Cooperative Extension Service
College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa

Turf and Ornamental Pest Control

A Guide for Commercial Pesticide Applicators

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Pesticide Risk Reduction Education
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Foreword and Acknowledgments

This publication contains basic information to help you meet the standards of the Hawaii Department of Agriculture and the Environmental Protection Agency for pesticide applicator certification and to engage in turf and ornamental pest management. Additional relevant information not included in the manual may be obtained from other CTAHR publications on specific topics relating to weed control and from programs and short-courses conducted by the CTAHR Cooperative Extension Service.

The assistance of Dr. Roy K. Nishimoto, CTAHR Department of Plant and Environmental Protection Sciences, in providing information on Hawaii's weeds of turf is sincerely appreciated. The cover photo was taken by Steven E. Swift.

Portions of this publication were adapted from Chapter 25 of the Military Pest Management Training Manual. The illustrations of insect metamorphosis were taken from *Pest control quality assurance evaluator training handbook,* Naval Facilities Engineering Command, 1991. Additional materials were adapted from other manuals and publications, which are thankfully acknowledged:

Brennan, B.M. 1979. *Ornamental and turf pest control; Commercial pesticide applicator training manual*. Miscellaneous Publication 174, College of Tropical Agriculture and Human Resources, University of Hawaii.

Brennan, B. M., P.M. Horton, and S.F. Swift. 1999. *Military pest management training manual for certification of pesticide applicators*. Curriculum and Research Development Group, University of Hawaii.

Cox, L.J., J.R. Hollyer, and D.M. Schug. 1991. *An economic profile of Hawaii's landscape services*. Research Extension Series 128, College of Tropical Agriculture and Human Resources, University of Hawaii.

Haselwood, E.L., and G.G. Motter, eds. 1983. *Handbook of Hawaiian weeds*. 2nd edition. University of Hawaii Press.

Wixted, D., R. Flashinski, C. Boerboom, and J. Wedberg. 1999. Pesticide applicator training manual. University of Wisconsin.

Learning Objectives

After studying this publication on turf and ornamental pest control, the pest manager should be able to do the following:

- Name and describe common insect pests of turf and ornamentals
- Describe ways of monitoring for insect pests using both passive and active sampling techniques
- Describe ways of managing insect pests of turf and ornamentals
- Name three requirements to sustain a disease and describe six ways to manage diseases
- Name and describe common diseases of turf and ornamentals
- Differentiate between infectious and noninfectious diseases
- Discuss ways of controlling weeds using nonchemical or chemical methods
- Explain five factors that may result in phytotoxicity
- Discuss management strategies for snails and slugs.

Caution: Pesticide use is governed by state and federal regulations. Read the pesticide label to ensure that the intended use is included on it, and follow all label directions.

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Turf and Ornamental Pest Control

A Guide for Commercial Pesticide Applicators

Agriculture in Hawaii changed significantly during the past three decades. Statistics indicate that landscape and horticultural services have become increasingly more important relative to agricultural production activities. Landscaping activities make a significant contribution to Hawaii's economy, as evidenced by the millions of dollars of gross sales of landscape services to homes, government agencies, and businesses including golf courses, private parks, hotels, private schools, and cemeteries.

Production and maintenance of high-quality turfgrasses and ornamental plants by Hawaii's landscape and horticultural industry requires an effective pest management program. Pesticide applicators are frequently called upon to identify the cause of damage to turf or ornamentals and to "treat" the plants with a suitable product to correct the damage. While such use of a pesticide may be appropriate, many people incorrectly assume that the only way to *prevent* plant damage is with some type of pesticide. This assumption may lead to misuse of pesticides and damage to the plants or the environment.

Various things may cause damage to turf and ornamentals, including biotic factors such as infectious diseases and insects and abiotic factors such as weather, lack of or too much fertilizer or irrigation, and other poor management practices. Pesticides will not correct improperly diagnosed problems.

Extensive lawns, golf courses, and other recreation areas represent an important investment in land management. A grass cover prevents erosion and makes the landscape attractive. Appropriate pest management operations help protect this investment and make a place pleasant to work, reside, or relax in.

Knowledge is power—pesticides will not correct improperly diagnosed problems

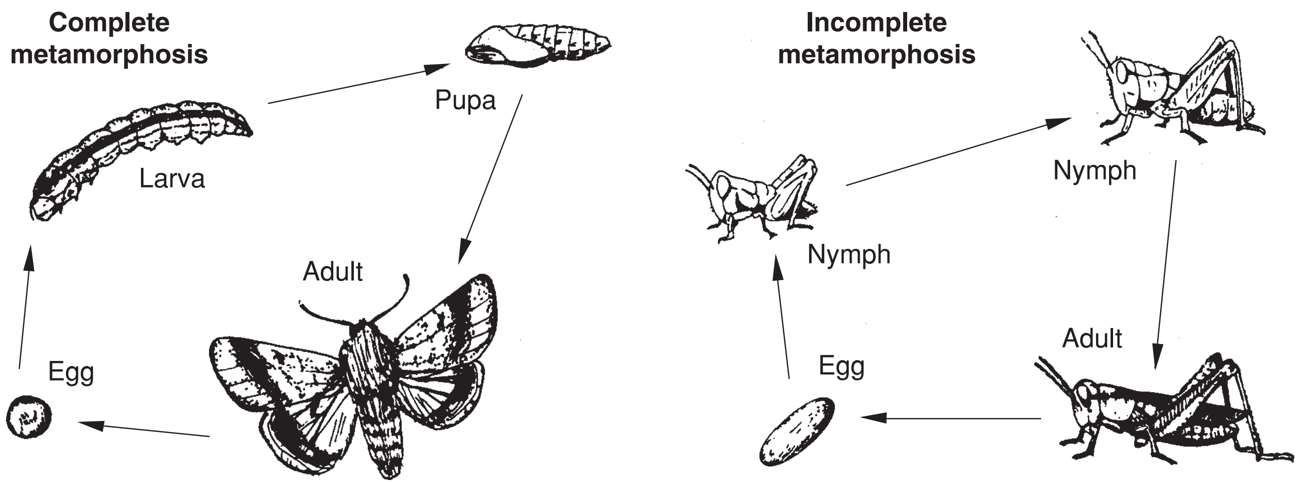
In this publication, turf insects are grouped according to the part of the plant they feed on. Ornamental insects are grouped by the type of mouthpart they use to feed. Pest monitoring and management techniques are sometimes similar for both turf and ornamental insect pests, but some specific techniques are described for turf insects.

The importance of plant diseases and weeds cannot be overlooked when working with valuable turf and ornamental plantings. Pesticide applicators must be able to identify weeds and plant diseases in order to develop appropriate management programs.

