths possess wings without scales, which makes them appear clear or transparent. Many species resemble bees or wasps. Unlike most moths, they are active during the day. The larvae are white with a light-brown head. The larvae bore into roots, trunks, or branches of trees and shrubs.

Lilac borer. This is a destructive ash borer that leaves round holes on the main stem and lateral branches. Moist sawdust may be present at the base of infested plants. Adult females lay eggs on bark from May through June. Larvae emerge from eggs in summer and tunnel into trees and shrubs where they overwinter. In spring, brown pupal cases protrude from the holes that indicate adults have emerged.

Apply insecticides to tree trunks in May and June to kill adults and newly hatched larvae.

Ash lilac borer adult

Carpenterworm moths. Carpenterworm moths have large bodies with narrow, pointed wings. The larvae excavate wood leaving large galleries that can cause serious plant damage.

Sawdust-like material may be present at the base of infested trees, which originates from the tunnel made by the borer. If sawdust is present, look for small holes in branches and the trunk. In addition, sap may exude from the tunnel opening, which may become moist and discolor the bark.

Follow these management practices to alleviate problems with wood-boring insects:

- **Water and fertilizer.** Be sure trees are thoroughly watered throughout the season, especially during periods of drought. Always conduct a soil test before applying fertilizer. If plants do require fertilizer, apply the correct amount.
- **Pruning.** Prune new and established plants to remove dead, diseased, or damaged material. Prune back to the branch collar so cuts heal properly. Never leave stubs.
- **Mowing.** When mowing, avoid bumping plants with the lawnmower, which may cause wounds that girdle plants. Always

place a 2- or 3-foot circle of mulch at the base to prevent injury.

- **Plant selection.** Select trees and shrubs suited to the local climate to reduce susceptibility to borer attack. Ash, cottonwood, poplar, linden and maple are particularly vulnerable.
- **Wrapping.** Wrap the trunks of young or transplanted trees with a material to prevent females from depositing eggs in the bark. This may also prevent sun scald and mechanical damage.

Once borers enter the tree, they are extremely difficult to manage. A number of practices may alleviate problems with wood-boring insects or keep borer-infested trees alive. First, maintain tree health by implementing appropriate cultural practices such as watering, fertility, mulching, and pruning. Proper care minimizes stress, reducing susceptibility to wood-boring insects. Apply contact insecticides at the right time to kill newly hatched larvae or emerging adults and ensure thorough coverage.

Carpenterworm life stages

Carpenterworm damage

Pine Tip Moths

The pine tip moth is the most serious shoot borer in Kansas. Larvae destroy new growth and may cause deformities in young trees up to 15 feet tall by slowing growth and ruining their normal symmetry. Repeated attacks may eventually kill a tree. Pine tip moth attacks Scotch, Austrian, and Ponderosa pine. White pine appears to be less susceptible.

Pine tip moth overwinters as pupae in terminal buds or under the bark near the tips of infested shoots. First-generation adults begin to emerge in early April and complete development by the end of the month.

Adults are small, gray moths with red-brown to copper colored patches on the forewings and tan-colored hind wings. The wingspread is about one inch. Adults hide among needle fascicles (a bundle of pine needles) where they are well camouflaged. Adults are weak flyers that only move short distances from tree to tree in the evening. During the day, they fly only when disturbed.

Mating occurs and females begin laying eggs soon after emergence. Eggs may be deposited on buds and twigs but most are laid on needles. Adult moths live about 8 days. Each female lays about 25 eggs.

Eggs are small and yellow, and usually found on the upper surface of needles about one inch above the base. Larvae emerge from eggs in 7 to 8 days. Larvae are cream-colored, but gradually turn light-brown or orange. The head is dark-brown to black.

After emergence, the small first-instar caterpillar tunnels into the needles. The caterpillar continues to tunnel toward the base of the needles, where it migrates to the outside, spinning a web around itself and the needle fascicle. The larva continues to tunnel toward the terminal shoot, sometimes feeding on the fascicles or needles or on material just under the bark. The number of larvae in a shoot can vary from one to 10. Feeding causes needles to turn yellow and infested shoots to die. New growth may develop below damaged areas, resulting in multiple leaders and disfigured trees.

Caterpillars eventually leave the shoot and tunnel into buds. Pine tip moth pupates in shoots but may also pupate in needle fascicles. When leaving a shoot, caterpillars spin a web between the needles and the bud. The caterpillars may be covered with resin from the damaged bud or shoot, which hardens into a solid mass.

Pupae are dark-brown and about ¼ inch long and 1/16 inch in diameter. Pupation takes about 10 days. Second-generation adults emerge from June through July, about six weeks

after first-generation adults. After mating, females lay eggs for the next generation. A third generation occurs from July through August, approximately four weeks after second-generation adults emerge from eggs laid by third-generation female adults. Larvae develop during the fall and overwinter as pupae.

Insecticides may be used on larger plantings where moderate to heavy infestations occur. Contact insecticides should be applied after larvae hatch but before they tunnel into shoots. Timing is critical. The best times to apply insecticides to control pine tip moth is April through May (first generation), June through July (second generation), and July through August (third generation).

Pine tip moth adult

Pine tip moth damaged shoot with pupae

Bark Beetles

Adult bark beetle females create tunnels between the bark and wood where they lay eggs. After hatching, larvae create tunnels that radiate from the egg tunnel. Larval tunnels usually are packed with frass. Excessive tunneling can girdle and kill trees and shrubs. When adults tunnel through the bark and emerge, the surface looks as if it was riddled with buckshot.

Adults are 1/16 to ¼ inch long, cylindrical beetles that are red to dark-brown or black in color. Larvae are grub-like, thick-bodied, legless, generally C-shaped, and white or cream in color. Female egg-laying and life cycle vary depending on the species.

In Kansas, the most destructive bark beetle is the smaller European elm bark beetle, which transmits the Dutch elm disease fungus.

Smaller European Elm Bark Beetle

This beetle was detected in the United States in 1909. Since then, it has spread throughout the United States. The beetle is 1/12 to ⅛ inch long, and brown to black in color. Females lay eggs in crevices or tunnels under the bark of stressed elm trees. The females create tunnels within the wood, following the grain of the wood. Eggs hatch into larvae that create tunnels around the trunk or branch, which extend away from the centrally located egg tunnel.

Adult beetles emerge in April, fly to healthy trees, and feed in the crotches of twigs. At this time adults are capable of introducing Dutch elm disease fungal spores that adhere to their bodies. The beetle, which emerges from diseased elm trees then feeds on healthy trees is an efficient vector of this deadly disease.

The smaller European elm bark beetle undergoes three generations per year, and usually overwinters as larvae in elm trees or logs that have been recently cut. Refer to the disease section for Dutch elm disease control recommendations.

Smaller European elm bark beetle adult

Black Vine Weevil

The black vine weevil is a nursery pest that feeds on a wide range of plants, including yew, azalea, rhododendron, and euonymus. Adults feed on leaves, causing mostly aesthetic damage. Larvae feed on roots and are the most damaging life stage. Heavy larval infestations may kill plants.

Black vine weevil overwinters as either an adult or larva. Overwintering adults begin emerging in May and continue until July or August. Females lay eggs about two weeks after they emerge from the soil as a pupae. Egg hatch continues throughout the season. After hatching, the larvae burrow into the soil and feed on plant roots.

To reduce larvae populations, apply insecticides before females lay eggs. Adults continue to emerge over a long period of time. Scouting is recommended to time applications when they will be most effective. To check for black vine weevil adults, place a white sheet of paper under a branch. Shake the branch vigorously. If present, adults will be dislodged and fall onto the paper. If none are detected, repeat this procedure every three days. Begin scouting in April. Monitor plants between 9 and 11 p.m. Treat with an insecticide labeled for black vine weevil. Apply material to leaves and soil at volumes high enough to saturate the soil around the plants where larvae are located. Repeat applications every three weeks.

Study Questions

1. How do aphids damage trees?
   a. by removing plant fluids
   b. by chewing leaves
   c. by boring into branches
   d. they do not damage trees

2. Which of these insects excretes honeydew?
   a. pine tip moths
   b. wood borers
   c. leaf beetles
   d. aphids

3. The two most common spider mite pests are:
   a. banks grass mite and blue spider mite
   b. orange-backed spider mite and black spider mite
   c. twospotted spider mite and spruce spider mite
   d. little green mite and eight-legged spider mite

4. Two-spotted spider mites overwinter as:
   a. eggs
   b. adult females
   c. immature forms
   d. none of the above

5. Most plant galls cause minimal damage to host plants.
   a. T
   b. F

6. Hackberry nipple galls are caused by:
   a. mites
   b. psyllids or jumping plant lice
   c. aphids
   d. bacteria

7. Petiole gall of poplar is caused by:
   a. mites
   b. a small wasp
   c. an aphid
   d. a virus

8. The succulent oak gall on pin oak in Kansas is caused by:
   a. a tiny wasp
   b. two-spotted spider mite
   c. an aphid
   d. a leafhopper

9. There are two common groups of wood-boring insects:
   a. flies and wasps
   b. beetles and moths
   c. aphids and scales
   d. mites and mealybugs

Study Questions (continued)

10. What stage in the life cycle of wood-boring insects should an insecticide be directed at?
    a. large larvae
    b. eggs
    c. pupae
    d. newly hatched larvae

11. Trees infested by the bronze birch borer die:
    a. from the bottom up
    b. starting in the mid-region and spreading up and down
    c. from the top down
    d. in no specific pattern

12. The cottonwood borer is an important pest of:
    a. elm
    b. pine
    c. poplar
    d. honey locust

13. The lilac borer is an important pest of:
    a. elm
    b. honey locust
    c. sycamore
    d. ash

14. What is the best way to avoid problems with wood-boring insects?
    a. maintain plant health
    b. overfertilize plants
    c. withhold water from plants
    d. cover the crown with mulch

15. Pine tip moth overwinters as an:
    a. egg
    b. larva
    c. pupa
    d. adult

16. Pine tip moth larvae or caterpillars, immediately after hatching from eggs, tunnel into the:
    a. twig
    b. bud
    c. needle
    d. trunk

17. How can bark beetles kill trees?
    a. by eating foliage
    b. by covering trees with honeydew
    c. tunneling and girdling trees
    d. bark beetles do not kill trees

18. Black vine weevil larvae feed on:
    a. roots
    b. leaves
    c. trunks
    d. live in water

Vascular Feeders

Scales

Scale insects typically develop a shell-like or waxy covering. They can be divided into two categories: soft and hard scales. Soft scales are flattened, convex, and oval or globular in shape, and produce a waxy covering. Hard scales appear circular or rounded and produce a waxy covering called a test. This protects adult females that live under the cover and shelters eggs and crawlers from natural enemies and fluctuations in environmental conditions. They typically overwinter as mature females or as eggs underneath the body of dead females. Scales may feed on plant stems, branches, leaves, or fruit.

Damage

Scales feed by using their piercing-sucking mouthparts to remove plant fluids. Soft scales produce honeydew (sticky clear liquid), but hard scales do not. Black sooty mold fungi use honeydew as a growing medium. Black sooty mold fungus on leaves may inhibit the ability of plants to produce food via photosynthesis. Feeding can also reduce plant vigor, increasing susceptibility to environmental factors such as drought and extreme cold, which increases susceptibility to wood-boring insects and certain diseases.

Life Cycle

Scale insects in Kansas overwinter either as eggs or immatures. The female deposits eggs under her shell or waxy covering. After the eggs hatch, "crawlers" or nymphs leave to search for feeding sites. After the crawlers settle and begin feeding, they develop the characteristic soft or hard scale covering.

Management

Dormant oil. A dormant oil applied according to label directions just before bud break may effectively suppress hard- and soft-scale populations. Dormant oils can be applied to most evergreen and broadleaf woody plants but should not be applied after bud break or when new leaves emerge. Dormant oil sprays kill scales by suffocation. It is important to cover all plant parts thoroughly.

Insecticides. Insecticides are effective in suppressing soft and hard scale populations. Apply when crawlers are active according to label instructions. The protective covering of adults reduces penetration. Timing will vary depending on the species. Eggs hatch over an extended time period so multiple insecticide applications may be required.

Aphids

Root Aphids

Root aphids feed on the roots of trees and shrubs. During the summer they may be present on host plants such as fir. They migrate to roots with the help of ants that gather and tend to eggs over the winter. In the spring, ants transport eggs and young larvae to plant leaves or stems.

Bark Aphids

Bark aphids are large — approximately two to four times the size of most aphid species. They are difficult to see because their brown to purple-brown color enables them to blend in with host plants. Cornicles are short, tube-like, and somewhat triangular. Bark aphids feed on tree bark, particularly new growth. They use their piercing-sucking mouthparts to penetrate the bark and withdraw plant fluids.

Galls

Stem and twig galls vary in shape, depending on the insect or mite responsible. Shapes range from slight swellings to large, irregular, and sometimes spiny masses. Root galls resemble small, distorted pockets of plant tissue, either localized or present throughout the root system.

Indoor Plant Pests

Insect and mite pests that attack indoor plants tend to be small and difficult to see. Damage may appear before insect or mite pests are visible. A 10× hand lens can be used to detect problems early. Most problems of indoor plants are the result of improper cultural practices — too much or too little water, insufficient light, too much heat, exposure to cold, too much fertilizer, and poor drainage.

Pest classification. Pests of indoor plants may be classified as growing medium pests or leaf and stem pests. The first group includes springtails and fungus gnats, which generally are not serious and are fairly easy to manage.

The second group consists of leaf and stem feeders. These are insect and mite pests with piercing-sucking mouthparts including aphids, mealybugs, mites, scales, thrips and whiteflies.

Damage symptoms. Most indoor insect and mite pests cause distinct damage. Symptoms of plant diseases associated with fungi, bacteria, and viruses may resemble those caused by insect and mite pests. The following list may help in early detection:

- Honeydew is a clear, sticky liquid exuded by insects with piercing-sucking mouthparts such as aphids, whiteflies, mealy bugs, and soft scales. Honeydew accumulates on leaves and stems, providing a growing medium for black sooty mold fungi, which can interfere with the plant's ability to produce food via photosynthesis.
- Mottled leaves or leaves with small specks may indicate the feeding of whiteflies, mites, aphids, scales, or mealybugs.
- Leaves that are stippled or speckled with webbing present are associated with spider mite infestations.
- Leaves and stems with gray-brown spots may indicate scale infestations.
- Plant stunting or leaf flagging may be caused by aphids, scales, fungus gnat larvae, and/or whiteflies.

Pests of Leaves, Stems, and Soil

The following describes the major insect pests of indoor plants. Control measures are listed after the description of each pest.

Aphids

Aphids or plant lice are less than ⅛-inch long, soft-bodied, somewhat pear-shaped, with a pair of tailpipe-like-protrusions extending from the rear-end of their abdomen. Aphids typically occur in large colonies on new growth, at the base of buds and on the undersides of leaves. Aphids vary in color from green, yellow, orange, black, and red depending on the host plant with both winged and non-winged forms.

Indoor environmental conditions such as high temperatures allow aphids to reproduce continuously throughout the year. Aphids only produce females that, when mature, give birth to live aphids without mating (parthenogenesis).

Aphids withdraw plant fluids by inserting their piercing-sucking mouthparts into plant tissue. This causes plant stunting, leaf yellowing, and/or distorted (curled) leaves or terminal growth. Aphids also produce honeydew, a clear, sticky liquid present on plant leaves and stems, which provides a growing medium for black sooty mold fungi that covers leaves and reduces the plant's ability to produce food by means of photosynthesis. Honeydew also attracts ants, which protect aphids from natural enemies (parasitoids and predators). Aphids are efficient vectors of plant viruses.

Aphids feeding on plant.

Mealybugs

Foliar mealybug. Mealybugs are 3⁄16 inch long, oval in shape, flattened, and yellow to orange in color. Eventually mealybugs, as they mature, develop a white, waxy covering over the body. Some mealybugs have extended filaments around the body periphery or on the abdomen.

Mealybugs, unlike adult scales, do not remain in place but move around on plants, even after they find a feeding site. Females lay eggs in cottony, waxy sacs that are located on plant stems, leaves, or in leaf axils. Eggs hatch within 10 days, and crawlers reach maturity in six to eight weeks. Females can lay up to 600 eggs before they die.

Mealybugs use their piercing-sucking mouthparts to remove plant fluids from the vascular tissues. Feeding causes plant stunting and leaf yellowing and distortion. Mealybugs also excrete honeydew, which promotes mold growth and inhibits food production through photosynthesis.

Mealybugs on leaf.

Soil mealybugs. Soil mealybugs are common pests of indoor plants, especially African violets. Soil mealybugs are pink and oval, with distinct striations or grooves on the back. Both adults and nymphs are covered with a fine, powdery, waxy material. Their bodies lack the marginal projections typical of foliar mealybugs. Soil mealybugs are usually found in soil crevices or chambers coated with a white wax-like material, which may cover the surface of the root ball.

Both nymphs and adults feed on plant roots. Heavy infestations may result in plant stunting and leaf yellowing, and possibly death.

Mites

Mites are small (sometimes microscopic), wingless arthropods that are oval with two distinct body regions (cephalothorax and abdomen). Two mites that may be a problem on plants are the cyclamen mite and the twospotted spider mite.