Insect pests of turf

Knowing the insect's life cycle is the key to effective control

During development, most insects change their form in stages called instars; this change is called metamorphosis. The two general types of metamorphoses are incomplete or gradual and complete metamorphosis. Incomplete metamorphosis has three developmental stages—egg, nymph, and adult. Complete metamorphosis has four developmental stages—egg, larva, pupa, and adult. Some insects do extensive damage during their nymphal and adult stages (e.g., billbugs and crickets). Others (including cutworms and armyworms) do the most damage during their larval stage. Both the larvae and adults of some beetle species feed on branches and twigs of ornamentals.



Insects and other pests that damage and sometimes kill turfgrasses and other grassy plants are grouped according to how they attack the plants and the types of damage they cause. Some live in soil and feed on plant roots; others live above ground and feed on leaves and stems. Several turf insects and related pests are common in Hawaii. Mites suck the juices of Rhodes grass and bermudagrass. Mole crickets and billbugs live in the soil. The grass webworm and lawn armyworm eat the grass leaves.

NOTES . . .

Other insects and related pests such as fleas, earwigs, millipedes, ticks, and sowbugs do not damage turf but may become nuisances because they bite people and crawl into houses, garages, and swimming pools. It is important to identify the cause of the damage or nuisance so the proper treatment can be selected.

Insects damaging leaves and stems

Webworms and armyworms

The grass webworm and the lawn armyworm are the most destructive pests of grasses in Hawaii; for additional information, see CTAHR publication IP-5, *Destructive turf caterpillars in Hawaii*).

Grass webworms differ from armyworms in size and feeding habit. Webworms feed primarily at night. They remain in a curled position on or near the soil surface during the day. This habit makes them difficult to find. Damaged areas are often first noticed along hedges and flowerbeds. Injury begins in a few spots, which often are only 2 or 3 feet in diameter. These spots cover large areas during heavy infestations. It is not until the pests are full-grown larvae that their feeding becomes noticeable. The damage shows up almost overnight. This, along with their night feeding habits, explains how extensive damage may occur before they are noticed.

Grass webworm eggs are deposited singly or in a mass on the upper surface of grass blades near the base, along the midrib. The five larval instars together last about two weeks. Larger larvae construct tunnels leading from the surface of the turf into the thatch, where they rest during the day. The pupal stage lasts about one week. From hatching to adult takes about 22 days.

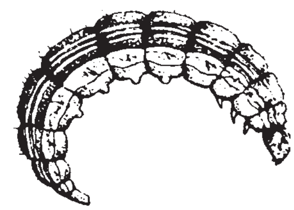
Injured grass has notches chewed into the sides of the blades. The foliage may be completely stripped off in patches. Close-cropped areas may be yellowish to brownish. The turf may die in hot and dry weather.

Armyworm

The lawn armyworm grows to 1½ inches long and is greenish when small and dark brown when full grown. It has a light mid-stripe along its back, and darker bands on each side end in an inverted "Y" on its head. The adult moth lays eggs on grass and on almost any object near turf areas. Development is much like that of the grass webworm. However, armyworms pupate in the soil.

Injury by the lawn armyworm is similar to that of the grass webworm but is usually more scattered. It is not unusual to have populations of armyworms, webworms, and other caterpillars at the same time in the same location.

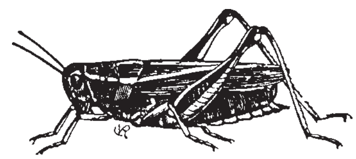
To check lawns for caterpillars, examine grass in the off-color areas for chewed blades. Small green pellets of excrement are numerous on the soil surface when the insects are present. Unlike webworms, armyworms do not rest in a curled position. Early instars feed during the day and may be seen crawling over the grass. Mature instars feed primarily at night.



Cutworm

Cutworms

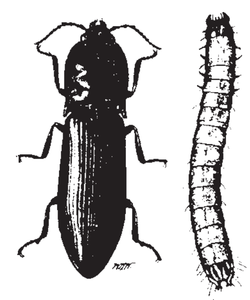
Many species of cutworms occasionally damage turf. The adults are nocturnal, medium-sized moths with a wingspread of 1–2 inches. They are usually multicolored with dull hues of brown, gray, or dirty white. The larvae are nearly 2 inches long, smooth, and green, brown, or off-white. They come out at night to feed on roots and underground stems. Some species cut grass off at the soil line, while others feed on leaf blades. These larval feedings leave small, elongated, or irregular, closely cropped brown turf.



Grasshopper

Grasshoppers

Although grasshoppers are not a big problem in Hawaii, they can become a problem when they feed on range vegetation or grassy areas. Most species are 1–2 inches long. They vary in color from mottled shades of tan to green and yellow, with or without spots and stripes. The migratory grasshoppers are highly destructive during large population outbreaks. These pests produce one or two generations annually and fly in swarms, laying their eggs in well defined common beds. They cut grass stems and blades close to the ground, often eating only part of what they destroy.



Wireworm adult and larva

Frit fly

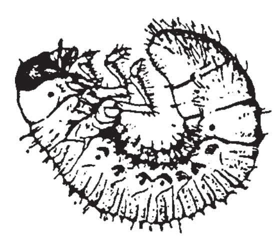
A relatively new introduction to the island of Oahu, this pest (possibly *Oscinella frit*) develops on bermudagrass and its hybrids. The larvae feed at the base of the succulent young leaves, causing the tips to yellow and wilt. The older leaves, however, remain green. As the larvae continue to feed, the stem is severed, causing the tip to wither.

The pest's small, white eggs are laid in leaf sheaths. They hatch in 3–4 days. Mature larvae are about ⅛ inch long. The adult fly is small, $^3/_{16}$ inch long, and black with yellow on the legs. Adults can be found in grass clippings, on freshly cut grass, and on white objects such as golf balls and white towels. Three to four generations a year have been reported in temperate areas. The warmer conditions in Hawaii will likely produce more generations per year.

Insects infesting soil and roots

Grubs

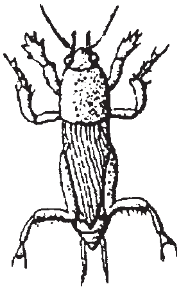
Many beetle larvae, also called grubs, attack grass roots. They are white to gray and, with a few exceptions, they all lie in a curled position.



Grub

Wireworms

The adults of wireworms are slender, brown "click beetles." Their larvae, commonly called wireworms, may be 1–1½ inches long at maturity and are usually hard, smooth, yellow-brown, and wormlike. They bore into underground parts of many plants including agricultural crops. Wireworms remain and develop in the soil for 2–6 years, moving only a few yards during their entire development. They are widely distributed. Wireworms are most serious in areas that have high rainfall or are irrigated.