Cyclamen mite. These are microscopic, white to pale brown mites, which feed in the terminal growth of plants. Females lay eggs at the base of buds. Eggs hatch in three to seven days into larvae that have only six legs. The larval stage is followed by two nymphal stages, which have eight legs and require four to six weeks to develop into adults. Cyclamen mites may attack a wide variety of plants. Cyclamen mites prefer a high relative humidity (70 to 80%) and temperatures around 60°F.

Leaves of infested plants are distorted or curled and buds fail to open. Sometimes leaves may appear purplish in color. Flowers may be distorted or open with streaks or blotches present.

Twospotted spider mite. Twospotted spider mites are small (1/50 inch or less in length), elliptical, soft-bodied, and green to yellow in color. Females can lay up to 200 eggs during their lifetime. Under hot, dry conditions, the life cycle can be completed in just 7 days and may result in extensive population outbreaks. Twospotted spider mites are sensitive to sunlight. All life stages — eggs, larvae, nymphs, and adults — can be found on the undersides of leaves.

The mite uses a stylet-like mouthpart to remove chlorophyll (green pigments) from plant cells. Feeding can cause stippling, speckling, or bronzing of leaves, and webbing may be present on heavily infested plants.

Scales

Scales feed on a wide range of trees or plants. They are more likely to be noticed when they reach the adult stage because crawlers are very small. Populations cause substantial damage and may even kill plants.

Females either lay eggs or give birth to live offspring (young). First-instar crawlers may travel great distances before choosing a location to settle down and start feeding. They use piercing-sucking mouthparts to withdraw fluids from host plants and remain in this location for the rest of the life cycle, which is completed in 4 to 8 weeks.

Adult males have a single pair of wings, eyes, legs and antennae. Long stylet-like projections may extend from the back of the abdomen. Males lack mouthparts and do not feed.

Hard scales. Hard scales appear circular or rounded in shape, and produce a hardened covering. Hard scales do not produce honeydew.

Soft scales. Soft scales are flattened, convex, and oval or globular in shape, and produce a waxy covering. Soft scales excrete honeydew while feeding. Two scales that are common indoor plant pests are the brown soft scale and hemispherical scale.

Brown soft scale. Brown soft scale adult females are flattened, shiny yellow to brown, with dark-brown mottling. Females give birth to live young, which crawl around the host plant before settling down to feed. Brown soft scale feeds on a wide range of indoor plants. Brown soft scale produces copious amounts of honeydew, which attracts ants.

Hemispherical scale. Hemispherical scale adult females are convex, brown and shiny. Hemispherical scale feeds on a wide range of indoor plants including ferns, palms, and cycads.

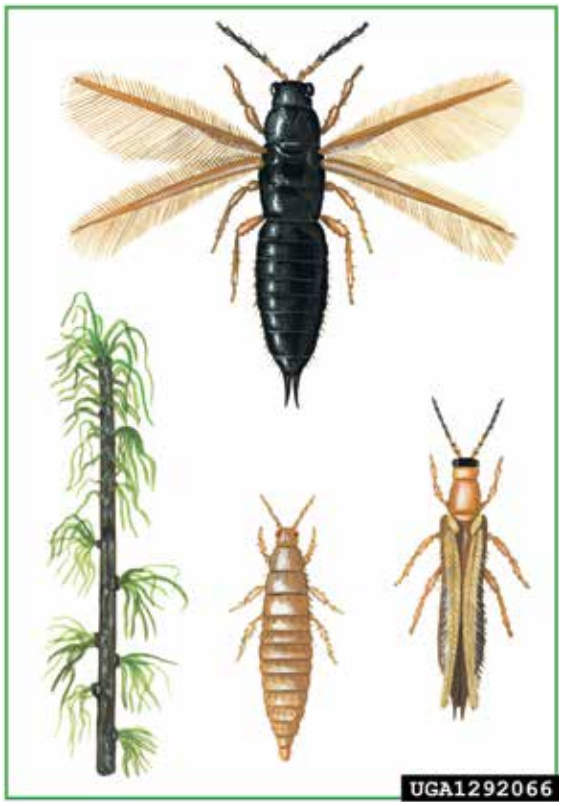
Soft scales use their piercing-sucking mouthparts to withdraw plant fluids. This causes stunting, leaf yellowing, and overall reduced plant vigor. Soft scales excrete honeydew, a clear sticky liquid that covers leaves and provides a suitable growing medium for black sooty mold fungi. This can block or inhibit the plant's ability to manufacture food through photosynthesis.

Brown soft scale on stem

Thrips

Thrips are small, slender about 1/16 inch in length, with two pair of wings covered with a fringe of hairs. Females insert their eggs into leaf tissue. Eggs hatch in two to seven days into nymphs. Two nymphal stages (first and second) feed on leaves or flowers. Eventually, the second instar nymph moves to the base of plants and enters the soil/growing medium to pupate. Two pupal stages follow, which do not feed. Adults emerge from the pupae in four to six days. The life cycle from egg to adult may be completed in two to three weeks depending on temperature.

Thrips damage plants by feeding on plant fluids, which reduces overall plant vigor. Damaged plant tissue is white with silvering, blotching and streaking of leaves and flowers. Plants infested with thrips usually have black spots on leaf undersides, which is the excrement exuded by thrips. Sunken tissue may also be evident on plants infested with thrips.



Eggs, larva, pupa, and adult stages of thrips

Whiteflies

Adult whiteflies are 1/8 to 1/4 inch in length and resemble small moths. Wings of the adults are covered with a white waxy powder. Each female lays about 150 eggs over her 30- to 40-day life span. Eggs are laid in a semi-circle of 20 or more, which are spindle shaped and located on a short petiole. Eggs hatch in 5 to 10 days into first instar nymphs, which are yellow-green with legs and antennae. After locating a feeding site, the nymphs insert their mouthparts into plant tissues and begin feeding. After molting (shedding of old cuticle) they cannot move and are scale-like, flat and transparent to green-yellow in color. After molting three times within three weeks, the third-instar nymph tranforms into a pupa (actually a fourth instar nymph), which is yellow-green in color, enlarged, with distinct red eyes. The edges of the body may be perpendicular to the leaf surface and surrounded with waxy, thread-like projections or the body may appear flattened on the leaf surface. Adults emerge in 14 to 28 days. Adult females may commence laying eggs in 2 to 7 days after emergence. The life cycle may be completed in 21 to 28 days, depending on temperature.

Both adults and nymphs feed on plant leaves, primarily on the leaf undersides. The adults and nymphs use their piercing-sucking mouthparts to withdraw plant fluids from the vascular tissues. Feeding causes plant stunting, leaf yellowing, and distortion of leaves and terminal growth. In addition, the nymphs excrete honeydew, a clear, sticky liquid that serves as a growing medium for black sooty mold fungi. Black sooty mold fungi cover plant leaves preventing them from producing food by means of photosynthesis.

Whitefly adult, nymphs, and pupae

Nuisance Pests

Fungus Gnats

Fungus gnats are small (less than ⅛ inch in length), dark-colored flies that resemble mosquitoes. They possess a distinct "Y-shape" pattern on the forewings. Adults, which are ⅛ inch long, fly near the base of plants near the growing medium. They may fly near people's faces when populations are abundant, especially when disturbed. Larvae are white to translucent, about ⅛ inch long, with a characteristic shiny black head capsule. They primarily feed on decaying organic matter and plant roots. Fungus gnat larvae are a problem when growing medium remains moist due to overwatering.

Larvae damage plants by feeding on roots. This results in plant stunting, leaf yellowing, and plant dieback. In addition, feeding by larvae creates wounds that allow soil-borne plant pathogens to enter.

Springtails

Springtails are gray, wingless insects, about 2 to 4 mm long. They can jump with the aid of a forked appendage (tail) or furcula located at the tip of the abdomen. Springtails reside in moist environments and may become a problem when plants are overwatered or growing medium does not drain well. Under these conditions, extensive populations of springtails may be present. Springtails are primarily a nuisance as they feed on decaying organic matter.

Symphylids

Symphylids may be mistaken for springtails. But symphylids are ⅓ to ½-inch long, with 12 pair of legs, whereas springtails are smaller with only three pair. Symphylids are white, very active and reside in moist habitats such as decaying organic matter and growing medium that is overwatered. Symphylids primarily feed on fungi and decaying organic matter. They rarely, if ever, feed on plant roots.

Management

Cultural. Examine and isolate new plants for three to four weeks before incorporating them in with the regular plant collection.

The use of sterilized growing medium or prepackaged potting soil will minimize problems with fungus gnats, springtails, and symphylids.

A forceful water spray may be effective in quickly removing aphids, mites, thrips, whiteflies, scales, and mealybugs from plants. It is important to get the leaf undersides where most insect and mite pests are located. If performed routinely (twice per week) this can prevent outbreaks from occurring. Heavily-infested plants should be immediately disposed of. When only a few plants are involved, using a cotton swab dipped in alcohol may be effective.

Pesticides. Although there are pesticides registered for use indoors, it is recommended to take plants outdoors to be sprayed as odors may be objectionable and cause allergic reactions.

Apply pesticides at 7- to 10-day intervals or until populations have been noticeably reduced. Spray to cover both upper and lower leaf surfaces. Certain plants may be sensitive to pesticides so watch for signs of injury or phytotoxicity such as marginal leaf burn or necrosis, leaf spotting or yellowing, curling of leaves, and terminal dieback. In general, pesticides should never be applied to flowers. Always read the pesticide label to determine those plants that should not be treated.

Flower Garden Pests

Many insect pests attack flowers. In addition to those discussed below, refer to those listed in the section on Indoor Plant Pests.

Cutworms

Caterpillars are greasy-looking, gray in color, and 1 to 2 inches long. They curl up when disturbed. Adult moths are robust, brown in color and somewhat hairy. At rest, adults appear triangular in shape. The forewings have a spread of approximately 1½ inches and are dark-brown in color, with streaked or mottled patterns in various shades of yellow, brown or copper, gray or black. The hind wings are white to light-gray in color with no markings.

Damage

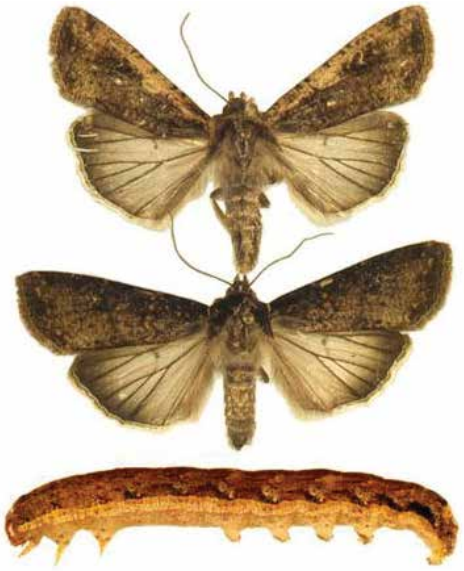
Caterpillars chew plants off at the soil level, or climb on to plants and feed on leaves and buds. They usually feed at night and hide in the soil and debris during the day. Adults fly at night and are attracted to artificial lighting.

Cutworm larval migrations from the soil or weedy areas may be inhibited by means of insecticidal spray barriers. Drench applications of an insecticide to the soil near the base of plants may be effective in managing caterpillars before they cause damage. Collars made of cardboard wrapped around the base of the plant stem may prevent cutworm larval damage.

Identification

Two cutworms of importance in Kansas are the variegated cutworm and the black cutworm. Of these, the variegated cutworm is the most destructive. Caterpillars are 1½ inches long when fully grown, gray to brown in color with dark markings, and a series of yellow spots extending down the middle of the back, with one on each body segment, and a dark "W" on the eighth abdominal segment.

Eggs are laid en masse, often in rows of 60 or more on twigs and leaves. Females may lay more than 500 eggs in a life span. The variegated cutworm overwinters as a pupa.Black cutworm larvae are up to 1¾ inches long. They are greasy-looking and brown in color with pale, longitudinal stripes. Females lay single eggs or several in clumps in the soil. Black cutworm larvae chew the base of stems, cutting them at the soil line and causing plants to fall over. The black cutworm overwinters as a larva or pupa.



Variegated cutworm moth and larva

Slugs

Slugs are classified as mollusks. Active at night, they consume leaves and stems of various plants, creating ragged holes with their chewing mouthparts. Damage may be mistaken for that of caterpillars. However, caterpillars leave black fecal deposits, while slugs leave a shiny, silvery trail on the soil or plant leaves. Slugs chew completely through leaves or stems, but caterpillars may leave leaf veins or partially eaten stems.

Slugs lay eggs in clusters of 20 to 100 in moist locations such as mulch, underneath plant containers, boards, and plant debris. Eggs hatch into young that are lighter in color and smaller in size than adults. When soil temperatures exceed 50°F, eggs hatch in less than 10 days. Slugs may mature in three months to a year with mature adults living for a year or more. Slugs contain both male and female organs, and may be males and females at different times of their adult lives. Under certain conditions, slugs may induce self-fertilization.

Slug management involves the use of molluscicides and appropriate cultural and sanitation practices. These include plant inspection, removing weeds and debris such as boards and empty plant containers, and taking care not to overwater. Traps, including old newspaper or pieces of garden hoses, can be randomly placed around the area and checked during the day for hiding slugs. Slugs can then be placed into a container of soapy water.

Slug

Pillbugs and Sowbugs

These are crustaceans, not insects, which are related to crabs, shrimp, and lobsters. They have seven pair of legs, a pair of antennae, breathing gills, and a series of plates on the back. Pillbugs roll up into a ball whereas sowbugs do not. Sowbugs possess silkened protrusions that extend from the back of the body. They are black, elliptical, and approximately ½ inch long. They are detritivores (consume decaying plant matter) and may feed on the plant roots of young seedlings or tips of green leaves. Both sowbugs and pillbugs are primarily active at night. They hide in soil, plant debris, boards, and under flower pots during the day. An abundance of organic matter in the soil and high humidity favor survival and development. Because their bodies cannot control water loss, they are located in moist areas.

Adults may live a year or more. Sowbugs and pillbugs develop from eggs, which are retained in a "pouch" on the underside of females. A female may lay up to 75 eggs. The young remain in the pouch until they can care for themselves. Development to adult takes about one year. Removing all hiding places will reduce populations of sowbugs and pillbugs. A number of insecticide baits are commercially available.

Pillbug

Caterpillars

Caterpillars are the larvae of moths and butterflies. Caterpillars eat leaves, bore into flower buds and roll up or bind leaves together. Mature caterpillars cause the most damage. Contact or stomach poison insecticides may be effective if applied when caterpillars are young and small, but all plant parts must be thoroughly covered.

Plant Bugs and Leafhoppers

These are relatively small insects that use their piercing-sucking mouthparts to withdraw plant fluids. Plant bugs are oblong with bodies tapering toward the abdomen. The head is small and triangular, with prominent eyes. Color varies from yellow to green to dark brown. Leafhoppers are yellow or green, and wedge-shaped. Nymphs run sideways when disturbed. Some leafhoppers can vector or transmit certain plant diseases.

Contact insecticides may be used against leafhoppers but they may avoid exposure to spray applications because of their mobility. It is important to thoroughly cover all plant parts and make repeat applications. Removing weeds from the area will help alleviate problems with both plant bugs and leafhoppers.

Plant bug nymph

Leafhopper adult

Stalk Borer

The stalk borer is a caterpillar that attacks flower stems, tunneling into stalks, which causes them to wilt and die. Caterpillars tend to feed on plants located on the edge of landscapes or gardens as caterpillars can migrate from weeds located nearby.

The stalk borer produces one generation per year. Caterpillars are slender, creamy white in color, with purple stripes extending lengthwise down the body and a brown or purple band behind the head. Because stalk borers overwinter as eggs, weed removal is an important management strategy.

Well-timed insecticide applications may provide control. If stalk borers are confirmed as the source of the problem, begin treating in May, with additional applications through mid-June. Once borers enter stalks, they cannot be controlled with insecticides. Treatments may keep borers from infesting other plants after adults emerge.

Grasshoppers

Adult grasshoppers are difficult to kill with insecticides due to their migratory behavior and waxy cuticle, which prevents penetration of insecticides. Sprays to control small nymphs should be conducted in early June. It is recommended to apply insecticides in the morning to obtain best control. Remove weeds from the area to alleviate problems with grasshoppers.

Flea Beetles

Flea beetle adults are small, mobile, dark-colored insects that create small holes in leaves of many garden plants. Feeding tends to affect seedlings more severely. Flea beetle feeding is usually not a problem on larger plants. Flea beetles are an early season pest because they overwinter as adults. Adults emerge from the soil when temperatures increase. To control flea beetles apply insecticides as soon as leaf damage is noticed.

Flea beetle adult

Blister Beetles

Blister beetles can be a problem from late June through July when adults attack a wide range of plants and feed on leaves and flowers. Because larvae consume grasshopper eggs, the presence of blister beetles may be associated with an abundance of grasshoppers. Blister beetles numbers may increase as grasshopper numbers increase.

Blister beetles are brown, black, gray, or striped-brown in color. There is one generation per year. Blister beetles may be controlled with recommended insecticides.

Ants

Ants do not feed on plants but may loosen soil around roots. They also feed on honeydew, a clear, sticky liquid secreted by aphids and soft scales. Ants protect aphids and soft scales from natural enemies (parasitoids and predators). Ant control is not warranted outdoors.

Study Questions

1. Which of these insects excrete honeydew?
   a. leafhoppers
   b. scales
   c. mites
   d. honeybees

2. What life stages of scales are easily controlled with contact insecticides?
   a. adult
   b. egg
   c. crawler
   d. all stages

3. The two general types of pest problems associated with indoor plants are:
   a. water and container pests
   b. light and dark colored pests
   c. soil and leaf/stem pests
   d. outdoor and indoor pests

4. Damage symptoms of aphids, whitefly nymphs, scales and mealybugs include:
   a. holes chewed in the leaves
   b. sticky deposits on leaves and stems
   c. stems excised near the soil surface
   d. leaves have a shot-hole appearance

5. Shortly after mealybugs start feeding, they create:
   a. large black drops of oily material
   b. a white waxy material
   c. small red pellets
   d. medium sized balls of leaf tissue

6. Cyclamen mites are small and are what color?
   a. white
   b. green
   c. pale brown
   d. all of the above

7. Soft scales damage plants by:
   a. chewing holes in leaves
   b. notching the outer edges of leaves
   c. removing plant fluids from tender growing parts
   d. excising plants at the soil surface

8. Thrips adults are small insects, but are easy to identify because they possess a fringe of hairs on their wings.
   a. T
   b. F

9. Whitefly adults and nymphs feed by:
   a. chewing holes in leaves
   b. removing plant fluids from the leaves
   c. chewing notches in the stem
   d. excising plants slightly under the soil surface

10. Symphylids are frequently mistaken for:
    a. aphids
    b. mites
    c. springtails
    d. scales

11. Which plant parts are most susceptible to injury from insecticides?
    a. flowers and flower buds
    b. stems
    c. roots
    d. leaves and leaf buds

12. Which caterpillars are the most destructive to flower gardens in Kansas?
    a. white cutworm
    b. corn earworm
    c. cabbage looper
    d. variegated cutworm

Study Questions (continued)

13. Which of these organisms is not an insect?
    a. plant bug
    b. grasshopper
    c. sowbug
    d. springtail

14. Grasshoppers are most easily controlled at which stage?
    a. egg
    b. adult
    c. nymph
    d. pupal

15. Flea beetles overwinter as:
    a. adults
    b. eggs
    c. larvae
    d. pupae

16. Which life stage of ants should be controlled?
    a. do not need to be controlled
    b. egg
    c. larva
    d. pupa

Disease Management

Ornamental plants in Kansas are subject to many diseases. Some are quite serious and kill large numbers of plants. Others cause only minor damage and do not warrant control. Disease control begins with an accurate diagnosis of the problem. Knowing what a healthy plant looks like makes it easier to recognize abnormalities. Some diseases are relatively easy to identify. Others, such as root diseases and vascular wilts, are difficult to diagnose without considerable experience.

Close observation and answers to a few questions will aid in identification. First, determine the species and cultivar of the affected plant. Note cultural practices and weather conditions at the time the problem occurred. Observe the distribution of symptoms in the landscape. Is the problem confined to one plant and one species? Is it uniform, or does it occur in patches? Record your observations. Note the part of the plant affected and type of symptoms — chlorosis, necrosis, galls, or cankers.

Prevention

Most diseases are difficult to control once the pathogen has infected and colonized the host plant. Prevention is critical. A few cultural practices can help prevent an epidemic.

- **Buy healthy plants.** Contaminated plants or infested soil harbor pathogens. Inspect plants carefully before purchase.
- **Select plants carefully.** Choose plants adapted to the local environment and specific site.
- **Plant disease-resistant varieties.** Maintain plant health through proper irrigation and fertilization.
- **Provide adequate water and nutrients.** Maintain plant vigor with proper fertilization and irrigation.
- **Destroy diseased plants.** Pathogens survive on dead plants. Remove plant debris to reduce the chance of infection the following season.
- **Control weeds.** Weeds can host pathogens and create a microclimate that favors infection.

In some cases, chemicals may have to be applied to provide adequate protection against certain diseases. Most fungicides are preventive and must be applied to the plant surface before pathogen infection and colonization. Proper timing of the application — based on the pathogen life cycle as well as yearly weather patterns — is critical for control.

Fungicides fall into two main categories. Contact fungicides are active on the plant surfaces, but are not taken up in appreciable amounts by the plant tissue and may have to be reapplied at routine intervals. Most contact fungicides affect several biochemical pathways in fungi. Plant pathogens developing resistance to these chemicals usually is not a problem.

Systemic or penetrant fungicides are absorbed and translocated to some extent within the plant. Penetrants move within the plant to protect plant tissues that were not directly treated. Systemic fungicides may provide longer intervals of protection from plant pathogens than contact chemicals. There are many types of penetrant fungicides, but many interrupt only a single biochemical reaction. This narrows the range of diseases they control and increases the risk of the pathogen developing resistance.

Abiotic Injury

Abiotic injuries, or environmental stresses, may cause significant damage to plants, especially shrubs and trees. This section addresses a few of the most common problems.

Scorch

Scorch is a general term used to describe a dry browning or necrosis (death) of leaves or needles. Symptoms start at the margins or tips of the foliage and progress toward the leaf base. Scorch is often associated with drought conditions. During dry weather, water is lost

through the leaves (transpiration) more rapidly than the ability of the plant to uptake water from the soil. This results in burned leaf margins. Scorch can result from other factors such as a poor root system, root or trunk injuries, girdling roots, or toxic materials in soil such as herbicides, high salts, and excessive fertilizer. It is difficult to tell what caused the scorch by looking only at leaf symptoms.

Leaf scorch on maple

Scorching of pine caused by drought

Winter Kill or Winter Injury

Winter injury or winter kill is a common problem of both evergreen and deciduous trees and shrubs in Kansas. Cold temperatures can kill winter tender shrubs and trees. Sudden drops in temperature after warm weather are more damaging than steady declines. Trees actively growing after a warm, wet autumn and late summer fertilization are more easily damaged.

Winter drying or desiccation is the most common cause of injury to evergreens. Evergreens retain their leaves throughout the winter so they continue to transpire some water. If the soil is dry or frozen, the plant cannot replace water lost from the leaves, resulting in scorching of leaf (needle) margins.

Trees with thin, smooth bark are susceptible to sunscald damage. This type of injury usually occurs in late winter when tree trunks are exposed to bright sunlight and warm temperatures during the day followed by a sudden drop in temperature after sunset. Large irregular or elongate patches of the bark are killed, often on the southwest side of the trunk.

Frost cracks are longitudinal splits in the bark and wood of a tree, caused in part by old wounds and by differential contraction rates of the inner and outer wood in the tree trunk upon exposure to a sudden drop in temperature.

Sunscald on American hornbeam

To minimize winter injury select trees that are adapted to the region. Trees and shrubs should be watered thoroughly in the fall before freezing weather sets in. Conifers may need to be watered again during the winter if weather is unusually warm and dry, but avoid watering when soil is frozen. Avoid planting trees or shrubs in poorly drained soils. If possible, plant evergreens where they will be protected from desiccating winter winds. Mulching prevents frost from penetrating deep into the ground and can help reduce winter injury.

Transplanting Shock

Newly transplanted trees are severely stressed and often show leaf scorch, leaf drop, and slow growth. Much root damage occurs during transplanting even with ideal care. Tree stress can be reduced during and after transplanting with appropriate planting technique, irrigation, and other care.

Iron Chlorosis

Iron deficiency results in stunted, yellow leaves with the leaf veins remaining green. With severe iron chlorosis, leaves develop brown irregular spots and die. Iron chlorosis is more severe as soil pH increases. Pin oaks, sweetgums, and soft maples are the most commonly affected trees, although many other trees and shrubs also show symptoms. Avoid planting trees and shrubs that are sensitive to iron deficiency on alkaline soils. In some cases, iron deficiency can be corrected with foliar sprays or trunk injections of iron-containing compounds, or by soil amendments.

Iron chlorosis on pin oak

Herbicide Injury

Many tree problems result from careless use of herbicides. Symptoms of herbicide injury include yellowing or distortion of leaves, scorching of leaves, branch dieback, and even death of the tree or shrub. Homeowners should keep in mind that herbicides applied to lawns for the control of broadleaf weeds will damage ornamentals if improperly used. Soil sterilants, used along driveways, fencerows, and ditches to eliminate vegetative growth can be absorbed by tree roots long distances from the tree trunk, resulting in extensive damage to the tree.

Phenoxy herbicide damage to several tree species in a windbreak.

Distorted redbud leaves typical of herbicide injury.

Girdling Roots

Girdling roots can be major cause of tree decline in urban landscapes. This problem occurs when roots that circle the base of the tree begin to enlarge and press into the bark on the trunk. This affects the outward growth of the trunk and will eventually begin to interfere with nutrient and water movement. As nutrient movement is inhibited, the tree may begin to show a gradual decline and exhibit branch dieback. If not corrected, the girdling root may eventually "strangle" and kill the tree.

Proper nursery production and landscape planting techniques and care are the key to prevention. Unfortunately, girdling roots are often not discovered until the tree is in an advanced state of decline. At this stage it is difficult to save the tree.

Girdling roots on maple

Diseases

Plant diseases are caused by living organisms (pathogens) that penetrate and colonize plant tissue. The most common plant pathogens are fungi. In addition, other types of organisms, including viruses, bacteria, and nematodes can incite plant diseases.

Many diseases cause little injury to the host plant. It is not feasible or necessary to control them all. Certain plant diseases may cause temporary or permanent damage to the plant's aesthetic quality, utility, or vigor. A few are capable of killing trees or shrubs.

The number of diseases and the diversity of pathogens that cause diseases of ornamentals and shade trees is enormous. It would be impossible to cover every disease of every ornamental plant in this text. Certain general categories and a few specific problems will be described. If you are not sure of the problem, ask your local extension agent for help in diagnosing the problem.

Leaf Diseases

Leaf diseases are caused by a diverse group of fungi and bacteria. Some can seriously affect plant health and some are minor. Most leafspot organisms require moisture on the leaf surface to penetrate the host plant. Cultural practices to reduce the number of hours leaves remain wet, such as providing good air movement and avoiding overhead irrigation, will reduce the incidence of these diseases. The following is a short list of the more common leaf diseases you will find in the landscape.

Powdery Mildew

Powdery mildew is a common category of foliage disease on many ornamentals and shade trees. This fungal disease appears as a white powdery growth on the surface of leaves, flowers and stems. The fungus absorbs nutrients from the leaf, resulting in a weakened plant. The unsightly lesions can greatly reduce the aesthetic quality of the plant.

Powdery mildews are important on flowers including zinnia and phlox, as well as shrubs such as lilac and rose. Although powdery mildews may also be common on trees such as oak, they normally develop late in the season and seldom cause significant damage. The fungi that cause powdery mildew are host specific; the mildew fungus that infects one species of plant will usually not infect another.

Powdery mildew often thrives on plants that are located in partially shaded areas with poor air movement. Therefore, avoid planting susceptible plants in these locations. If available, select plant varieties with resistance to powdery mildew. For example, many crabapple cultivars have good resistance to this disease. Certain fungicides will provide protection against mildew. These fungicides need to be applied at routine intervals. Though the fungicide will prevent further disease development, the unsightly lesions may remain on the leaves even though the fungus has been killed.

Example of powdery mildew

Powdery mildew on lilac

Rusts

Rust is another type of fungal foliage disease that affects a wide variety of ornamental plants. Rusts are common on junipers, hawthorns and flowering crabapples, ash, rose, hollyhock, and many other ornamental plants. Rust pathogens, such as the powdery mildews, are host specific. For example, the rust fungus that infects ash is different from the rust fungus that infects rose.

Rust diseases often result in the formation of small, orange to brick-red pustules or blisters on the leaves. The blisters are filled with powdery spores of the rust fungus. Excessive rust on leaves may result in early defoliation. On certain plants such as junipers, pines, ash and hawthorns, rusts can cause swellings or galls on twigs and branches.

Cedar-apple rust and the related cedar-quince and cedar hawthorn rusts are common in Kansas. These rust fungi spend part of their life cycle on eastern redcedar and other junipers, and the other part on certain species of apple (including crabapple) and hawthorn. In the spring, the cedar-apple rust fungus produces bright orange, gelatinous galls on juniper. Although these galls are are visually striking, they rarely cause significant injury to the juniper. Fungal spores produced by these galls are dispersed by wind and infect developing leaves of apple and flowering crab in April and May. The first symptom of the disease on apple is the formation of bright yellow-orange spots on the upper surface of the leaves in late June. Eventually, an orange, cup-like fungal structure is formed on the lower leaf surface and produces spores that infect junipers. Apple leaves with numerous spots drop prematurely during the summer. This weakens the tree and reduces winter hardiness and fruit set the following year. The cedar-quince rust infects hawthorn twigs, resulting in small galls and twig dieback.

Cedar apple rust on eastern red cedar

Cedar apple rust on apple

The best means of controlling cedar-apple rust is use of resistant varieties of apple, flowering crabapple, and junipers. Avoid planting susceptible junipers and flowering crabapples close to each other. If susceptible varieties are used, fungicide can be applied to protect the trees. This is usually done in April and May when galls are active on the junipers. Several applications may be needed.

Anthracnose

Anthracnose is a general term used to describe a group of fungal diseases whose symptoms include foliar and/or twig blighting. In Kansas, anthracnose is most common in spring and early summer on deciduous trees such as ash, elm, maple, sycamore, and black walnut. The fungal pathogens differ for each tree species.

Anthracnose causes a range of symptoms, depending on the tree species and weather conditions. Symptoms may include leaf spots and twig blight. These diseases may occasionally result in premature defoliation, but often damage is minimal. In fact, most shade trees in vigorous condition recover rapidly from anthracnose infections.

Sycamore anthracnose is the most serious of the anthracnose diseases in Kansas. During wet, cool springs, the fungus may kill leaf buds and expanding shoots. Repeated killing of young twigs can result in abnormal branching, giving the tree a ragged appearance. Later fully expanded leaves develop elongated tan to brown lesions along the veins.

Anthracnose rarely causes significant damage to shade trees in Kansas. Consequently, specific control measures generally are not required. Nevertheless, the disease may be unacceptable in high visibility landscape settings, particularly on sycamore. Several cultural practices, including proper tree spacing, fertilization, and irrigation will decrease severity of anthracnose. Fungicide sprays normally are not necessary, but fungicides can be applied at bud swell to control the disease on ash, elm, maple, oak, and sycamore. One to two additional applications may be necessary. Certain fungicides are labeled for systemic injection into sycamore trees for the control of anthracnose. Read the label for accurate information on timing.

Anthracnose on maple

Apple Scab

Scab is a serious disease of apple and flowering crabapple. Scab first appears in the spring as olive-green spots on the undersides of new leaves. Spots quickly turn a dark green or brown and affected tissue begins to dry. Eventually, lesions are formed on both upper and lower leaf surfaces. Numerous infections will cause premature defoliation. Blossoms and fruit may also become infected.

The best way to control scab is through the use of resistant cultivars. Disease resistance, aesthetic quality, and the adaptability to Kansas conditions should all be considered before choosing a flowering crabapple variety.

Since the fungus overwinters on fallen leaves, raking and removing leaf debris in the fall may partially control the disease. This will not give complete control since even a few leaves missed during sanitation can start the infection process in the spring.

For susceptible apples and flowering crabapples, several fungicide sprays may be required for control. The most critical application period is April and May when primary spores of the fungus are being released from leaf debris.

Apple scab

Black Spot of Rose

Black spot is the most common foliar disease of roses in Kansas. Affected leaves develop black, roughly circular spots with a feathery margin (edge). Leaf tissue surrounding the spots turns yellow and eventually the entire leaf yellows and drops from the plant. Early defoliation weakens the plant and makes it more susceptible to winter injury.

All leaf debris should be removed in the fall to avoid reinfection of leaves the following

spring. Avoid overhead watering, which favors fungal infection and disease development. Several fungicides will control black spot if applied routinely throughout the growing season. Select resistant varieties for new rose plantings.

Black spot of rose

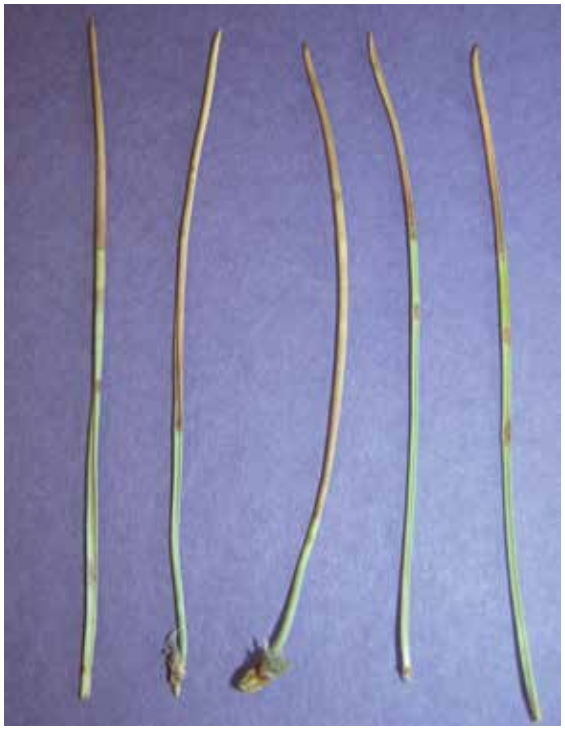
Dothistroma Needle Blight

Dothistroma needle blight can be a serious disease of Austrian and ponderosa pines planted for windbreak and ornamental purposes. The disease causes pine needles to drop prematurely the year following infection. Because pines typically retain needles for three years, premature loss of the foliage results in a reduced photosynthetic area and a loss in tree vigor.