Mole cricket

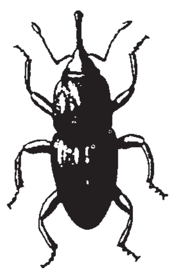
Mole crickets

This pest lives in the soil and feeds on grass roots. It occurs primarily in sugarcane fields but it may be an occasional lawn pest. The adult has front legs that are short, stout, and well adapted for tunneling through the soil. Its eggs are laid in cells several inches below the soil surface. The nymphs look like the adults except they are smaller and lack fully developed wings; they require several months to reach maturity.

Adult mole crickets may burrow 3–4 feet until favorable conditions of temperature and moisture are found. They are most active at night, especially after rain or irrigation. They come to the surface and burrow in the upper 2 inches of soil.

Mole cricket damage to lawn grass and other plants is primarily through feeding on the roots. Also, their burrows loosen the soil, causing grass to dry up.

Grub



Billbug adult

Billbugs

The hunting billbug is one of the most serious pests of turfgrasses in Hawaii. It attacks zoysiagrass most severely but may also attack bermudagrass and other grasses. Both adult and immature stages are responsible for damage, which appears as large areas of dead grass. Check for billbug damage by pulling on the grass by hand. If it pulls up easily and roots appear to be cut off, there is possibly a billbug problem. Checking for presence of grubs and adults in soil near the edge of a damaged area should confirm the presence of this pest. Control measures should be begun as soon as dead grass is discovered.

The hunting billbug is a dark, reddish-brown weevil about 2/5 inch long with a curved beak at the front of its head. The tip of the beak bears a pair of mandibles for chewing tender, growing points of grass. The adults can fly and spread their activity from one lawn to another. Eggs are laid in grass stems or leaf sheaths. The white grub that emerges in a few days will feed for a time within the grass stem and then move down to the roots. They can be found just below the surface of the soil for the next 3–5 weeks. The pupal stage lasts for 7–10 days.

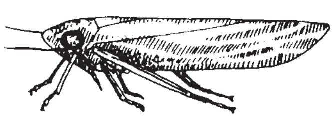
Ants

Ants are among the most common and abundant of all insects, and they can be both beneficial and a nuisance. They may ruin the appearance of lawns, golf courses, and parks with their unsightly nests. They steal seeds from seedbeds and injure or defoliate plants. Also, they may protect and spread other injurious insects, such as aphids and mealybugs. Ants are especially annoying when they bite and sting.

The most common ant species causing damage to grasses in Hawaii are the bigheaded ant (*Pheidole megacephala*) and the common fire ant (*Solenopsis geminata*).

Sucking insects and mites

Leafhoppers



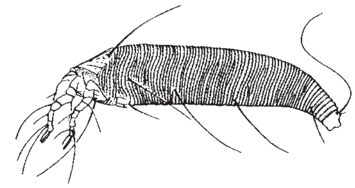
Leafhopper

These members of the order Homoptera are very small, less than 1/5 inch long, and slender, with tiny, bristlelike antennae. Their hind legs are adapted for jumping. Resting adults hold their wings in a rooflike position. They readily fly short distances when disturbed. Nymphal stages resemble the adults but lack functional wings. Both nymphs and adults suck plant juices and may cause extensive discoloration in lawns. These insects also transmit plant diseases.

Mites

The bermudagrass mite, an eriophyid mite, is sometimes a serious pest of bermudagrass lawns. This mite is extremely small (microscopic), yellowish-white, and wormlike in shape. It multiplies very rapidly and requires only about 7 days to complete its life cycle.

Because the bermudagrass mite is very small and remains hidden beneath the leaf sheath, it is identified primarily by the symptoms of its damage. It causes a characteristic damage in which the grass blades turn light green and curl abnormally. The internodes shorten, the tissues swell, and the grass becomes tufted so that small clumps appear. The grass loses vigor, thins, and may die. Injury is more pronounced when the grass is stressed due to dry weather or poor maintenance. The most severe damage usually occurs to coarser varieties like common bermudagrass and various bermudagrass hybrids.

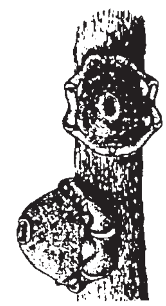


Eriophyid mite

Scale insects

The most common and troublesome grass scales in Hawaii are the Rhodesgrass and Ruth's grass scales. Both species are found on several grasses. The Rhodesgrass scale is spherical and covered with a white, cottony secretion up to 1⁄8 inch in diameter, usually found near the base of the grass. Ruth's grass scale is oval or circular, white, and 1⁄16–1⁄10 inch in diameter. It feeds in the leaf axis at the soil surface.

The adult female scales lay eggs within their secreted covering. Newly-hatched scales (crawlers) spread throughout the grass before settling down to feed. The life cycle is probably 6–8 weeks. Scales have piercing-sucking mouthparts, and infested grass turns yellow, thins, and may die if the scales are not controlled.



Scale

Insect pests of ornamentals

Ornamental plants are subject to attack from an extremely wide variety of insects and other related pests. Few people can identify all of these pests, but exact identification of the species is usually not important as far as control is concerned. The *type of damage* is important in a general identification of the pest and usually indicates which pest management strategy to apply. The type of damage depends on the type of pest mouthpart that causes it. Thus in the following sections, pest insects will be grouped by their type of mouthpart.

Identifying the type of damage provides clues to effective insect control measures

Insects with piercing-sucking mouthparts

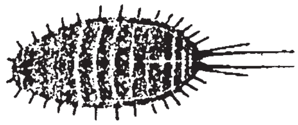
Piercing-sucking insects include scales, mealybugs, aphids, whiteflies, thrips, and lacebugs. These pests insert their beaklike mouthparts into the plant and withdraw the plant juices. Most feed on the underside of the leaf or on the stem. If these insects are present on leaves, the upper sides will appear stippled with chlorotic (yellowish) areas. The leaves may curl, especially if they are new growth.

Soft scales, mealybugs, whiteflies, and aphids excrete large amounts of honeydew, which provides an excellent medium for the growth of a black fungus called sooty mold. Besides being unattractive, sooty mold interferes with photosynthesis and somewhat retards the growth of the plant. Sooty mold usually weathers away following control of the insect infestation. Ants feed on the honeydew and when ants are observed, plants should be examined closely for these sucking pests.