Symptoms of Dothistroma needle blight are evident first in late summer or early fall. Diseased needles exhibit dark green bands or scattered yellow to tan spots. The spots often enlarge and develop into red bands that encircle the needle. A light yellow region may border the red bands on the needle. The tip of the needle beyond the red band eventually turns brown. The needle base remains green. Infection is most common in one- or two-year-old needles, but current season needles also may show symptoms. Typically the disease is most severe in the lower portion of the tree crown.

Collection and removal of diseased needles on the ground around trees may reduce the severity of Dothistroma needle blight. Nevertheless, sanitation probably will not eliminate the disease because many diseased needles remain attached to the tree. In areas where the disease is severe, consider planting another type of tree. Dothistroma needle blight also can be suppressed with fungicide applications. Two applications, typically one in mid-May and a second in mid-June, are recommended to reduce disease.

Needle spotting



Brown needles caused by Dothistroma.

Dothistroma needle blight causes browning, then shedding of interior needles.

Shoot Blights

Certain fungi and bacteria cause a rapid dieback of new shoot growth. This results in a symptom called blight. Two of the more common blight diseases in Kansas are tip blight of pines, and fireblight of crabapple.

Pine Tip Blight

Pine trees may be seriously damaged or killed by a disease called tip blight. All pine trees are susceptible to the disease, but it is most severe on mature Austrian pines. Symptoms of tip blight first appear in late May or early June. New developing shoots, or candles, fail to elongate properly and turn yellow or tan. Small droplets of resin often form on the stunted needles. Normally, all infected needles remain attached to the branch. Dead shoots are more common in the lower portion of the tree crown, but trees that have had repeated infections over several years can have dead shoots and branches throughout the crown. Small black fruiting structures of the fungus are sometimes visible on the undersides of cone scales.

Management. Control of tip blight is aimed at protecting the susceptible, expanding shoots from fungal infection in the spring. Tip blight can be controlled with two applications of an appropriate fungicide if the chemical is applied at the right time. The first application should be made just as the new growth is expanding and again in two weeks. A third application two weeks later may be necessary during wet springs. Removal of dead shoots will improve the appearance of the diseased trees, but it will not prevent infection since most of the fungal spores are produced on cones that remain attached to the tree.

Sphaeropsis tip blight

Fireblight

Fireblight is a bacterial disease that affects a wide range of rosaceous plants including apple, flowering crabapple, and pear. Symptoms are most noticeable in spring on blossoms and succulent new growth. Young infected shoots rapidly turn brown or black and wilt, as if scorched by fire. The terminal end of the diseased shoot becomes hooked and is commonly referred to as a shepherd's crook. During wet weather, small droplets of amber-colored ooze containing millions of bacteria can be seen leaking from infected tissue. After initial infection of shoots, the bacterium may move long distances within living tissue and kill large portions of the plant.

Management. Several cultural practices will reduce or prevent the occurrence of fireblight. Avoid excess fertilization. Dead shoots should be removed during the winter, at least 12 inches below the visible signs of disease. Pruning tools should be disinfected between each cut.

Fireblight on pear

Virus Diseases

Several virus diseases may affect the quality of ornamental plants. Viruses tend to be more destructive in the greenhouse environment, but certain virus diseases may be found in the landscape.

Rose mosaic

Rose mosaic is common in Kansas rose gardens. It has a wide range of symptoms, including ringspots, wavy lines, chlorotic vein banding, an oak-leaf pattern, a mosaic pattern, and a yellow net pattern. Symptoms start showing

up late spring and are present throughout the growing season. Symptom expression varies with the cultivar and the time of year. Some plants infected with rose mosaic viruses remain symptomless.

Transmission of the virus is through vegetative propagation of infected plant material. Infected grafting material can include buds, scions, or rootstocks. An important point to remember about virus-infected plants is that once they become infected, they remain infected for the life of the plant even if symptoms come and go.

Rose plants infected with viruses that cause rose mosaic tend to be more susceptible to winter injury. Although the disease produces unsightly foliage and tends to reduce plant vigor, it will not kill the plant.

There are no practical control measures for virus-infected plants. Severely diseased plants should be removed and destroyed. Certified disease-free roses should be purchased whenever possible.

Rose mosaic

Root Diseases

Several fungal pathogens are capable of causing significant losses of ornamentals, both in production and in the landscape. They can attack seedlings, saplings, and mature plants. Unlike the host-specific rust and mildew fungi, the root rot pathogens, in general, are capable of attacking a broad range of bedding plants. Many root diseases are more common in poorly drained soil.

Root rots are caused by a number of soilborne fungi including Pythium, Phytophthora, Rhizoctonia, and Thielaviopsis. These organisms persist in the soil for long periods of time and infect roots when environmental conditions are favorable. Above ground symptoms of root diseases include yellowing of leaves, shoot or branch dieback, stunting, wilting during moisture stress, and overall low plant vigor. Belowground symptoms include roots that are discolored or rotted and root systems that are smaller than normal and lack fine feeder roots.

Management. Root pathogens may be introduced on transplants or on equipment transporting plant material. Carefully inspect all incoming material for evidence of root rots. Pull plants from trays and inspect roots with a hand lens. Look for root discoloration and/or unusual coloring of root tissue. Maintain plants in a healthy state. Plants weakened by suboptimal growing conditions are predisposed to root rot damage. Improve drainage at the site.

Root and crown rot

Crown Gall

Crown gall is a bacterial disease of many plant species. In Kansas, euonymus, rose, cottonwood, willow, apple, and cherry are commonly affected. Swollen galls normally develop near the soil line, although occasionally they may develop on branches. The galls first appear fleshy colored, but later turn dark. The centers of the galls are hard and woody. Numerous galls on the rots can disrupt the normal flow of nutrients and water such that growth is greatly reduced.

Management. The best way to prevent crown gall is avoiding the introduction of the pathogen into the soil. Carefully inspect plants for galls before planting. Any plants showing galls on the roots should be discarded. The crown gall bacterium infects the plant through wounds, so eliminating wounding will prevent crown gall infections.

Rose crown gall

Canker Diseases

Cankers are localized dead spots in the bark of woody plants that are primarily caused by pathogenic fungi and bacteria. Cankers are one of the most devastating diseases of trees and shrubs because they destroy bark tissue. The bark is an extremely important component of the tree, protecting the sapwood from desiccation and attack by insects and diseases. Bark also protects the vascular cambium, a thin band of plant cells located between the bark and sapwood. The vascular cambium is responsible for radial growth of the tree each season. Damage to bark and cambial tissues affects the development of new wood and bark and may severely restrict the movement of water and nutrients. Girdling cankers will kill the tree.

Symptoms. Canker symptoms vary depending on the pathogen, the tree host, and environmental conditions during infection and colonization. Nevertheless, some symptoms are common to most canker diseases. Bark tissue initially infected by canker pathogens becomes discolored. Healthy, inner bark tissue is usually greenish-white to light tan in color, while infected bark turns red, dark brown or black. There is usually a sharp demarcation between healthy and diseased tissue. Canker pathogens infect and colonize bark. They usually enter through some type of wound, such as a pruning cut or lawnmower injury. Some pathogens infect bark during late fall or early winter, while others attack during the spring and early summer.

Canker diseases are difficult to control once infection has occurred. Focus efforts on proactive practices that prevent canker development.

- Maintain optimal tree health with proper fertilization and irrigation.
- Avoid all unnecessary wounds. Bark injuries allow canker pathogens to enter.
- Prune properly. Do not leave branch stubs or cut branches flush with the trunk.
- Do not treat fresh pruning cuts with wound dressings or fungicides.
- Avoid canker susceptible trees including flowering plum, Rocky Mountain juniper, hybrid poplars, and Russian olive.
- Remove branches with cankers.

Canker on branch of black walnut

Bark discoloration associated with Thyronectra canker on honeylocust

Wilt Diseases

Wilt pathogens colonize the water conducting tissues in the plant. Three common wilt diseases of trees are discussed below.

Verticillium Wilt

Verticillium wilt is caused by a fungus and affects a diverse range of trees, woody ornamentals, and herbaceous plants. In Kansas, the disease is common on catalpa, maple, Russian olive, redbud, smoketree, golden-rain tree, cherry and other stone fruits, and barberry. The disease occasionally occurs on ash and elm.

Symptoms. Symptoms of Verticillium wilt vary depending on the species of tree infected, time of symptom development and other environmental and host factors. Initially, leaves on diseased branches appear off-color (pale green to yellow) and are limp or flaccid. These symptoms may appear on individual branches in a section of the tree crown or throughout the entire tree. In some cases, the disease progresses slowly over a period of months or years, resulting in gradual defoliation, branch dieback, and a general tree decline. Trees affected in this manner are stunted, unthrifty, and eventually may die. In other cases, affected foliage wilts, turns dry and brittle, and drops from the tree in a matter of days or weeks. This type of wilting can result in rapid branch or tree mortality. Symptoms of Verticillium wilt can develop throughout the growing season, but are more common in late spring or early summer in our state. Another diagnostic symptom of Verticillium wilt is vascular discoloration or streaking in sapwood of diseased branches.

Verticillium wilt of trees may be avoided through prevention and sanitation. Susceptible trees should not be planted in areas where the disease has occured previously.

Discolored sapwood associated with Verticillium wilt.

Verticillium wilt of American smoke tree

Dutch Elm Disease

Dutch elm disease, caused by a fungus, kills many American elms in Kansas each year. Initial symptoms include discoloration and wilting of foliage. The pattern of wilting depends somewhat on when and how infection occurs. Trees infected by bark beetles carrying the fungus typically develop symptoms in late May or occasionally in late August or September. The major vector (disease-transmitting insect) in Kansas is the smaller European elm bark beetle. This insect feeds primarily on small branches high in the tree crown.

Symptoms. Initial wilt symptoms are usually detected on one or more small branches relatively high in the tree. Foliage on diseased branches first appears off-color then turns yellow. Eventually, foliage throughout the crown wilts, and the tree dies. Depending on the time of infection (fall or spring), diseased trees may survive for up to a year. The fungus may also move from diseased to healthy trees through root grafts.

Another diagnostic feature of the disease is the formation of brown streaks in infected sapwood. The sapwood of healthy branches should appear cream-colored without streaking. Do not look for streaking on dry, dead branches or branches not showing wilt symptoms.

Management. A Dutch elm disease management program should emphasize prevention and sanitation. Early detection is critical for control. Trees showing more than 5 to 10 percent crown symptoms seldom can be saved and should be removed immediately. Root grafts between healthy and diseased elms should be disrupted by mechanical trenching before the diseased tree is removed. All diseased elm wood should be burned or chipped. It should not be used for firewood unless the bark is removed. Systemic fungicides injected into the tree may be used to prevent Dutch elm disease, but in conjunction with cultural practices. Fungicide injection is not a substitute for sanitation.

Pine Wilt

Pine wilt is an unusual type of wilt disease because it is caused by a microscopic worm called a nematode, specifically the pinewood nematode. The disease is common in Scots, Austrian, and Mugo pines. Pine wilt is common in the eastern half of Kansas and has been found in western Kansas as well.

Symptoms. Symptoms of pine wilt usually appear in late summer or early fall. Needles on infected trees initially show a light grayish-green discoloration, then turn yellow and brown. The disease may progress uniformly through a tree or branch by branch, depending upon the size of the tree and the environmental conditions during the growing season. Diseased trees often die within two to three months, but the needles may remain attached for up to six to twelve months. The tree death contrasts with other pine problems such as fungal diseases, insects, or environmental stresses.

The pinewood nematode is carried from healthy to diseased trees by a wood-boring insect called the pine sawyer. In May through June, adult pine sawyers emerge from nematode-infested pine trees killed the previous fall and fly to feed on the bark of young pine shoots. The pine may become infected as the nematodes migrate from the beetle to the open feeding wounds on the shoot. Once inside the pine, the nematode population increases rapidly. Within 4 to 5 weeks, the nematode has spread throughout the tree. Trees infested with the pinewood nematode die within 3 months after becoming infected. The pine sawyer insect lays eggs in the dying trees and the new adults that emerge the following spring are contaminated with the nematode.

All dead pines should be removed and wood destroyed by chipping or burning before May 1 to prevent emergence and flight of the pine sawyer beetle. Trees should be removed to ground level. No stumps should be left. There are several injection products available to prevent pine wilt. They must be applied using appropriate equipment. There are no effective chemicals after the tree is already infected.

Pine wilt of Scots pine

Wood Decay

Wood decay is the progressive deterioration of the wall substances of wood. Decay is caused primarily by a handful of fungi that possess the enzymes capable of degrading wood cells. These wood decay fungi gain entrance into trees through wounds, branch stubs and other openings. The action of these wood decay fungi inside the tree can result in a structural weak-

ening of the tree. This may ultimately result in a hazard tree that is subject to breakage during violent weather. The tree has natural defense mechanisms which may "wall-off" the decay to a certain portion of the tree, but this barrier may be breached with additional wounding or injury to the tree. Once the decay process has been initiated it is very difficult to stop.

Symptoms. Indicators of wood decay in living trees are present, but not foolproof. First, inspect the tree carefully for any evidence of branch dieback or unthriftiness in the tree crown. Dieback and decline symptoms may indicate damage to the main trunk or roots. When pruning limbs in the upper part of the tree, look at the cross-sectional cut to see if the wood is punky or decayed. If it is, continue to check for further decay. Obviously, any open, hollow areas in the trunk are indicators of poor tree health and potential wood decay. If you suspect decay, you may need to determine its extent. This can be done by removing a small core with an increment borer or by measuring resistance when drilling into the tree with a small diameter drill bit. There are also more sophisticated devices for detecting wood decay.

A strong indicator of decay is the presence of fungal fruiting structures on the trunk or roots. These may be mushrooms or hard, hoof- or shelf-shaped structures called conks. These fruiting structures may indicate a substantial column of decay. If you find these, submit them to the diagnostic lab for identification.

Management. Wood decay can be avoided by preventing unnecessary wounds to the tree both above and below ground. Proper pruning is essential to control decay. Prune when branches are small and do not leave stubs. Avoid damaging roots during construction, utility work, and other site renovations. Inspect trees routinely for symptoms or signs of decay, such as conks, and remove trees that may be a hazard to property or humans.

Hoof-shaped fungal structures called conks indicate internal wood decay.

Study Questions

1. The first step in the control of plant pathogens:
   a. proper watering of the plant
   b. proper fertilizer
   c. use of a fungicide
   d. accurate diagnosis of the problem

2. Some information which should be obtained for disease diagnosis includes:
   a. species and cultivar of plant
   b. records of cultural practices
   c. record of specific plant symptoms
   d. all the above

3. Which of the following statements about fungicides is true?
   a. Contact fungicides are mobile within a plant
   b. Systemic fungicides tend to require more frequent applications than contact fungicides
   c. Timing of application is not important for fungicides to be effective
   d. Pathogens can sometimes become resistant to systemic fungicides

4. Winter injury to trees and shrubs can be minimized by:
   a. watering them adequately in the fall
   b. choosing trees and shrubs with very thin bark
   c. mulching under the plants
   d. a and c above

5. Iron chlorosis results in:
   a. bright green leaves
   b. green leaves with yellow veins
   c. yellow leaves with green veins
   d. bright yellow leaves with yellow veins

6. Herbicide injury may include:
   a. all the following
   b. distortion of the leaves
   c. scorching of the leaves
   d. branch dieback

7. The most common plant pathogens are:
   a. aphids
   b. fungi
   c. leafhoppers
   d. cankers

8. Powdery mildew is caused by a:
   a. smut
   b. virus
   c. bacteria
   d. fungus

9. Which statement about powdery mildew is NOT true:
   a. there is only one species of powdery mildew than infects all plants
   b. powdery mildew can be reduced by improving airflow and reducing shade
   c. powdery mildew absorbs nutrients from the leaf, weakening the plant
   d. for some types of plants, varieties resistant to powdery mildew are available

10. Rust is caused by a:
    a. fungus
    b. bacteria
    c. virus
    d. salt

11. To control cedar-apple rust, routine sprays on the apple/crabapple host must be applied during:
    a. January and February
    b. April and May
    c. July and August
    d. October and November

12. Scab fungus on apple and flowering crabapple overwinters:
    a. on the twigs
    b. under bark on the trunk
    c. on fallen leaves
    d. on fallen fruit

13. The most common foliar disease of roses in Kansas is:
    a. winter kill
    b. black spot
    c. stem rot
    d. white spot

14. Rapid dieback of new shoot growth is called:
    a. new shoot death
    b. a canker
    c. blight
    d. none of the above

15. Young infected shoots that rapidly wilt as if scorched by fire have the disease:
    a. Anthracnose
    b. Scab
    c. Black Spot
    d. Fireblight

16. Rose mosaic virus is transmitted by:
    a. aphid
    b. leafhoppers
    c. vegetative propagation
    d. mantids

17. Which statement is TRUE about root diseases?
    a. most root diseases are caused by fungi
    b. root diseases are most common in sites with poor drainage
    c. it is a good practice to avoid using plant material that shows signs of root disease
    d. all of the above

18. Above ground symptoms of root disease include:
    a. yellowing of leaves
    b. branch and shoot dieback
    c. wilting during stress
    d. all the above

19. Crown gall disease is caused by:
    a. bacteria
    b. aphids
    c. mites
    d. scales

20. Bark injuries serve as entrances for canker pathogens.
    a. T
    b. F

21. Symptoms of Verticillium wilt are more common in:
    a. mid to late winter
    b. late spring to early summer
    c. early to mid fall
    d. late fall to early winter

22. Dutch elm disease moves from diseased to health trees:
    a. by leaf beetle feeding
    b. by elm bark beetle feeding and through natural root grafts
    c. by birds
    d. by windblown spores

23. Pine wilt is unusual because it is caused by a:
    a. bacteria
    b. fungus
    c. nematode
    d. virus

24. Wood decay is caused by:
    a. insects
    b. bacteria
    c. fungi
    d. viruses

25. "Conks" are:
    a. orange spots on leaves
    b. fruiting bodies of wood decay fungi
    c. insect feeding wounds
    d. nematode eggs

Weeds

A weed is a plant out of place that is unwanted, harmful, and persistent. Weeds may reduce yields, increase labor, impair human health, or detract from the natural beauty of the landscape.