Scales and mealybugs

On many ornamental plants, scale insects are the most serious pests. Most ornamentals are susceptible to one or more species of scales. Heavily infested plants appear unhealthy and produce little new growth. Scales may cause yellow spots to appear on the upper sides of leaves. These spots progressively become larger as the scales continue to feed. If the scales are not controlled, the leaves will drop prematurely, and sometimes portions of twigs and branches are killed.

Scales are distinguished as armored or unarmored types. The armored scale secretes a waxy covering over its body. This covering is not an integral part of the insects' body, but the scale lives and feeds under this covering, which resembles a plate of armor. The cover varies in size from 1⁄16 to 1⁄8 inch in diameter and can be almost any color, depending on the species. Adult female armored scales may be circular, oval, oblong, or pear-shaped. The mature males are tiny, two-winged, gnatlike insects that are seldom seen. In Hawaii, Florida scale and oleander scale are examples of armored scales that affect turf and ornamentals.



Mealybug

The unarmored (soft) scale also secretes a waxy covering, but it is attached to its body. Soft scales vary widely in color, size, and shape, ranging from 1⁄8 to 1⁄2 inch in diameter and from nearly flat to almost spherical in shape. Examples of soft scales are brown soft scale, hemispherical scale, and green scale.

Life cycles of various scales differ slightly, but in general the eggs are laid underneath the waxy covering and hatch in 1–3 weeks. The newly hatched scales (called crawlers) move about over the plant until they locate succulent new growth. Then they insert their piercing-sucking mouthparts into the plant and—in the case of the female—remain there the rest of their lives. In some armored scales the adult stage is reached in 6 weeks, and there are several generations per year. Some soft scales require a year to reach maturity.

Presence of ants is often a sign of honeydew-producing insects with piercing-sucking mouthparts

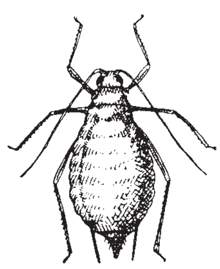
Mealybugs reach maturity in 4–5 weeks. Unlike armored and soft scales, they are able to move about throughout their lives. They usually have wax filaments extending from their body, giving them a white, powdery appearance.

To detect scale infestations, inspect plants closely. If necessary, use a 10-power (10X) magnifying glass. Sometimes scales are mistaken for fungal growths or even for part of the plant. Scales are found on both sides of the leaves as well as on the twigs and branches. They may be somewhat hidden in crevices of the bark and the leaf axils.

Aphids

Aphids or "plant lice" may infest almost any plant. They are commonly found on camellia, crepe myrtle, gardenia, hibiscus, ixora, oleander, rose, and palms, as well as nearly all annual plants. Aphids have piercing-sucking mouthparts and cause damage by sucking plant juices. Some aphids are important vectors of plant viruses.

Aphids are soft bodied, pear-shaped insects generally less than 1⁄8 inch long and usually green, but they may be black, brown, pink, yellow, blue, or white. They are commonly found on the stems or undersides of leaves in clusters or colonies of individuals. Most aphids are wingless, but when colonies become overcrowded or the host plants become undesirable, winged forms are produced to establish new colonies. The most distinguishing feature in the identification of aphids is the short cornicles, or tubes, two of which extend from the end of their bodies.



Aphid

Aphids may be found on plants throughout the year in Hawaii. They seem to be especially troublesome on plants in shaded areas. Their feeding makes the leaves curl or crinkle, and flower buds may become hardened, causing the flowers to be distorted.

Aphids are unlike most insects in two ways: almost all are females, and they reproduce without mating. They do not lay eggs in Hawaii but give birth to living young.

Aphids have the ability to reproduce rapidly, and many generations are produced in a year. Each female aphid produces 50–100 daughters during her life span, and each daughter begins reproducing in 6–8 days.

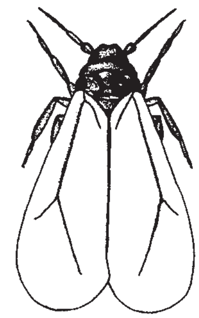
Whitefly

Whitefly is a common pest of many ornamental plants. Plants most frequently attacked include rose, citrus, poinsettia, crepe myrtle, ferns, gardenia, hibiscus, plumeria, croton, and many annuals. The adult whitefly resembles a tiny white moth, although it is not closely related to moths but more nearly related to scales. It is only about $\frac{1}{16}$ inch long and has four wings. The wings and body are covered with a fine white powder.

Immature stages (nymphs), which are found on the undersides of leaves, are flat, round in outline, and slightly smaller than a pinhead. They are light green to whitish, somewhat transparent, and resemble tiny fish scales.

A generalized whitefly life cycle is as follows: eggs are laid on the undersides of leaves and hatch in 4–12 days into active six-legged nymphs (crawlers). Crawlers move about for several hours, then insert their beaks into the leaves and remain in one place for the rest of their immature stages. After molting three times, they pupate (resting stage) and transform into adults. The life cycle from egg to adult may vary considerably, but it generally averages 30 days.

Whiteflies have piercing-sucking mouthparts with which they puncture the leaf and suck the plant juices. The feeding of these insects on the undersides of the leaves causes the upper sides of the leaves to become pale or spotted.

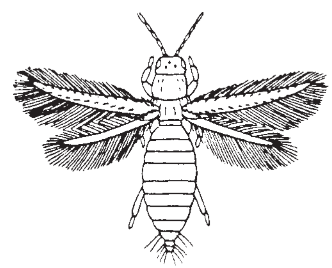


Greenhouse whitefly

Thrips

Thrips are very small, slender insects from $\frac{1}{25}$ to $\frac{1}{8}$ inch long, usually yellow-brown or black. Their life cycle (egg to adult) is 2–4 weeks.

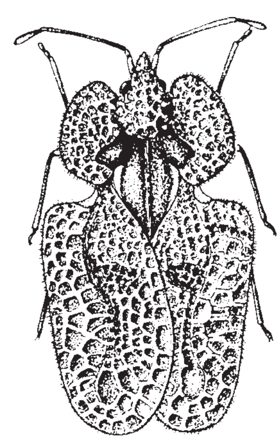
Thrips feeding damages both foliage and flowers of many ornamental plants. Red-banded, Cuban-laurel, and greenhouse thrips are the most common on foliage. Infested leaves have a stippled appearance, and small brownish specks of excrement will usually be noticed on the underside of the leaves. Infested buds fail to open, or the flowers are deformed and become streaked and discolored. To detect thrips, shake flowers or leaves suspected of being infested over a sheet of white paper, or soak them in soapy water.



Thrips

Lacebugs

Lacebugs are about $\frac{1}{4}$ inch long, broad, and flat. Their bodies are usually brown, and the wings are clear with a fine, lacelike appearance. Immature lacebugs are wingless and covered with spines. Their damage appears as whitish speckling on the upper side of the leaf, caused by their feeding on the underside. The presence of shiny black spots of excrement on the leaf underside is a good indication of a lacebug infestation. The most prevalent species are found on azalea and lantana.

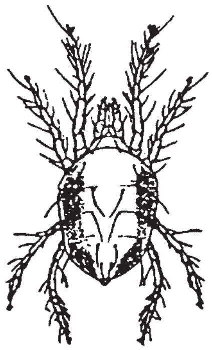


Lace bug

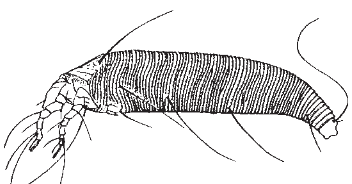
Mites

Spider mites are among the most common pests attacking ornamentals in Hawaii. Mites are not classified as insects. Mature mites are usually less than 1/50 inch in length and are generally found on the undersides of leaves. Mite infestations are often not detected until the plants are severely damaged.

Spider mites have needlelike, piercing mouthparts that puncture leaves. Damage from light infestations appears as yellow or gray stippled patterns on the leaves. The undersides of infested leaves usually have fine silk webbing spun across them. Heavy infestations cause the leaves to turn yellow, gray, or brownish and eventually to drop



Spider mite



Eriophyid mite

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off. Webbing may be spun over entire branches or, in the case of small plants, over the entire plant. When the undersides of leaves are examined closely with a 10 or 15-power (10–15X) magnifying glass, the small mites can be seen. They may be reddish, green, yellow, purple, black, or almost colorless. The body contents sometimes show through their transparent body walls, giving them a spotted appearance. Cast skins may also be seen among the live mites, imparting a grayish residue to the underside of the leaf.

Flowering ornamentals are commonly infested with spider mites, false spider mites, thread-footed mites, and eriophyids. Carmine and broad mites infest practically all kinds of flowering ornamentals including pikake, carnation, chrysanthemum, cymbidium, and rose.

Carmine spider mites are found on the underside of leaves. When leaves are heavily infested they have large amounts of silk webbing and appear bleached due to feeding punctures. These leaves will drop prematurely. Hot, dry conditions of summer favor mite multiplication, which can be astounding. Carmine spider mites can complete development from egg to adult in a week, and each female can have 13,000,000 progeny within a month.

Buds and leaves infested with thread-footed mites such as the cyclamen and broad mites are often aborted and malformed. Population increases of these mites are favored by cool, moist conditions. The life cycle from egg to adult is completed in less than a week. However, these mites are not nearly as prolific as the carmine spider mite. Each female lays about 20 eggs during her life span of nearly 3 weeks. Compared to spider mites, these mites are much smaller and not as brightly colored.

At least five species of false spider mites are occasional pests of flowering ornamentals. Although closely related to spider mites, they do not spin silk webs. Because development from egg to adult requires nearly 30 days, several months are usually necessary before a damaging population builds up.

Eriophyid mites are wormlike, sluggish, four-legged, mostly colorless, and very small. They are commonly referred to as rust mites, bud mites, or gall mites, depending on the type of feeding damage. Although they rarely occur on annual flowering ornamentals, they are very common on perennials. Damage to hibiscus and gardenia is usually minimal and requires no chemical control.

Because mite populations may be explosive, it is essential to recognize incipient infestations of different mites and start control measures promptly.

Insects with chewing mouthparts

Caterpillars

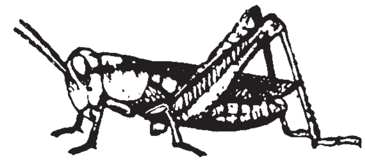
Numerous species of caterpillars, which are the immature or larval stage of moths and butterflies, feed on ornamentals. They chew holes, skeletonize, or notch the edges of leaves, or they may entirely strip leaves from the plant. Mature caterpillars, just before pupation, vary from ¼ inch to 4 inches in length. Leaf rollers are caterpillars that roll and tie leaves together with strands of silk for protection. They also feed on the foliage. Cutworms are the caterpillars of certain moths. Typically, they stay in the soil during the day and feed at night on the bases of tender plants. Some climb the plant and feed on buds and leaves.

Grasshoppers and katydids

These insects occasionally consume large quantities of foliage on ornamentals, leaving an ugly, irregular appearance. Grasshoppers are easy to see and should be controlled before they become numerous. Katydids, which are green and feed at night, are commonly found in large numbers.

Beetles

These hard-shelled insects have chewing mouthparts in both the adult and immature (grub) stages. Various beetles attack roots, foliage, stems, branches, or flowers. Some feed at night and hide beneath the plant during the day. Flower beetles are difficult to control because they may fly in from adjacent areas in large numbers. Two of the major pests of ornamentals are the Chinese rose beetle and the Fuller rose weevil.

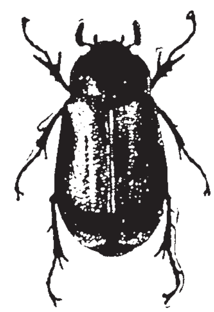


Grasshopper

The Chinese rose beetle attacks a wide variety of ornamentals and cultivated crops. The adults feed at night, leaving a lacelike appearance on the damaged foliage. Eggs laid in the soil beneath the plant hatch after 1–2 weeks. Grubs spend 3–4 weeks feeding on decaying plant material. Although the adults are attracted to lights, they will not preferentially feed on plants exposed to bright lights.

Leaf miners

Leaf miners are larvae (immatures) of several kinds of insects. They make unsightly "mines" in the leaves by tunneling through the leaf between its upper and lower surfaces. Examples are the serpentine and blotch leaf miners, so named for the shape of the mines.



Beetle

Borers

Many species of insects cause injury by burrowing into ornamentals and trees. Some bore just under the bark, while others bore deeply into the trunk and branches. The black twig borer will attack the terminal twigs of acacia, coffee, avocado, and orchids. This borer attacks plants in fairly good vigor, while other borers are commonly found attacking only dead or dying wood. The tiny (1⁄16 inch long), reddish-brown female remains in its gallery (bore-tunnel) throughout most of its life, unable to fly, and cultures a fungus. It lays 8–20 eggs over a period of one week. Upon hatching, the grubs feed on the fungus for 6–8 days and then pupate in the gallery. The entire life cycle lasts about a month.

Both the orchid weevil and the lesser orchid weevil are major pests of various orchids. The adults bore small holes in stems or pseudobulbs in which they deposit their eggs. The grubs bore into the tissue, often causing it to become blackened. Orchid weevils are approximately 3⁄16 inch long.