Annual, Biennial, and Perennial Weeds

Annuals

Annual weeds are most troublesome in intensely cultivated ornamentals. They can be divided into two categories:

Summer Annuals

- Summer annual grasses that germinate during the spring and summer (crabgrass, fall panicum, and barnyardgrass)
- Broadleaf summer annuals germinate during the warm season and are killed by hard frost (purslane, pigweed, and lambsquarters)

Winter Annuals

- Winter annual grasses germinate during the late summer or fall (annual bluegrass and annual bromegrass), and
- Winter annual broadleaf weeds that survive freezing temperatures (horseweed, common chickweed, bittercress, and pepperweed).

Crabgrass

Biennials and Perennials

Biennial and perennial weeds are most troublesome in uncultivated ornamentals. Underground plant parts (rhizomes) enable them to survive from year to year and to spread in several ways:

- Many weeds spread easily when carried in soil, in root balls, and on cultivating equipment, as well as by seeds. These include bermudagrass, johnsongrass, quackgrass, nutsedge, mugwort, and wild garlic.
- Seeds of perennial weeds such as dandelion and goldenrod are spread primarily by wind and water.
- Horsetail rush spreads by underground plant parts and by spores.

Barnyard grass

Common purslane

Weed Control

When choosing a control method, consider both the weeds and ornamental plants. Use cultural methods, mechanical methods, herbicides, or a combination of the three. A weed may be resistant to certain controls. No herbicide is safe for all plants. Newly planted ornamentals may be injured more easily than established plantings. The label tells how to use the herbicide safely and effectively.

Herbicides kill weeds through the leaves or the roots or both. Selective herbicides kill some plants without killing others. Nonselective herbicides kill or have activity on all plants they come in contact with. The main types of herbicides used in or around ornamentals are preemergence herbicides, postemergence herbicides, soil fumigants, and sterilants.

Persistence, or how long a herbicide stays active, varies with the herbicide, dosage, soil type, water solubility, and many other factors. Persistent herbicides may leave residues that may injure a sensitive crop planted later. Repeated applications of persistent herbicides also can injure ornamental plants under certain soil and climatic conditions. Granular formulations are an efficient way to apply preemergence herbicides. Postemergence herbicides usually are less persistent than preemergence herbicides. Postemergence herbicidesmost commonly are applied as a directed spray.

Soil fumigants are nonselective and cannot be used in the root zones of desirable plants. Use fumigants before planting. The label will specify waiting periods between treatment and planting. Soil sterilants will control most weeds for long periods of time. In humid regions, however, no material is completely effective for more than one season. Soil sterilants are nonselective. They can damage nearby trees, shrubs, and turfgrass through root uptake or movement of the chemical by wind or water.

Common lambsquarters

Herbicide Effectiveness

Weed control using a given herbicide may vary in effectiveness from year to year or area to area. Factors that influence weed control with soil-applied herbicides include:

- kinds of weeds
- application rates and methods
- uniformity of application
- solubility of herbicide
- volatility of herbicide
- rainfall
- soil type
- organic matter

Factors that influence weed control using foliage-applied herbicides include:

- kinds of weeds
- application rates and methods
- uniformity of application
- spray additives
- loss due to rain or light
- retention on leaves

Understanding herbicide effectiveness will help you select an appropriate herbicide. For more information, read the label, or contact the dealer or your local extension agent.

Redroot pigweed

Proper Use of Herbicides

Herbicides are more effective when growing conditions are favorable, but they may cause more crop damage as well. Effects on a weed and crop plants vary with different herbicides.

To use a herbicide properly, select one that is appropriate for the crop and apply it under desirable weather conditions. If properly used, there should be minimum damage to desirable plants. Containers and excess product should be disposed of safely. Herbicides should not be applied with equipment that will be used to apply other pesticides.

Selection and Registered Uses

Selecting a herbicide depends on the crop being grown—such as trees, shrubs, field crops, vegetables, or turf. The choice depends also on the expected weed infestation, length of weed control desired, cropping sequence and cost. Use only a herbicide that has been registered for use on trees to be grown. Herbicides named in this publication (as of printing date) have been registered for the uses suggested. Uses described on current container labels also are registered.

Herbicide Labels

Read and follow all label directions and precautions. Labels on herbicide containers are written with great care to give needed information. The label of a registered herbicide must carry the following information: brand name or product name, ingredient statement giving the name and percentage of each active ingredient, toxicity of the chemical, and directions for use including rates and time to spray. The label also contains the net weight or measure of content, name and address of manufacturer, and EPA registration numbers.

Chickweed

Application Rates

Apply at the rate recommended for your soil or for the age of tree and/or stage of weed growth. Do not exceed the recommended amount. Apply properly over the treated area. Equipment must be calibrated to attain the recommended application rate.

Spray Drift

Spray drift resulting in damage to susceptible plants in adjacent areas is a serious problem. Apply herbicides on days with light to no breeze (5 m.p.h. or less). Apply at a maximum pressure of 30 pounds per square inch for boom sprayers.

Phenoxy Herbicides

Horticultural crops, woodlots, and numerous other economic plants frequently are damaged by careless or indiscriminate use of phenoxy herbicides. Each year professional horticulturists, herbicide specialists, foresters, and county extension agents receive many questions and complaints about twisted and distorted plants. Misuse of 2,4-D or other phenoxy herbicides can cause considerable damage. Prevent damage to your own or your neighbors' susceptible plants from phenoxy herbicides by following these rules:

- Use phenoxy herbicides only when specifically needed. In some cases use of other herbicides that are less hazardous can effectively control broadleaf weeds.
- Use the amine salt formulation when possible and when temperatures are expected to exceed 80°F. If the ester formulation must be used, apply a low-volatile ester formulation when air temperatures are expected to be below 85°F for several hours.
- Apply on days with light breezes (5 m.p.h. or less) or in evenings and early mornings when winds have subsided.
- Use low spray pressure to minimize spray drift.
- Use a separate sprayer for phenoxy herbicides and use another sprayer for other pesticides unless the sprayer can be thoroughly cleaned.

Sprayer Nozzle Tips

Use the correct nozzle tips for the desired applications. Tips vary in amounts of material they discharge and spray patterns they produce. Stainless steel or nylon tips are preferred when spraying wettable powders, because other types wear out more rapidly. Dealers can order such tips if they do not have them in stock.

When applying a herbicide in a band, use only nozzle tips designed specifically for band application— those that apply a uniform spray pattern across a band. Standard, "flat spray" nozzle tips should not be used since they give a feathered pattern at the edges and an uneven application across the band.

Herbicide Residues in Soils

Some herbicides may remain in the soil for a few days, others for many years. Persistence depends on decomposition and leaching characteristics of the herbicide, soil type, rainfall, soil temperature, soil microorganisms, and application rate.

Injury to future crops will depend on the persistence of the herbicide and susceptibility of the crops. Check and follow precautions on labels for cropping limitations, before you select a herbicide. Plan a cropping sequence and herbicide program that will avoid soil residues that could adversely affect susceptible crops in the cropping sequence.

Horseweed

Herbicides for Nursery and Ornamental Plants

Properly using herbicides to control weeds in nurseries can reduce labor costs, improve quality and grade to stock, and increase salable plants per acre. A good program starts with healthy plants in weed-free soil cleaned by sterilization, crop rotation, and cultivation. Control practices in nursery plantings include spot hoeing and cultivation supplemented by herbicides as needed to maintain weed-free conditions.

Before applying herbicides, read the label directions for rates of application. Do not exceed recommended rates. Apply each of the herbicides mentioned in the following table only to species or ornamental plants recommended on herbicide container labels.

Preemergence Herbicides for Landscape Ornamentals

Benefin + oryzalin
Benefin + trifluralin
Corn gluten
Dichlobenil
Dithiopyr
Metolachlor
Napropamide
Oryzalin
Oxadiazon
Oxadiazon + napropamide
Oxadiazon + prodiamine
Oxyfluorfen + oxadiazon
Pendimethalin
Prodiamine
Trifluralin
Trifluralin + isoxaben

Bermudagrass

Selective Postemergence Herbicides for Landscape Ornamentals

Bentazon
CAMA
Clethodim
Fenoxaprop
Fluazifop-p-butyl
Imazaquin
Mecoprop
MSMA
Sethoxydim

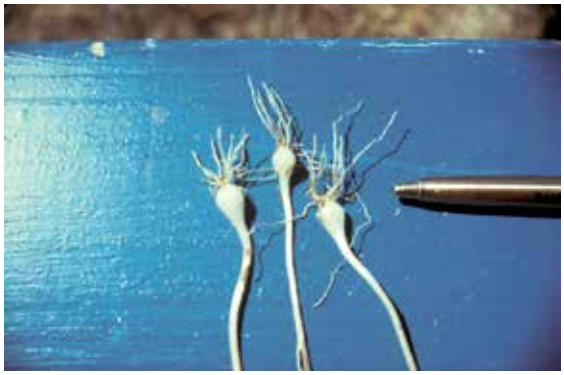
Yellow nutsedge

Yellow nutsedge

Non-selective Postemergence Herbicides for Landscape Ornamentals

Cacodylic acid
Dichlobenil
Diquat
Glufosinate
Glyphosate
Pelargonic acid

This list is not intended to be exhaustive. Omissions do not necessarily mean that other herbicides cannot be used. Always check the label to determine whether or not a product can be used. These products are intended only for directed spray use in ornamentals unless otherwise noted on the label.



Wild garlic

Dandelion

Foxtail

Foxtail seed head

Study Questions

1. Which of the following is not an annual weed?
   a. crabgrass
   b. purslane
   c. johnsongrass
   d. common chickweed

2. Factors which influence weed control with soil-applied herbicides include:
   a. kinds of weeds
   b. solubility of the herbicide
   c. rain fall
   d. all the above

3. Which of the following does not influence weed control when using foliage-applied herbicides:
   a. kinds of weeds
   b. uniformity of application
   c. retention on leaves
   d. solubility of herbicide

4. Herbicide damage to ornamentals can occur when:
   a. wind speeds are greater than 5 m.p.h.
   b. applied at the incorrect rate
   c. ester formulations of 2,4-D are used when the temperature is greater than 85˚F
   d. all of the above

5. Herbicide persistence in the soil does NOT depend on:
   a. soil type
   b. rainfall
   c. crop susceptibility
   d. application rate

6. Weed control in ornamentals begins with:
   a. crop removal at the end to the growing season
   b. planting plants in weed-free soil cleaned by crop rotation, cultivation, and/or sterilization
   c. selection of a crop which resists weed invasion
   d. a trial run through the field to determine applicator competence

Equipment

Several types and sizes of equipment are available for applying pesticides to shrubs, nursery stock, shade trees, and other ornamental plants. Manually operated sprayers, low-pressure power sprayers fitted with spray guns, or light-weight, powered mist blowers are suitable for shrubs and small trees. High-pressure, high-volume, hydraulic sprayers or air-carrier sprayers are required for tall shade trees. Each type of sprayer has distinct uses and features.

Sprayers for Shrubs and Small Trees

Manual sprayers are typically used for ornamental plants. They are relatively inexpensive and easy to clean and store. Most use compressed air or carbon dioxide to apply pressure to the supply tank, forcing spray liquid through a nozzle. Small, power sprayers are capable of delivering 1 to 3 gallons per minute at pressures of up to 300 pounds per square inch (psi). They are usually used with spray guns. Powered mist blowers use much less water, enabling the operator to cover larger areas without refilling. Rotary nozzle sprayers are also available, which distribute liquid at lower volumes and produce less drift.

Compressed-Air Sprayers

Compressed-air sprayers may be used for shrubs, small trees, and other ornamental plants. Pressure for this type of sprayer is provided through a hose by a manually operated air pump that fits into the top of the tank. Compressed-air sprayers hold about 1 to 5 gallons of spray. They can be carried by hand, on a shoulder strap, or mounted on a small cart. A built-in, hand-operated pump compresses air into the sprayer. Pressure forces spray out of the tank through a tube. The user squeezes a trigger or valve to turn the spray on and off.

Most compressed-air sprayers use a single nozzle, but multi-nozzle wands are available on some units. The applicator should have interchangeable or adjustable nozzles to suit the requirements of various pesticides and target areas. Typically, nozzles can be adjusted to deliver spray in various patterns, from a solid-stream to a fine, hollow-cone. Because these sprayers lack a built-in agitation system, users must gently shake the tank to maintain a uniform spray mix. Shaking may be inadequate for formulations such as wettable powders.

Pressure Regulation

Compressed-air sprayers may not come equipped with pressure gauges or controls. Pressure in the tank drops as the liquid is sprayed from the tank and the air expands. Because pressure changes easily, manual sprayers have a tendency to apply in a nonuniform manner. Fluctuations can be addressed by filling the tank only two-thirds full with the spray material (or to a fill line) so that air space remains for initial expansion, and by repressurizing the tank frequently. If the sprayer has a pressure gauge, note that normal spraying pressure is between 20 and 60 pounds per square inch (psi). When it drops about 10 psi from the initial reading, it is time to repressurize.

A pressure-regulating valve, such as the CFValve, placed in the output line of the sprayer, typically just before the nozzle, helps to control pressure. This special valve allows fluid to pass only at a certain preset pressure and flow rate. The pressure may be preset or adjustable, depending on the valve.

With the CFValve, pressure and flow at the nozzle is regulated by using the throttling pin, moving in and out to vary the size of the inlet orifice. If the tank pressure is too low, the valve closes, alerting the operator that more pressure is needed. In this capacity, the CFValve serves as a check valve, closing completely without dripping when the pressure falls below the valve's preset pressure. If the tank pressure is too high, the valve reduces the output to the preset pressure. By keeping nozzle output pressure constant, the flow rate from the nozzle is also held during the application.

Another version of the compressed-air sprayer uses a precharged cylinder of air or carbon dioxide to provide pressure in place of a manual pump. These units include a pressure-regulating valve that maintains consistent spray pressure. They can be mounted on wheels for easy portability. Pesticides may be applied through a spray gun or short boom.

Backpack Sprayers

Most backpack sprayers have capacities similar to those of compressed-air units and can be used for many similar types of applications. Because a backpack sprayer is carried on the operator's back, the weight is supported across both shoulders and does not cause undue fatigue. Tank capacity ranges from 2 to 6 gallons.

Pumps

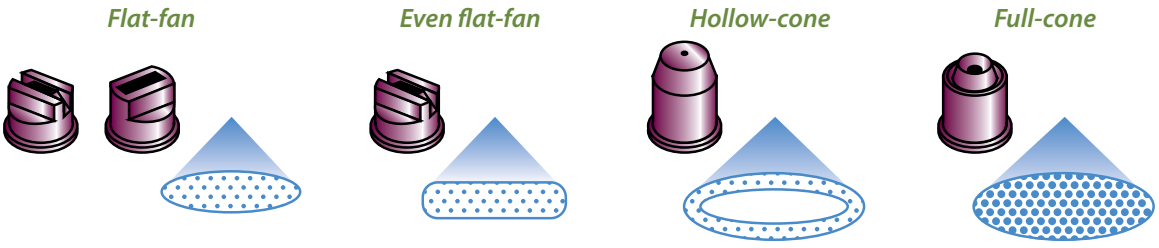
For many backpack sprayers, pressure is supplied by a hand-operated piston or diaphragm pump. A few strokes of the handle are required to provide the initial pressure, and intermittent strokes (about every 2 or 3 seconds, depending on the flow rate) are required to maintain the pressure. An air chamber helps smooth out pump pulsations. Piston pumps can provide higher pressures, often up to 90 psi, but cannot be used with abrasive formulations such as wettable powders. This higher pressure makes backpack sprayers suitable for applications of insecticides and fungicides.

By contrast, diaphragm pumps cannot provide such high pressures (upper limit around 60 psi), but they can tolerate abrasive formulations. Diaphragm pumps are most suited for applications in which higher outputs are required, such as application of herbicides in which a medium or coarse droplet size is required. Some newer backpack sprayers have pumps capable of reaching up to 150 psi. The applicator should take care when using high pressures because of the increased risk of drift due to the small droplet sizes formed at high pressures. Backpack sprayers with either pump design may provide hydraulic or mechanical agitation, which is critical for applying pesticide formulations such as wettable powders. With hydraulic agitation, a uniform mix is maintained by bypassing some of the liquid back into the tank through an agitator nozzle. Some backpack sprayers use electric or two-cycle engines to provide pressure. The electric-powered sprayers have rechargeable batteries that can spray up to 120 gallons before needing to be recharged. Because the pump is electronically controlled, a constant and uniform spray flow is maintained automatically.