Monitoring for turf and ornamental insects

Most monitoring methods can be classified as either active or passive. Both have the capability to help in predicting pest problems or quantifying existing damage and pest infestations. The most popular and efficient active sampling method involves visual inspection (scouting). Passive systems use traps (light, pheromone, or mechanical) and require fewer site visits per season. The trade-off between visual and passive systems is accuracy. Traps can tell if an adult insect is present in the sampling area but do not show if it is causing injury or how extensive the population is. These usually can be determined only by visual inspection. The best monitoring program combines both visual inspections and a variety of passive methods.

Pest monitoring keys

Regardless of the sampling methods used, the trade-off becomes time for accuracy versus cost. Scouting cost and time can be reduced and accuracy maintained if monitoring is concentrated on key pests in key locations. *Key pests* are those responsible for major losses at a particular site. *Key locations* reflect the behavior of the key pest to habitually select and damage the same areas or plants over time. *Key areas* are sites that are unique because of aesthetics, rarity of plant material, or historical value. These

Accurate records are important in identifying key locations and appropriate management tactics

areas may require lower damage thresholds to meet the expectations of visitors.

Predetermined key locations should be intensely monitored to detect the first occurrence or first damage. Many insect pests require warm, moderately dry turf conditions for optimal development. Billbugs will lay more eggs close to driveways and sidewalks than in the open turf. Pesticide applicators need to understand how a particular site may affect the biology and behavior of pests.

Accurate records are important in identifying key locations. If historical documentation is unavailable, pest damage, site, and weather characteristics should be recorded. Detailed, factual recordkeeping will help managers select appropriate management tactics. Once a key site is identified, modification of the habitat or vegetation can reduce the reinfestation problem and, in the long term, reduce pesticide use. In many situations the elimination or replacement of a host turfgrass or ornamental with an improved variety or species may solve the problem.

Active sampling techniques

Visual inspection

The quickest, most accurate, and most frequently used technique for detection of insect problems is visual inspection. But to make correct diagnoses, the pesticide applicator must have a background or training in turf and ornamental pest management. Detection of insect damage or prediction of pest outbreaks depends on repeatedly observing adult insect activity and recognizing small changes in plant appearance that are diagnostic of pest injury. The frequency of scouting visits depends on the pest complex, visitor expectations, thresholds, and costs. Typically a weekly or bimonthly schedule is sufficient, while a monthly schedule is acceptable in cooler climates after mid-August. The following examples show situations and conditions where direct observations are essential to a successful integrated pest management program.

Spot sampling

Trained individuals can quickly make accurate observations and pest counts. For example, a 30-second spot count per square foot sample in 20 or so turf locations should provide information on the scope of damage, stages of pest present, and population estimates. Spot counts require thorough search of the thatch and root zone. All pest species can be detected with this method. Although accurate, visual inspections only reflect a population response to the environmental and site conditions at one point in time. For example, the weather may be cool or excessively wet at the time of sampling. These conditions tend to slow down insect development, daily movements, and response to flushing agents. Generally, samples taken under extremes in temperature and moisture tend to underestimate populations. This can be avoided by increasing the number of sample dates each month or avoiding sampling during weather extremes. Supplemental sampling with traps should provide a better population estimate because counts reflect an average over longer periods of time. Traps collect samples every day regardless of most environmental conditions, personal discomfort, and human variability. Scouting is usually done during daylight hours, but during hot weather insects may not be active until late evening, so traps may alert pest managers to unseen problems. If a problem is identified via a spot count, one of the following methods will provide a better estimate of threshold populations than spot sampling.

Irritant sampling

This method is more accurate than the 30-second spot count, particularly where insects are hidden in thick thatch or cracks in the soil. Irritants are only recommended for sampling highly mobile insect pests. Irritants will not expose soil pests such as white grubs and billbug larvae. Irritant sampling is most effective when turf is mowed or clipped before making observations.

Pests living in the thatch, such as sod webworms, cutworms, and billbug adults, will respond to irritant agents. Flushing mole crickets from the soil is also possible, but accuracy may be diminished due to variations in thatch thickness, soil temperature, soil moisture, and depth of feeding activity. To flush with soap in nonthatch situations, use 1 ounce of liquid detergent in 1 gallon of water per square yard.

Use of the irritant method requires both a thorough soaking of the thatch layer of soil and close observation in order to detect the excited insects. Most insects will exit the thatch within 5–6 minutes and move out of the sample area quickly. One person may have difficulty observing this activity over an area of a square yard, so the area can be reduced to 2 square feet if necessary. To take an irritant sample, a circular metal retaining frame 27 inches across by 6 inches high is forced into the soil through the thatch layer and filled with 4 ounces of liquid detergent in 4 gallons of water. The number of insects that float to the top after 10 minutes is then counted.

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Soil sampling

Sampling the soil provides the most accurate determination of white grub and billbug larval densities. Samples are initially taken in areas where turf insects have been or are expected to be a problem. This includes sunny areas with adequate moisture, areas where insect damage is visible, and areas where previous treatment was needed. The location and severity of grub infestations are detected by circular-pattern sampling. Once areas of grub infestation are located, samples are taken in a circular pattern that expands out from the initial site. Pest managers should continue to sample outward from the initial site until grub counts become low enough to no longer be a concern.

Using a sod spade is the least destructive but most time-consuming way to sample turf. A square-foot sample is cut on three sides to a depth of 3–4 inches and the sod square is folded back to expose the soil. The soil is then broken apart, the grubs are counted, and soil is returned to the hole. The grub counts are recorded and the sod flap is replaced on top of the loose soil.

Many samples are required for a good population estimate. A standard golf course cup cutter allows more samples to be taken, increasing sampling accuracy relative to the spade technique. Using a sod cutter is faster, but the spade method is more accurate. Some grubs will be missed if they feed at the thatch level or well below the 2–3 inch level, particularly species that move rapidly up and down in the soil profile in response to moisture, such as the oriental beetle grub.

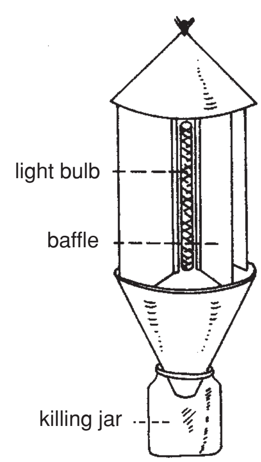
Passive sampling techniques

Light traps, mechanical traps, and pheromone traps can all be important components of an integrated pest management program. Passive sampling can be used to supplement visual methods. Light and pheromone traps may actually be better at sampling nocturnal pests.