Nozzle Selection

As with boom sprayers, nozzles are a critical component of backpack sprayers. Various nozzle types are available, including many of those used on boom sprayers. Flat-fan nozzles are recommended for many uses, including applications of herbicides, insecticides, and fungicides. They are a good choice for making broadcast applications. Although hollow-cone nozzles are often recommended for insecticide and fungicide applications, they produce fine droplets and should be used with caution. Proper selection of flat-fan nozzle size and operating pressure ensure droplet sizes that are effective while minimizing the risk of drift.

Some backpack sprayer manufacturers offer a small, flooding nozzle for use with their sprayers that work well for low-pressure herbicide applications where drift is a concern. Even flat-fan nozzles should be used for band applications. Adjustable nozzles that produce patterns that vary between a straight stream and hollow cone allow for flexibility. They are a good choice for a backpack sprayer that will be used for a variety of spraying tasks. The straight-stream pattern works well for spot application and spraying longer distances. The hollow cone works for covering foliage on trees



Nozzle types

and shrubs; but again, caution should be exercised whenever a hollow cone pattern is used because of the risk of drift.

The applicator should maintain a constant flow rate to ensure uniform application. Changes in flow rate occur due to variations in pressure as the sprayer is pumped. A pressure-regulating valve, such as the CFValve, placed in the output line of the sprayer, helps to control pressure. Certain backpack sprayer models come with built-in adjustable pressure settings that allow the applicator to select a preset pressure and others with a pressure gauge built into the spray-wand handle. For models that do not include these features, a pressure gauge can be added as an accessory.

Application

Rate. The three factors that determine the spray application rate, usually measured as gallons applied per 1,000 square feet, for a backpack sprayer are speed, nozzle flow rate, and effective sprayed width, just as with a boom sprayer. Speed is determined by walking speed or the speed of arm motion while making the application. When you are making an application with a backpack sprayer, it is important to maintain a uniform walking speed and a consistent hand and arm motion.

Technique. When using a backpack sprayer with only a single nozzle at the end of a wand, effective spray width is usually the distance between the centerline of each pass with the nozzle. For example, if you make a pass across a patch of grass, and on the return pass the center of the spray pattern is 15 inches from the centerline of the previous pass, the effective sprayed width is 15 inches. The recommended distance between each pass is based on the required overlap for the type of nozzle at the end of the wand. All nozzles used on a backpack sprayer, except an even flat fan, require a certain amount of overlap. Instead of being adjusted by boom height and distance between nozzles as on a boom sprayer, overlap with a backpack sprayer is set by the distance between each spray pass, as previously discussed, and the height the nozzle is held above the target.

To determine whether you have the correct amount of overlap when making an application, make several passes with water on a flat surface such as concrete. Then watch the evaporation rate. All of the water should evaporate at about the same time. If you notice streaking, adjust the amount of overlap by changing either the nozzle height above the target or the distance between each pass.

For the most accurate broadcast application using a backpack sprayer, choose a boom designed for use with handheld sprayers. These booms typically have two to four nozzle positions. Flat-fan nozzles should be used on the boom, and as with a powered boom sprayer, overlap is controlled by adjusting the height of the boom. Move the boom down closer to the target to reduce overlap, and move it higher to increase overlap. To monitor and control boom or nozzle height during an application, dangle a piece of string from the spray wand that is the same length as the required height. Use this as a visual indicator of height.

Nozzle flow rate is measured in gallons of spray emitted by the nozzle in one minute — gallons per minute (gpm). Nozzle output depends on orifice size. Larger openinings and higher pressure increase flow rate and smaller orifices and lower pressure reduces flow rate.

Mist Blowers

Powered mist blowers feature lightweight engines and fans that create a fine mist. Because air carries pesticide to the plant, less water is needed and the pesticide solution is 3 to 10 times more concentrated than with a pressure sprayer. The air blast results in more thorough coverage. Spray reaches the undersides of leaves, stems and branches, as well as leaf surfaces. With the the mist blower's low water advantage, the operator can cover a large area quickly without refilling. Drift is a major concern because small droplets may blow past the target plant.

Small Power Sprayers

Small power sprayers with 3-horsepower gasoline engines and 15- to 30-gallon spray tanks are well-suited for use by commercial applicators in nurseries, parks, and similar areas. Different pumps may supply low pressures (up to 60 psi) or high pressures (about 300 psi) for different types of spraying. A variety of spray guns, wands, extensions, nozzles, and booms are available to adapt these sprayers to a wide range of conditions and uses. Small, power sprayers are capable of applying pesticides to a wide variety of ornamental plants more

economically than larger and more expensive tractor- or truck-mounted sprayers.

Rotary Nozzle Sprayers

Rotary nozzle sprayers are lightweight handheld units that have a battery-powered spinning cup with interior grooves that force the spray from the edge of the cup. As the spray reaches the edge, it is dispersed in a hollow-cone pattern, 4 to 7 feet in diameter. The cup rotation speed controls the droplet size, creating larger drops at slower speeds and smaller drops at higher speeds. The droplet size tends to be more uniform than that from hydraulic nozzles. For a typical herbicide application, a speed of 2,000 revolutions per minute (RPM) produces about 250 micron droplets. For insecticide and fungicide applications, a speed of 3,500 to 5,000 RPM will generate about 80 to 150 micron droplets. The units apply low amounts of spray solution and require small amounts of energy.

Applicators for Shade Trees

When applied to shade trees, pesticide must thoroughly cover all target areas, including leaf, stem, and trunk surfaces. Much more energy is required to treat a large tree than a small plant because spray must be projected over much greater distances and cover a much larger surface area. High-pressure, high-volume hydraulic or air-carrier sprayers are typically used for this purpose. Hydraulic sprayers use pressure to propel the spray solution, while air-carrier sprayers transport and distribute spray solution through the air using high- or low-pressure liquid systems. Tree injection may also be used to treat ornamental shade trees. With this method, specially formulated pesticides are injected into the tree's vascular system and are distributed by the movement of water through the plant.

Hydraulic Tree Sprayers

Hydraulic sprayers use pressure to distribute sprays in tall trees. They are generally equipped with tanks, pumps, and control systems that can handle high volumes of spray material at high pressures. Sprayers are available with tank capacities of up to 1,500 gallons and pumps that can supply up to 60 gallons per minute at pressures of up to 800 psi. Hand-operated spray guns direct the spray to the tree. Liquid is applied to the point of runoff to ensure through coverage.

Relief Valves

A relief valve is necessary on all high-pressure hydraulic sprayers to protect the system from excessive pressure and to control pressure applied to the spray gun. Liquid that does not go to the spray gun returns to the tank through the bypass line. When the line to the spray gun is shut off, the entire output of the pump is bypassed to the tank. Relief valves must be sized to handle the desired flow rates and pressures.

When pressures of more than 200 psi are used, the relief valve should be replaced with an unloader valve. This valve will decrease the pressure on the pump and the load on the engine when the spray valve is closed. If an unloader valve is used in a system with hydraulic agitation, the agitation flow may be insufficient to keep wettable powders in suspension when the valve is unloading.

A pressure gauge covering the range of pressures to be used should be installed in the supply line to adjust and monitor sprayer operation. A damper is needed to protect the gauge from the pump pulsations. All components of the system must be designed to withstand the high pressures produced by the pump.

Spray Guns

Handheld guns are used with most hydraulic tree sprayers. For short trees and shrubs, a multiple-outlet gun may be used, but the single-outlet gun with a pistol-grip valve is most common. Many applicators use a variable-discharge-angle-gun. With a twist of the handle, the spray angle can be controlled from a wide angle for short trees and shrubs to a solid stream for tall trees. Uniform distribution of the spray in the tree depends on the applicator's technique. A systematic approach will help the applicator thoroughly cover the tree, with a minimum amount of runoff.

When vertical reach becomes a problem, the applicator will achieve better results by selecting a nozzle with greater capacity than by increasing pressure. The greater the nozzle capacity and narrower the spray pattern, the higher the spray will reach. Guns and nozzle kits are available that can spray trees up to 100 feet tall at pressures between 350 and 450 psi.

Nozzles wear with use over time, particularly when used to spray abrasive materials such as wettable powders. As they wear, the orifice becomes larger and the nozzle output increases. To minimize wear on high-pressure equipment, use wear-resistant components made from materials such as hardened stainless steel or ceramic. Discs are available with hard center cores that can be replaced when they become worn. Multiple nozzle arrangements with smaller nozzles may be used. They tend to provide better coverage because they produce smaller droplets. Drift increases and vertical reach decreases with smaller droplets. While larger droplets can reach higher into the tree, they may bounce or roll off leaves and other plant parts, reducing coverage.

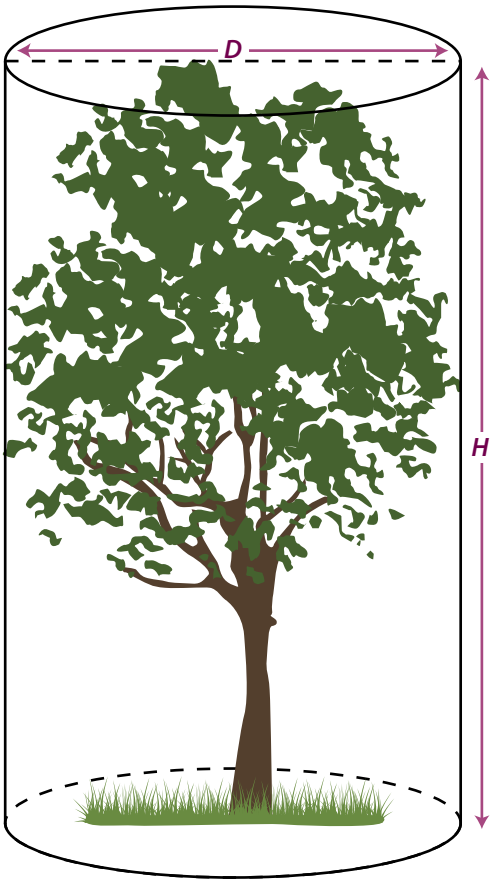
Air-Carrier Sprayers

Compared to hydraulic sprayers, air-carrier sprayers distribute the spray into the foliage with a blast of air. They are equipped with powerful fans to generate the required air current. Nozzles dispense the spray droplets into the high velocity airstream. Various combinations of air volume, air velocity, liquid volume, and liquid pressure are used to obtain uniform spray distribution.

Spray Volume

To provide thorough coverage, air sprayers must displace the air within and around the tree and replace it with spray-laden air. The volume of air delivered by the sprayer must be at least equal to the volume of the tree area. For example, if a shade tree is 50 feet tall and 25 feet in diameter, its volume can be considered as a cylinder, with H representing height and D representing diameter. Approximately 25,000 cubic feet of air is required to displace the air in and around a tree that is 50-feet tall with a crown that is 25-feet in diameter. The radius (R) is equal to half the diameter (D = R squared). To obtain uniform coverage with an air-carrier sprayer, direct a larger proportion of the spray material to the top of the tree. A general guideline is to apply two-thirds of the material into the top half of the tree.

Because air-carrier sprayers use air and water to transport the pesticide, they can use more concentrated sprays than hydraulic sprayers. It is important to understand that the same amount of pesticide is applied to the tree, but less water is used than with a spray gun. Using concentrated sprays requires less labor, water, and time than using dilute mixtures. However, because the spray pattern of air-carrier sprayers is difficult to see and the operator does not spray to the point of runoff, determining how much spray volume to apply is more complicated than spraying to the point of runoff.



$volume = \pi \times R^2 \times H$
where = radius of crown (½ of diameter or D)
H = height of tree
$= 3.14 \times (12.5)^2 \times 50$
= 24,531 cubic feet

Calculating tree volume.

Uniform distribution of spray material depends not only on the correct spray volume, but also on the velocity of the airstream. If the distance from the tree to the sprayer is too great, the velocity will be insufficient to penetrate the canopy. Most airstreams lose 75 percent of their velocity in the first 25 feet after leaving the sprayer. Therefore, the sprayer should be as close to the tree as possible.

Air-carrier sprayers cover trees faster and require less refilling than hydraulic sprayers.

For this reason, they are more economical to use on a large number of trees than are hydraulic sprayers.

Injection Equipment

Pesticides can be injected directly into the trunk and delivered to other parts of the tree through the vascular system. Because pesticide is delivered through the tree's transport system, the tree must be actively transpiring and treatment is most effective when injected into living tissue (xylem). Some pesticides require special equipment for tree injections. Others are formulated and packaged in ampoules or syringe-like capsules that can be used without specialized equipment.

Macro-injection equipment uses a 12-volt DC powered diaphragm pump and will develop low pressures (8 to 12 psi) to inject the material into the tree. The pesticide solution is pumped through a ¼-inch hose to tees that are inserted in the injection holes. A small tank of around 35 gallons is used to hold the solution as it is pumped into the tree. Injections must be made slowly and at low pressures to allow the tree time to take up the pesticide. If injections are made too quickly, the pesticide may cause the bark to separate from the tree, or the pesticide may squirt or seep out of the hole. High pressure may harm the tree's vascular system and slow pesticide uptake.

Technique

Micro-injection the application of a concentrated pesticide packaged in a single-use capsule. The injection holes are drilled, and the capsules are inserted into the holes and activated. Typically, the capsules are pressurized so that the pesticide is injected into the tree automatically.

The holes for tree injections are made at a depth of about ½ to 1 inch by drilling small holes, usually less than ¼ inch, every 4 to 6 inches around the tree. The number of injection holes needed is determined by the diameter in inches of the tree at breast height (DBH). Even spacing is important because the movement of material within the tree is mainly vertical, with very little radial or sideways movement. Nonuniform spacing of the injections will cause nonuniform treatment of the canopy. The drill bit should be sharp to drill a clean hole. A dull bit will damage the vascular system at the point of injection, reducing uptake. To prevent sap from clogging the xylem, rinse the hole with a small amount of distilled water after it is drilled. A tree will treat the hole as a wound and will begin to heal and close off the hole. The sooner the injection is started, the faster the uptake. To avoid spreading diseases among trees, disinfect the drill bit before moving to the next tree.

Another injection system uses even smaller holes, about 1/16 inch in diameter, to deliver a small amount (½ to 1 ml) of concentrated pesticide. With this method, phytotoxicity (damage to the plant) should be low to avoid harming tissue around the injection site, which reduces pesticide uptake. The applicator uses a squared-off needle to penetrate the sapwood, separating the bark slightly to accept the pesticide. It is best to treat in the spring when bark slips easily. Shortly after treatment, the bark settles back into place against the sapwood.

The pesticide label includes instructions on the number of injection holes and their location. Typically injections are made at the root flare or below the soil line. For better uptake and distribution avoid deep folds or creases.

Calibration

Regardless of the type of equipment used, the pesticide must be applied uniformly to an ornamental plant. To ensure adequate coverage with pressure sprayers, ornamental plants are sprayed to the point of runoff. The amount of spray required depends on the size and shape of the plant, the density of the foliage, and application techniques. With air-carrier sprayers, the plants are not completely wetted, and extreme care must be taken to ensure that the proper rate of pesticide has been applied.

Dilute Spraying to Runoff

Recommendations for insecticide and fungicide applications to ornamental plants are given as the amount of active ingredient (a.i.) or product to add to each gallon or 100 gallons of water. To calibrate, add the recommended concentration — tablespoons, ounces, gallons, or pounds of product — to each gallon or 100 gallons and spray until the solution begins to run off the tree or shrub. If recommenda-

tions are given as active ingredients, convert the amount of active ingredient into the amount of formulated product needed.

For uniform coverage using compressed air, backpack, and power hydraulic sprayers, spray to the point of runoff. Cover all parts of the plant until the solution begins to drip from the leaves and stem. Spraying beyond the point of runoff washes pesticide from the plant and may damage vegetation under the plant's drip line.

Although it is not easy to determine how much solution is needed, it is inefficient and potentially harmful to apply more pesticide than is necessary. First, determine how long it will take to spray a given tree to the point of runoff. Guidelines may be available for certain areas, such as orchards, but in most cases decisions will be based on experience. A tree in full leaf, for example, takes longer to spray than the same tree in early spring.

After determining the time required to spray to runoff, determine how much spray to apply to runoff by multiplying the time it takes to spray by the flow rate from the nozzle. For example, if a spray gun on a small power sprayer delivers 2 gallons per minute and a shade tree requires 5 minutes to spray, you will need 10 gallons of spray mix per tree (2 gallons per minute × 5 minutes). You can measure the flow rate from the nozzles by collecting the output for a timed period. For example, if a nozzle fills a gallon container in 2 minutes, the flow rate is ½ gallon per minute.

Example 1. A university recommendation calls for 2 ounces active ingredient of insecticide (a.i.) per gallon and directs the operator to spray to the point of runoff to control insects on ornamental plants. How many ounces of an 80 percent wettable powder should you add to a compressed air sprayer with a 4-gallon tank capacity?

Solution. First convert active ingredient (a.i.) to ounces (oz) of formulated product required per gallon.

2 oz a.i. per gallon × 100%/80% = 2.5 oz of product per gallon

Then, determine the amount of product to add to the tank.

4 gallons per tank × 2.5 oz per gallon = 10 oz product per tank

Example 2. You are hired to spray 25 tall shade trees. The insecticide label calls for 4 gallons of product per 100 gallons of solution. How much water and insecticide should you add to the spray tank to complete the job?

Solution. With water in the tank, determine the time it takes to spray a representative tree. For this example, assume the average tree in the group takes 6 minutes to spray to the point of runoff. Next, collect the spray from the gun for a measured time, such as 1 minute. For this example, assume the flow rate for the spray gun is 2 gallons per minute. The spray required to treat a single tree can be calculated by multiplying the flow rate with the time required to spray the tree:

6 minutes × 2 gallons per minute = 12 gallons of spray per tree

The total amount of spray required to treat all the trees can be calculated by multiplying the number of trees by the amount of spray required per tree:

25 trees × 12 gallons per tree = 300 gallons

To determine the amount of insecticide required, multiply the insecticide rate (gallons) by the total amount of spray solution, remembering to divide by 100 gallons because the product rate is amount of product per 100 gallons:

4 gallons of product × 300 gallons of spray/100 gallons = 12 gallons

To complete the job, mix 12 gallons of insecticide and 288 gallons of water and spray each tree for 6 minutes.

Concentrate Spraying

Spraying to the point of runoff is called dilute spraying and is generally done with hydraulic sprayers. Because air-carrier sprayers use air and water as carriers, they give equal coverage with less water than hydraulic sprayers. Using a lower water-to-pesticide ratio is known as concentrate spraying. With this technique, 3, 5, or even 10 times the amount of pesticide is used per 100 gallons of spray, but only one-third, one-fifth, or one-tenth as many gallons of spray is applied to the plants. In concentrate spraying, this rate is referred to as 3x, 5x, or 10x application. The resulting deposit of

pesticide on leaves should be the same as that produced with the dilute method.

Spray Volume

To determine the gallons of spray required per tree for concentrate spraying, first, determine as accurately as possible the amount of spray required for dilute spraying. Then divide the dilute gallonage by the concentration to be applied. For example, if 10 gallons of dilute spray are required per tree, then a 5x concentrate spray would require 4 gallons of spray per tree (20 divided by 5).

The process of determining the amount of concentrate spray you should use is relatively simple once you know how much spray would be required for dilute spraying. It is important to remember that concentrate spray is always based on the amount required for dilute spraying. In other words, saying that you are applying a 5x concentrate means nothing unless you know the dilute quantity required. If 30 gallons of dilute spray are required per tree instead of 20, the amount of a 5x concentrate spray will be 6 gallons instead of 4, even though the concentrate has remained the same. So if a tree is in full leaf in the middle of summer requires a greater amount of dilute spray than the same tree in spring, a 5x concentrate in the summer will require more spray than a 5x concentrate in the spring.

Once you determine how much spray is needed, you will need to calculate how long to spray. Spray is almost invisible, making it impractical to use runoff as a guide. To determine how long to spray, divide the gallons of spray required per tree by the flow rate from the nozzle. For example, if a 2x concentrate spray requires 4 gallons per tree and the nozzle output is 2 gallons per minute, you should spray the tree for 2 minutes (4 gallons per tree divided by 2 gallons per minute).

Example 1. A recommendation calls for applying 2 quarts per 100 gallons for dilute spraying. How much pesticide is required for a 5x concentrate spray?

Solution. Multiply the dilute rate by the concentrate factor:

2 quarts × 5x = 10 quarts per 100 gallons of spray

Example 2. Dilute spraying requires 12 gallons per tree. How many gallons of a 3x concentrate spray solution are needed to treat 75 trees?

Solution. First, determine how much 3x spray is required per tree:

12 gallons per tree/3x concentrate = 4 gallons per tree

Next, determine the amount to treat all 75 trees:

4 gallons per tree × 75 trees = 300 gallons

Example 3. You are to spray 56 shade trees with an air-carrier sprayer at 3x concentrate. Dilute spraying requires 8 gallons per tree. The recommended fungicide is 6 pounds of wettable powder per 100 gallons for dilute spraying. How much water and fungicide should you add to the spray tank?

Solution. First determine the amount of 3x concentrate required per tree:

8 gallons per tree/3x concentrate = 2.67 gallons per tree

Next, calculate the total amount of spray required to treat all 56 trees:

2.67 gallons per tree × 56 trees = 150 gallons of spray

Then determine the amount of fungicide needed per 100 gallons for the 3x concentrate:

6 pounds × 3x = 18 pounds of fungicide per 100 gallons

Finally, determine the amount of fungicide required to treat all 56 trees by multiplying the rate by the gallons of spray required, remembering to divide by 100 gallons because the rate is amount of product required per 100 gallons:

18 lbs of product × 150 gallons of spray/ 100 gallons = 27 pounds

Example 4. An air-carrier sprayer has a flow rate of 2 gallons per minute. How long should you spray each tree with a 4x concentrate spray if dilute spraying requires 12 gallons per tree?

Solution. First determine the gallons of 4x spray required per tree:

12 gallons of spray/4x concentrate = 3 gallons of spray per tree

Next, divide the gallons of 4x spray required per tree by the flow rate of the sprayer:

3 gallons per tree/2 gallons per minute = 1.5 minutes per tree

Example 5. The volume of your tree is 25,000 cubic feet, and your air-carrier sprayer can displace 50,000 cubic feet per minute. Therefore, you must spray for at least ½ minute just to deliver pesticide throughout the tree canopy. It takes 20 gallons of dilute spray to spray this tree to runoff, and your nozzle delivers 4 gallons a minute. What is the maximum concentrate you can use?

Solution. First determine how much spray will be deposited on the tree in ½ a minute:

4 gallons per minute × 0.5 minute = 2 gallons of spray per tree

Next determine the concentrate to use:

20 gallons per tree dilute/2 gallons per tree concentrate = 10x concentrate

Example 6. If you want to use a 5x concentrate on the tree in Example 5, what should the nozzle flow rate be?

Solution. First, calculate the gallons of 5x concentrate required per tree:

20 gallons per tree dilute/5x concentrate = 4 gallons per tree

Finally, determine the required flow rate by dividing the gallons of 5x required per tree by the 0.5 minutes needed to spray each tree:

4 gallons per tree/0.5 minutes = 8 gallons per minute

Spraying Small Surface Areas

For treating small areas with manual sprayers, recommendations are given as the amount of pesticide per 1,000 square feet. Determine the amount of spray solution to apply per 1,000 square feet by marking off a 1,000- square-foot area (20 feet by 50 feet, for example). Then add a measured amount of water to the tank, spray the area uniformly, and measure the amount of water remaining in the tank. The difference between the amount in the tank before and after spraying is the amount used. For example, if you added 4 gallons and had only 1 gallon left after spraying, the application rate would be 3 gallons per 1,000 square feet.

Example 1. You have a pesticide recommendation of 1.5 ounces of product per 1,000 square feet. Your 5-gallon air-compressor sprayer applies 2½ gallons per 1,000 square feet. How many ounces of product should be added to the spray tank?

Solution. First determine the area you can treat with a full tank by dividing tank capacity by the spray application rate, remembering to multiply by 1,000 because the rate is 2.5 gallons per 1,000 square feet:

5 gallon tank × 1,000 square feet/2.5 gallons = 2,000 square feet per tank

Next, determine the amount of product to mix in the tank by multiplying the product application rate by the area treated per full tank, remembering to divide by 1,000 square feet because the product application rate is 1.5 ounces per 1,000 square feet:

1.5 oz × 2,000 square feet/1,000 square feet = 3 oz of product per tankful

Study Questions

1. Which type of sprayer would be best used for wettable powder formulations?
   a. Compressed-air sprayer
   b. Backpack sprayer with hydraulic agitation
   c. Backpack sprayer with a hand-operated piston
   d. None of the above

2. What type of nozzle would be the best for low-pressure herbicide applications where drift is a concern?
   a. Hollow cone pattern
   b. Flat-fan nozzle
   c. Small flooding nozzle
   d. Adjustable nozzle

3. What factors do you need to know to determine the spray application rate?
   a. Speed
   b. Nozzle flow rate
   c. Effective sprayed width
   d. All of the above

4. What type of sprayer enables the operator to use much less water to apply a pesticide?
   a. Mist blower
   b. Rotary nozzle sprayer
   c. Compressed-air sprayer
   d. Hydraulic tree sprayer

5. What proportion of the spray material should be applied to the top half of the tree when using an air-carrier sprayer?
   a. One-third
   b. One-fourth
   c. Two-thirds
   d. One-half

6. When spraying trees and shrubs with a hand boom, the amount of spray that should be applied is:
   a. 20 gallons per acre
   b. 200 gallons per acre
   c. Until the ground is wet
   d. Until the point of runoff

Vertebrate Pests

Vertebrate animals damage ornamentals in several ways. Animals, such as mice and gophers, feed on roots and crowns. Others such as voles, rabbits, deer, and woodpeckers feed on stems, trunks, twigs, or foliage. Barriers, trapping, repellents, and pesticides may be used to help control damage caused by vertebrate pests.

Moles

The eastern mole is the only mole found in Kansas. Because habits and diet differ from pocket gophers, different control methods are needed. Both animals live in the soil, creating underground tunnels and leaving mounded earth on the surface. Preferring moist soil, moles dig two types of tunnels. One type, located an inch or two belowground, is created by the mole swimming through loose topsoil, leaving a ridge of earth on the ground surface. More permanent tunnels are found 6 to 10 inches below the surface. Burrowing moles push up mounds at intervals instead of leaving a ridge. Tunnels and mounds may be confused with those made by pocket gophers.

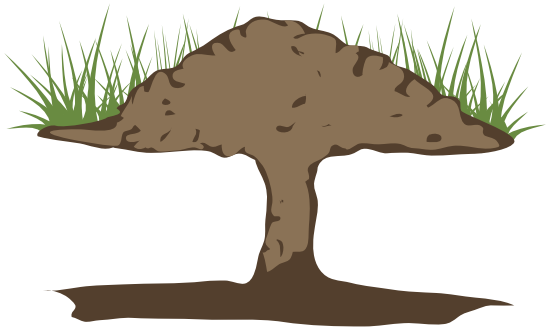
Eastern mole

Moles vs. Pocket Gophers

Knowing how mole and gopher mounds are constructed helps distinguish them. From the main tunnel of the mole run, a short shaft extends straight up to the surface. Soil expelled from the vertical shaft wells up like water. Successive loads form a nearly circular mound on which there may be ripple marks forming complete circles, with the earthen plug in the center. In contrast, a short inclined tunnel to the surface of the main tunnel is characteristic of the pocket gopher. Successive loads of soil are pushed through the tunnel in one direction with the earthen plug on the edge of the mound. Each heap lands partly on top of the one before, forming a mound on which half circles are visible. The diameter of the opening are also different in size. The mole burrow is about the diameter of a golf ball while the pocket gopher burrow is about the size of a tennis ball.

Although moles do not eat garden seeds and bulbs, they are often blamed. Runways in the garden may be a sign of moles looking for insects and earthworms to consume. More moisture, insect larvae, and earthworms exist within the rows than between them. The real culprits are voles and other seed and plant-eating animals that use the tunnels.

Gopher tunnel and mound



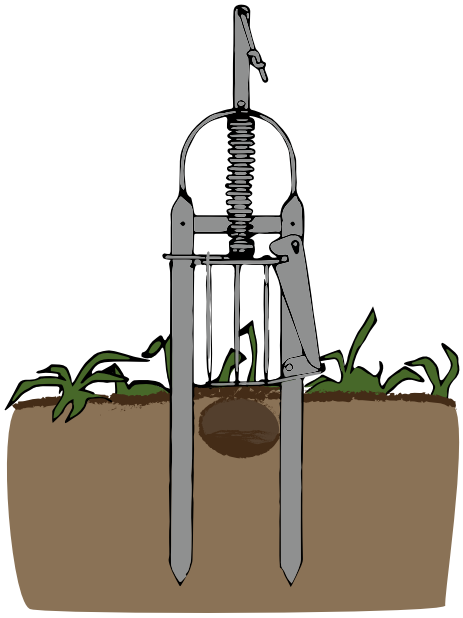
Mole tunnel and hill

Trapping Moles

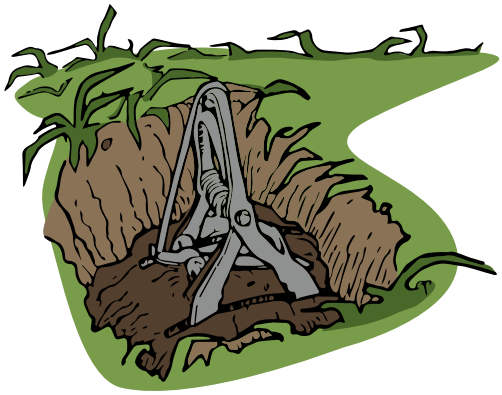
Trapping is the most common method of control. To be successful, consider mole habits and instincts carefully. Two good traps for catching moles in Kansas are the scissor type and the harpoon type.

Selecting a trap site

The selection of a frequently used runway for a trap set is critical. Place traps where ridge tunnels run in a straight line for a few feet. Because tunnels are used as travel ways, a trap that straddles, encircles, or is held suspended above the runway with the trigger pan resting on or hidden in a dirt blockade, is recommended so the mole cannot detect the trap. By pushing against the obstruction, the mole either lifts the trigger pan or pushes against the hidden trigger to release the trap spring.



Harpoon trap



Scissor-jaw trap

Poisons

Poisons are not normally used to control moles, which consume insects and earthworms. In cases where the poison seems to be effective, the user has probably frightened the mole with the scent or another quality of the poison or has killed its food.

Indirect Control

Moles deprived of food are required to move. Several insecticides can be used to reduce earthworm and insect populations so soil no longer provides enough food to fulfill daily requirements. Results may take several weeks, and moles may cause further damage searching for food.

Pocket Gophers

The major complaint against the pocket gopher stems from damage done in lawns, golf courses, parks, and alfalfa fields. Pocket gophers will eat plant roots and bring soil to the surface, resulting in dead plants. Dirt mounds create a nuisance when mowing.

Pocket gophers create a series of deep runways that lead to nests and food storage areas. These generally are about 4 to 5 feet below ground. These tunnels are not connected directly to the surface but lead to the runways about 8 to 10 inches underground.

The amount of soil pushed to the surface in a year varies from one gopher to another and depends on how far they travel in search of food. It is estimated that in a year the average gopher transports 2¼ tons of soil to the surface. At this rate, seven gophers per acre could cover the ground with a layer of loose soil 1 inch deep in 10 years. The tunnels also allow air and water to reach the roots of plants, promoting more vigorous growth.

Plains pocket gopher

Control Methods

The best time to control pocket gophers is when they are active near the surface, as indicated by fresh mounds of dirt. Labor and material may be wasted on unoccupied runway systems at other times. Removing unwanted perennial forbs and plants with large tap roots reduces the food supply for gophers.

Trapping

The best time to trap is when gophers can be easily located by soil that has been pushed to the surface. Set traps near fresh soil mounds.

Success depends on the proper use of traps. The following steps are suggested:

1. ***Locate the newest mound in the area.***
2. ***Probe to locate the main runway.*** To locate the main runway, find the plug where the gopher has filled up the lateral tunnel and left a horseshoe-shaped depression in a fresh mound. The main runway will be about 15 to 18 inches away from the mound on the same side as the horseshoe-shaped depression. To build a probe, use a piece of ¾-inch pipe about 35 inches long. The end forced into the soil should be solid and pointed. A foot pedal on the probe makes it easier to penetrate the soil. Ground friction will decrease when the probe drops into the runway.
3. ***Dig until you locate the runway.*** Then remove soil from the burrows so traps can be placed far back into the tunnels.
4. ***Connect the trap to a metal stake with a piece of wire.*** The stake anchors the trap and marks the set for tending. The gopher cannot pull the stake into the burrow.
5. ***Set and place two traps, one in each direction.*** Place the trigger (flat metal plate) away from the excavation.
6. ***Open burrows attract the gopher, so he can be caught while trying to plug them.*** If there is too much light the gopher may push a large amount of soil ahead of him. This may spring the trap and let the gopher escape. To prevent this, push traps as far back as possible in the open tunnel, or partially cover the entrances.

Hand-held gopher baiting apparatus

Gopher probe in burrow

Use of Poisons

With poison grain, use a burrow builder on larger areas or a hand applicator to apply the bait. The burrow builder is a machine that consists of a corn planter-type feed mechanism with packer wheels, power for feeding mechanism, coulter wheel, and steel pipe used to make the burrow.

The burrow builder makes an artificial burrow for the pocket gopher and at the same time places poison bait in this burrow. The machine is attached to a tractor and pulled back and forth across a field making a series of parallel burrows about 25 feet apart.

Soil condition, particularly soil moisture, should be considered before using the burrow

builder. Generally, if the soil is damp enough that a handful can be compressed and hold its shape, it is suitable for using the machine.

In general, a burrow depth of 8 to 10 inches is desirable. Burrow builder effectiveness depends on gophers finding the artificially constructed runway and using it long enough to find the poisoned bait. To make this possible, artificial burrows should be constructed at a depth and spaced out so as to cut through the greatest number of natural gopher tunnels. The burrow builder will give good control if used properly. Fumigation effectiveness is limited. Gopher burrow systems are extensive. Portions are blocked by earth plugs with the gopher occupying various sections at a time.