Blacklight traps

Backlight traps can collect large numbers of adult insects. But it may be difficult to correlate adult counts with larval numbers, which is an important consideration for insects that do most of their damage in the larval stage. The high cost of these traps is often prohibitive.

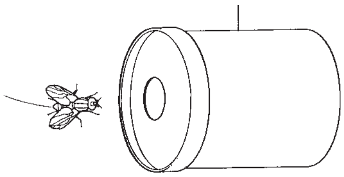
On the positive side, backlight traps can provide notice of the first occurrence of a pest and help delineate its geographical distribution. Measuring the relative abundance of pest species from one year to another can also help predict damage.



Blacklight trap

Pheromone traps

Pheromones are chemicals emitted by an organism to communicate with other members of its species. Many different synthetic pheromones are available to monitor the buildup of pest populations or to monitor variations in populations between geographic locations from one year to the next. Pheromone-baited traps have been used in integrated pest management programs for both ornamentals and turfgrasses.



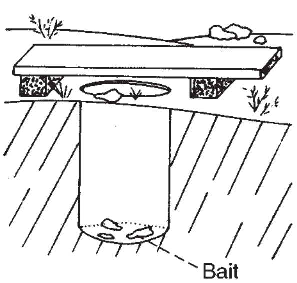
Pheromone trap

A well documented example of a pheromone trap is the Japanese beetle trap, which uses a floral lure and a female sex pheromone. The high cost per trap and the large number required per acre prohibit its use to significantly reduce adult beetle populations. Adding the sex pheromone to the floral lure increases the number of male beetles collected by 10–40 percent. The traps should be used without the sex lure component when they are used for population monitoring so that trap catches will more accurately reflect the normal 50:50 sex ratio. Monitoring the females is more important because they lay the eggs that give rise to the damaging grub population. Some parasites that attack the adults can be easily collected from trapped adult beetles and distributed to new locations.

Trap catches may be strongly influenced by temperature, rain, distance from host plants, soil type, groundwater levels, and natural enemies. Using several traps at each sampling location will help reduce the effect of this variability on population estimates.

Pitfall traps

Primarily used to monitor billbugs, mole crickets, and other highly mobile arthropods, pitfall traps have a small hole or pit lined with a slippery-sided container with the bottom filled with a liquid such as soapy water or alcohol. Small pinholes should be punched near the bottom of all cups to allow water drainage. Although the trap-line setup takes time, daily, season-long inspection is quick. This trap is best utilized for monitoring for the first occurrence of a pest.



Pitfall trap

Insect control

It is not the objective of this text to discuss in detail the various methods of controlling insect pests of turfgrasses and ornamentals. Recent publications specifically devoted to this topic include *Destructive turf caterpillars in Hawaii* (CTAHR publication IP-5), *Hibiscus erineum mite* (IP-7), *Bouganvillea looper* (IP-2), and *Root mealybugs of quarantine significance in Hawaii* (IP-6). In the brief discussion below, we divide the methods of control into five categories: chemical control, physical and mechanical control, cultural control, biological control, and legal control. The advantages and disadvantages of each method depend on a number of factors including the plant, the pest, and the cost and ease of application of the pesticide.

Chemical control of insects and mites affecting ornamentals and turfgrasses is similar to that used in controlling field crops. However, there are two related application problems that must be considered: phytotoxicity and drift. Both of these factors will be discussed in a later section. The value of an ornamental may be drastically reduced if it has signs of phytotoxicity or burn.

Several physical or mechanical insect control methods are commonly used to protect limited areas. Sticky bands on tree trunks may help to control crawling insects. Flying insects can be killed with electric traps or be attracted to light traps. Screens may not only provide a physical barrier to insect invasions, but they may also help regulate light, temperature, and humidity.

Cultural control measures are selected growing practices that prevent buildup of pest populations. These practices, such as mowing, field sanitation, and growing resistant varieties, are often the cheapest methods of pest control.

Biological controls have been effective against many of Hawaii's insect pests, particularly those attacking turfgrasses. Biological control involves the use of beneficial parasitic and predatory insects and infectious microbes that attack specific pests. Many of these beneficial insects are extremely small wasps. Although state and federal agencies conduct most biological control programs, pest managers are free to apply microbial pesticides, such as those containing *Bacillus thuringiensis,* as long as the use is included on the product label.

The enormous increase in air travel between countries has greatly increased opportunities for introductions of insect pests. Hawaii enforces federal and state regulations forbidding the movement of certain plants into the country and within the state. These specific prohibitions on the movement of plants between or within states or countries are called quarantines. It is illegal to ship nursery stock anywhere in the USA unless the shipment is accompanied by a certificate issued by a regulatory agency stating that it has been found apparently free of certain insects and plant diseases.

Plant diseases

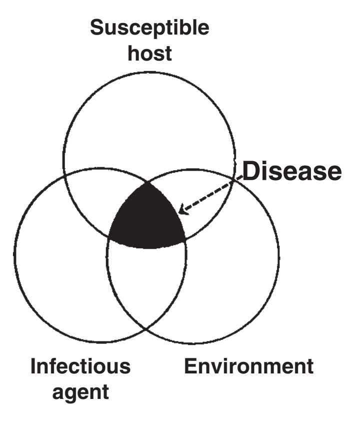
A plant disease is anything that interferes with the normal function of a plant. Biotic (living organisms) or abiotic (nonliving) factors may cause disease. An example of a disease caused by a living organism is brown patch. An example of an abiotic disease is chlorosis caused by lack of a plant nutrient such as iron. Biotic diseases are infectious; abiotic diseases are not. It is important that turf and landscape managers be able to distinguish between diseases caused by organisms and those that might be caused by inadequate plant nutrition, over- or underwatering, too much or too little shade, mechanical damage, and chemical damage (phytotoxicity). About 70 percent of all plant diseases or disorders are the result of abiotic factors. Managers responsible for turfgrass maintenance can consult some of the CTAHR publications on specific turfgrasses available on the college's Web site, <www.ctahr.hawaii.edu>.

Plant diseases

Infectious (biotic)
- ***Fungi***
- ***Bacteria***
- ***Viruses***
- ***Phytoplasma***
- ***Nematodes***

Noninfectious (abiotic)
- ***Unfavorable weather***
- ***Mechanical damage***
- ***Nutrient deficiencies***
- ***Excess salts***
- ***Toxic chemicals***

Biotic diseases require (1) a susceptible host, (2) an infectious agent, and (3) suitable environmental conditions. Therefore, diseases can be reduced or eliminated if any of these three factors are changed. For example, turfgrass managers should select grasses that are not susceptible to certain diseases. They may also be able to manipulate shade, drainage, or wind to create a desirable condition. Chemicals may be used to stop the growth of some infectious diseases. But in general, if turfgrass is healthy it is less susceptible to infectious diseases and therefore requires either no pesticide or less pesticide application.