Skunks

Two species of skunks in Kansas are the striped skunk and the eastern spotted skunk. The striped skunk is common and the one most often in conflict with humans. Skunks are classified as furbearers, which provides them with legal protection except during the hunting and trapping season or when they are causing damage. The eastern spotted skunk is rarely found. It is a threatened species and should not be destroyed.

Striped skunk

Eastern spotted skunk

Skunks are unpopular because of the disagreeable musk they discharge when provoked. Yet, they are beneficial, consuming a diet of one-half insects, one-fifth fruit, and one-fifth mice. They are particularly fond of potato beetles, grasshoppers, and white grubs.

A skunk's raised tail is a warning. Ordinarily, there is no discharge, but if the animal feels threatened, one spray will not empty the reservoir. To neutralize odor, wash everything with ammonia water. Neutroleum alpha mixed 2 ounces to a gallon of water is another product that effectively masks skunk odor.

Skunks have a habit of digging small cone-shaped holes in lawns and golf courses to search for beetle larvae and other insects. Damage is often attributed to moles or gophers. As a result, control efforts are misguided and fruitless.

Control

Control is best achieved by exclusion or removing the food supply. Skunks may carry rabies or other serious diseases. They should not be trapped alive and relocated. Animals that appear to be sick or acting abnormally should be avoided. Symptoms that may indicate the presence of rabies or other neurological diseases of mammals include unprovoked aggression, impaired movement, paralysis or lack of coordination, unusually friendly behavior, and disorientation. If you see these behaviors, avoid the animal and notify your local animal control officer. Rabies has been reported from a great variety of warm-blooded animals, but more than 50 percent of the cases are reported in skunks.

Skunks may be of limited value to the fur market when skins are prime. Because of disease risks, the American Veterinary Medical Association and the Council of State and

Territorial Epidemiologists do not recommend relocation. In most cases, wanton destruction is unwarranted and not desirable.

Trapping or relocation. Use cage or solid-sided traps to remove individual skunks or families. Traps that kill or capture the skunk by the foot may result in serious odor problems. Bait box or cage traps with marshmallows, a dead mouse, or canned pet food with a meat or fish base, canned or fresh raw fish, bacon, chicken parts, or whole eggs.

Skunks are relatively easy to trap in cages. If the trap is handled with a minimum of jarring or shaking and slowly wrapped with an opaque covering like a tarp or rug, animals can be transported to a remote area and released with little concern about being sprayed or bitten.

Exclusion. Properly constructed foundations will prevent skunks from denning beneath buildings. In lieu of continuous foundations, screening with ¼-inch hardware cloth is effective. Such screening needs to extend at least 10 inches beneath the soil to prevent the skunk from digging under.

Rabbits

There are two kinds of rabbits in Kansas. One is a true rabbit, the cottontail. The other is the jackrabbit, which is really not a rabbit, but a hare.

Control

Hunting. Under certain conditions, shooting has proven effective as a means of preventing rabbit damage. Systematic patrolling in the early morning and late evening may effectively reduce the population and suppress the damage in a localized area. Shooting rabbits after sunset with the aid of artificial light is illegal in Kansas.

Feeding and habitat removal. It is sometimes less troublesome or expensive to feed rabbits than to fight them. Use corn, alfalfa, orchard prunings or green foods at several places in the planting. This will often prevent damage. Clean cultivation of the planting is helpful, principally with cottontails, since it reduces their hiding places. Reduction of ground cover and low growing shrubs in the nearby areas will reduce the suitability of the area for rabbits.

Trapping during the winter with the box trap is often an effective control method for cottontails. It is not a successful method for controlling jackrabbits because of their reluctance to enter a trap or dark enclosure. Exclusion is most often accomplished by the construction of cottontail-proof fences and gates around the area to be protected.

Exclusion by fencing is desirable for small areas or individual plants, but most often is impractical and expensive for larger acreages of farmland. The use of protectors to guard the trunks of young trees or vines may also be considered a form of exclusion.

Repellents. The purpose of a rabbit repellent is to make the protected plants less desirable by treating with a material distasteful to the rabbit.

Repellents can be brushed or sprayed on the plants. Spraying is faster and more economical for small plants, but not all materials pass through spray nozzles easily. Repellents can be applied either to safe guard the bark of trees and shrubs during winter or vegetable and flower crops during the spring growing season.

Treat all stems and low branches to a point above which rabbits cannot reach while standing on top of the estimated snow cover. One application made during a warm, dry day in late fall should suffice for the entire dormant season. However, a second application may be necessary. Dogs that stay within the property boundaries are effective at keeping most rabbits out of a yard.

Poisons. No poisons are currently registered in Kansas for use in controlling either cottontail or jackrabbit damage.

Rodents

Cotton rats, field mice, voles, ground squirrels, wood rats, or tree squirrels and other native rodents at times girdle and/or strip bark from ornamental plants and dig holes and tunnels in turfgrass. The use of a properly formulated toxicant on a grain bait can be effective in controlling small rodents. Prebaiting may be required by the label and often improves bait acceptance. Closely mowed ground cover will help keep down rodent populations under trees.

Tree squirrel damage can be prevented with the use of electric fencing. On individual trees without connecting canopies, place a 2-foot wide metal band around the trunk about 6 feet off the ground. Repellents are another option. Shooting may be permitted in some situations. Squirrels are protected. Check state and local laws before shooting.

Deer

Deer can cause considerable damage to trees and other ornamental plants. Repellents may minimize damage. Consider fencing to prevent damage in small areas and encourage hunting during open seasons. Deer are protected by state laws. Report deer damage to the Kansas Department of Wildlife, Parks and Tourism.

Birds

Birds can also damage ornamental plants and turfgrass by feeding or roosting activities. Birds most often involved are blue jays, crows, starlings, English sparrows, and woodpeckers. Most birds generally will leave an area where they find they are not welcome. Attempts to scare birds should continue for five days. Noisemakers such as propane exploders, shell crackers, whirling objects, flags flying, shiny objects hanging in trees will encourage birds to leave an area where they cause damage. All birds in Kansas, except English sparrows, pigeons, and starlings, are protected by state and federal laws. Although shooting helps to reinforce other scare devices, it may require a permit from the Kansas Department of Wildlife, Parks and Tourism. Repellents also may be somewhat effective.

Study Questions

1. A good way to determine which animal, the mole or the pocket gopher, is responsible for damage to a lawn is to:
   a. wait to see the animal
   b. ask the County Extension agent
   c. set a trap for the animal
   d. learn to identify the characteristic mounds left by each animal.

2. A good trap for catching moles is one that:
   a. is properly set with a soil obstruction to block the runway
   b. leaves the runway unblocked
   c. creates a new runway
   d. is held suspended above the runway

3. Pocket gophers and moles are helpful to the environment because:
   a. their tunnels allow air and water to penetrate the soil
   b. they kill harmful insects
   c. they provide homes for other animals
   d. the ridges they form decrease erosion

4. The pocket gopher burrow is about:
   a. the size of a golf ball
   b. the size of a tennis ball
   c. the size of a softball
   d. the size of a basketball

5. Which of the following animals is protected year round in Kansas?
   a. pocket gophers
   b. moles
   c. spotted skunk
   d. striped skunk

6. Rabies is found in more than 50 percent of the reported cases in:
   a. skunks
   b. foxes
   c. bats
   d. rodents

7. One of the following methods is not allowed in Kansas for the control of damage caused by rabbits:
   a. hunting
   b. poisons
   c. trapping
   d. use of repellents

8. Before using any toxicant, it is a good idea to:
   a. read the label
   b. walk over the area
   c. consult an attorney
   d. hire a helper

9. Which one of the four birds listed below is protected by state and federal laws?
   a. starling
   b. English sparrow
   c. blue jay
   d. common pigeon

Environmental Hazards

The most serious adverse effects of pesticide misuse are:

- **Damage to desirable plants and trees.** Herbaceous, semi-woody, and woody species are all types of ornamental plants that can be found in the landscape that can be damaged. Herbaceous plants (chrysanthemums, petunias, grasses, etc.) usually are more susceptible to herbicide injury than woody plants. Young and tender woody plants are more susceptible to herbicide than older established woody plants.
- **Injury to soil organisms.** Soil can be degraded and the soil organisms can be damaged by misuse or over use of pesticides. The type of soil and the type of pesticide have an impact on the persistence in the soil.
- **Elimination of predators and pollinators.** Wild bees, certain wasps, honeybees and other insects are important in pollinating crops. Insect populations can decline with the use of certain types of pesticides and can have an indirect affect on crop yields.
- **Unwanted changes to wildlife habitat.** Protect wildlife habitat by not spraying around woodlots, ditches, hedges, rockpiles, fencelines, and wetlands. Use the lowest application rate recommended for the the product. Herbicides can also affect plants that are important to wildlife survival.
- **Drift damage.** The proximity of different susceptible plants requires that pesticide applicators certified in the ornamental category be aware of drift. Pesticide drift can damage nontarget sites and plants.
- **Poisoning of nontarget birds and mammals.** Wildlife can be directly exposed to pesticides by ingesting granules, baits, treated seeds, and direct exposure to spray. They can be indirectly affected by consuming treated crops, contaminated water, or eating contaminated prey.
- **Injury to fish.** Pesticides can enter the water through drift, runoff, soil erosion, leaching and applications to open water.
- **Soil erosion.** Prolonged devegetation by repeated use of residual herbicides or soil sterilants can cause erosion.

Some adverse effects can occur even with the proper use of pesticides. Pest control decisions must minimize the adverse effects and weigh them against the benefits. Every part of an environment changes somewhat when another part is modified. Since herbicides function is to injure certain kinds of plants, accidental plant damage of desirable plants can occur. For example, herbicides used to kill broadleaf weeds may also injure broadleaf trees, shrubs, and flowers. Insecticides and fungicides can also cause injury to sensitive plant species or damage normally tolerant plants under unusual conditions such as hot weather.

It is also important to realize that although the target species could be the only organism directly sprayed, other organisms may be affected indirectly if they depend on the one(s) removed. Removing any kind of plants, for example, helps the ones that remain to grow better, whether they are wanted or unwanted.

Weigh the environmental consequences of pesticide use against those of nonuse. The adverse effects of not using a pesticide may last for many decades. These effects may include:

- continuing weed problems which may keep desirable trees from growing.
- insect epidemics which may totally destroy, or change, the species composition.
- loss of seedlings in nurseries, and
- an increase in the time needed for revegetation.

Human Hazards

Pesticides used in ornamentals come in contact with humans at exposure rates high enough to cause injury. The risk is greatest for applicators, ground personnel, homeowners, or the general public. Observe all necessary

safety precautions during and after pesticide application. The primary routes of exposure are dermal, inhalation, oral and ocular. Dermal exposure is the most common because the skin is the largest organ on the body and acts like a sponge. Inhalation exposure occurs when the applicator breathes in vapors, gas, or fumes. Exposure may occur orally when the applicator eats, smokes, or drinks around pesticides or neglects to wash after the application. Pesticide may also enter through the eyes. Wearing the appropriate personal protective equipment can significantly reduce pesticide exposure.

Pesticide Labels

Forest lands are considered to be cropland when a stand of commercial trees is present. As such, "noncropland uses" listed on a pesticide label may not apply to forestry environments. However, herbicides registered for other crops, range, or non-croplands may be used before trees are planted. Pesticides used in forests, seed orchards, Christmas tree plantations, or nurseries must be labeled for use on the specific crop and pest species.

Forestry uses may be indicated on labels principally devoted to Christmas trees, seed orchards, or nurseries if the label includes directions stating that the product is:

- for use on ornamentals or shade trees, including conifers, and
- for use on the pest you need to control.

The pesticide label is the best source of information for safe use of pesticides on specific ornamental plants and in specific situations, such as nurseries. If the pesticide is not known to be safe for use on a specific ornamental plant, then the product should not be used.

Study Questions

1. What are some adverse effects of pesticide misuse?
   a. damage to desirable trees
   b. unwanted changes in wildlife habitat.
   c. direct poisoning of nontarget organisms
   d. all of the above

2. The entire environment responds when a pesticide is used. What is a typical response when a herbicide is applied?
   a. the target organism grows faster
   b. the remaining plants will grow better
   c. insects are destroyed
   d. the remaining plants will grow slower

3. Pesticides used in ornamentals come in contact with humans at injurious exposure rates. The risk is greater from which of the following?
   a. urban construction workers
   b. people who work in plant stores
   c. applicators, ground personnel, home owners, and the general public
   d. commercial airline pilots and passengers

4. When are forest lands considered to be croplands?
   a. when wild flowers are found in the forest
   b. when a stand of native trees is present
   c. when the forest is overcrowded with undesirable plants
   d. when a stand of commercial trees is present

Answers to Study Questions

Insects and Mites (Pages 5–10)

1. a	2. d	3. b	4. b	5. a
6. a	7. b	8. a	9. c	10. d
11. b	12. b	13. c	14. a	

Insects and Mites (Pages 12–21)

1. a	2. d	3. c	4. b	5. a
6. b	7. c	8. a	9. b	10. d
11. c	12. c	13. d	14. a.	15. c
16. c	17. c	18. a		

Insects and Mites (Pages 23–31)

1. b	2. c	3. c	4. b	5. b
6. d	7. c	8. a	9. b	10. c
11. a	12. d	13. c	14. c	15. a
16. a				

Diseases (Pages 33–45)

1. d	2. d	3. d	4. d	5. c
6. a	7. b	8. d	9. a	10. a
11. b	12. c	13. b	14. c	15. d
16. c	17. d	18. d	19. a	20. a
21. b	22. b	23. c	24. c	25. b

Weeds (Pages 48–52)

1. c	2. d	3. d	4. d	5. c
6. b				

Equipment (Pages 54–62)

1. b	2. c	3. d	4. a	5. c
6. d				

Vertebrate Pests (Pages 64-69)

1. d	2. a	3. a	4. b	5. c
6. a	7. b	8. a	9. c	

Environmental (Pages 71-72)

1. d	2. b	3. c	4. d

Photo Credits

Bagworm and succulent oak gall: Lacy Hyche, Auburn University, *www.bugwood.org*

Fall cankerworm: John H. Ghent, USDA Forest Service, *www.bugwood.org*

Elm leaf beetle: Clemson University, USDA Cooperative Slide Series, *www.bugwood.org*

Aphid damage: John A. Weidhass, Virginia Polytechnic Institue, *www.bugwood.org*

Bronze birch borer: Whitney Cranshaw, Colorado State University, *www.bugwood.org*

Carpenterworm damage, flatheaded appletree borer larvae: James Soloman, USDA Forest Service, *www.bugwood.org*

Flatheaded appletree borer: Katherine Parys, *www.bugwood.org*

Hackberry nipplegall: Jane Taylor, USDA Forest Service, *www.bugwood.org*

Carpenterworm life cycle: Gerald Lanhard, Louisiana State University, *www.bugwood.org*

Lacebug: Louis-Michel Nageleisen, Département de la Santé des Forêts, *www.bugwood.org*

Leafhopper: David Cappaert, Michigan State University, *www.bugwood.org*

Plant bug: Scott Bauer, USDA Agricultural Research Service, *www.bugwood.org*

Poplar petiole gall: Herbert A. "Joe" Pase III, *www.bugwood.org*

Thrips: Robert Dzwonkowski, *www.bugwood.org*

Whitefly: Clemson University, USDA Coop. Extension, *www.bugwood.org*

Slug: R.J. Reynold Tobacco Company Slide Set, *www.bugwood.org*

Anthracnose on Maple: Judy O'Mara, Kansas State University, Department of Plant Pathology

Eastern spotted skunk, Plains pocket gopher, Eastern mole: Bob Gress, Great Plains Nature Center, *gpnc.org*

Striped skunk: John Collins, U.S. Federal Wildlife Service, National Digital Library, *http://digitalmedia.fws.gov/cdm*

Gopher probe in the burrow: Glenn Shewmaker, University of Idaho Extension Forage Specialist

Hand-held gopher baiting device: Danielle Gunn, University of Idaho Agricultural Extension Educator, Fort Hall

All other images: K-State Research and Extension

Equipment text adapted from: Illinois Pesticide Applicator Training Manual, Equipment Used for Pest Control in Ornamentals, Scott Bretthauer, University of Illinois Extension

Frannie L. Miller
Pesticide Coordinator

Authors

Appreciation is expressed to the following for preparation of the material in this manual:
Raymond Cloyd, Entomologist, Ornamentals
Megan Kennelly, Plant Pathologist, Horticulture and Turf
Charles Lee, Wildlife Specialist
Ward Upham, Director, Rapid Response Center
Jared Hoyle, Turfgrass Specialist

Acknowledgments

Appreciation is expressed to the following for their cooperation in the Commercial Applicator Training Program:
Jeanne Fox, Certification and Training Chief
Jerry Wilson, Compliance Investigator
Pesticide and Fertilizer Program, Kansas Department of Agriculture

Publications from Kansas State University are available at:
www.ksre.ksu.edu

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

K-State Research and Extension is an equal opportunity provider and employer. Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, as amended. Kansas State University, County Extension Councils, Extension Districts, and United States Department of Agriculture Cooperating, John D. Floros, Director.

S11 April 2015