Infectious diseases are caused by living organisms such as viruses, fungi, bacteria, phytoplasma, and nematodes. Pesticides cannot directly control viruses, although some insecticides are useful to control insects that are vectors of virus. Fungicides, bactericides, and nematicides are the general categories of pesticides that target the other disease-causing organisms.

Fungi (plural of fungus) are the most common cause of infectious diseases. Most fungi have fine, stringlike filaments (hyphae) that penetrate plant tissues, causing both chemical and mechanical damage. As the fungus matures they produce reproductive spores, which are similar to plant seeds. Each spore may germinate to cause a new infection. Some spores are very long-lived (several months or years).

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Bacteria are the second most important infectious disease organism. Bacteria do not grow hyphae; they remain as single cells. They invade the plant passively, entering through injuries or naturally occurring openings.

Viruses are even smaller than bacteria. They cannot live outside the plant and must be introduced through injuries. Insects are important vectors of many viral diseases. Because there are no chemical "viricides," disease control depends on growing non-susceptible plants or controlling the insect vectors.

Nematodes are small (generally microscopic), wormlike animals that may be either free-living or parasitic; they should not be confused with earthworms, which are much larger.

Common turfgrass diseases

The following diseases are commonly found on turfgrasses grown in Hawaii.

Brown patch

This fungus, *Rhizoctonia solani*, lives in the soil. When its hyphae become hard (sclerotic) they are very resistant to fungicides. Brown patch appears as localized, irregular brown areas of turf that start small but may become many feet in diameter. Grass leaves and leaf sheaths turn olive-green, wilt, become light brown, and die. Portions of leaves may be yellow. Stems, crowns, and roots may also be infected. In light attacks, the roots usually are not infected, and the plants recover. Susceptible grasses include bentgrasses, bluegrasses, bermudagrasses, ryegrasses, fescues, zoysiagrasses, and stenotaphrum. Conditions favoring this disease are excessive thatch and mat development, high temperatures (75–95°F), high humidity, and soft, lush growth due to excessive nitrogen fertilizer. Managers should reduce shading and improve soil aeration and water drainage. Irrigate only when needed, and then to a depth of 8–12 inches if possible. Avoid excessive nitrogen fertilizer applications.

Dollar spot

This fungus, *Sclerotinia homeocarpa*, survives in the soil by means of sclerotia. The initial turf symptom is small circular areas about 2 inches in diameter that may merge to form large, irregular areas. The spots usually occur over the entire lawn. The turfgrass leaves appear water-soaked at first, later turning brown, and finally becoming straw-colored. Fine, white, cobwebby hyphae may be seen in the early morning. Susceptible grasses include bentgrasses, bluegrasses, bermudagrasses, ryegrasses, and fescues. Conditions favoring the fungus are moderate temperatures (60–80°F), excessive moisture, and an excess of turf mat and thatch. Turf deficient in nitrogen tends to develop more dollar spot than turf adequately fertilized with nitrogen. Thatch should be kept at a minimum. Irrigate only when needed to a depth of 8–12 inches, and apply adequate nitrogen.

Melting out

This pathogen, *Helminthosporium sorokinianum*, probably survives as mycelium and spores in infected grass plants or grass debris. It may be seed-borne. Melting out symptoms include general thinning of turf in scattered areas. Affected turf often has a general browning of lower leaves. Circular to elongated purplish or brown spots with brown centers occur on leaf blades, leaf sheaths, and stems. Susceptible grasses include bentgrasses, bluegrasses, fescues, ryegrasses, and bermudagrasses. Conditions favoring this disease are warm temperature (70–90°F) and high humidity. Melting out first appears on plants growing in shaded areas. It is most damaging on closely mown turf. Control depends on reducing shade and improving soil aeration and drainage. Thatch should be removed at regular intervals. Apply adequate nitrogen.

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Leaf blotch

This fungus, *Helminthosporium cynodontis*, probably survives in infected bermudagrass plants and debris as mycelium and as spores. It may be carried in the grass' seeds. Tiny purplish to reddish spots occur on leaf blades and leaf sheaths. Seedlings are very susceptible, but the plants rapidly become resistant. Affected seedlings wither and die. The roots and crown may develop small lesions. Bermudagrass is susceptible. Leaf blotch damages young seedlings or adult plants weakened by factors such as excess thatch, nitrogen deficiency, and unfavorable growing conditions. Control measures are similar to those used for melting out.

Grease spot

These fungi, *Pythium* species (mainly *P. aphanidermatum*) survive in the soil for long periods because they have thick-walled spores. Turf is killed in small roughly circular spots (2–6 inches), which tend to run together. Blackened leaf blades wither rapidly and turn reddish-brown. The leaf blades tend to lie flat, stick together, and appear greasy. Roots may be brown. All grasses are affected. Grease spot usually appears in low areas that are wet for long periods. The disease depends upon excess moisture. Turf managers should reduce shading and improve soil aeration and drainage. Water when needed to depth of 8–12 inches.

Seed rot and damping off

This disease may be caused by several fungi, including *Pythium* species, *Rhizoctonia solani*, *Fusarium culmorum*, and *Helminthosporium sorokinianum*. Seed rot is not mushy but rather dry. The hypocotyl area is particularly susceptible. At first, seedlings are water-soaked, then they blacken, shrivel, and turn brown. Frequently, affected seedlings are not killed but are yellow and stunted with markedly reduced root systems. All grasses are susceptible. Seed rot and damping off are favored by excess water, sowing seeds of low viability, and sowing seeds above the recommended rates, especially during periods unfavorable for seed germination and growth. Turf managers should improve soil aeration and drainage. Overwatering must be avoided. Sow only fresh, healthy seed at recommended rates and seasons.

Rusts

These fungi, *Puccinia* species, overseason in infected grasses and as airborne spores. Reddish pustules containing spores appear on stems, leaves, and leaf sheaths. Reddish spores adhere to fingers when the pustules are rubbed. In Hawaii, zoysiagrasses and stenotaphrum are affected. Moderately warm, moist weather favors rust development. Moisture in the form of dew for 10–12 hours is sufficient for spores to infect plants. Keep plants growing rapidly with optimal fertilizer and irrigation.

Fairy ring

This may be caused by several species of mushrooms; *Lepiota morgani* is the predominant one in Hawaii. A dark-green band of turf develops in a circle or semicircle. Mushrooms may or may not be present. Frequently, just behind the dark-green band is an area of sparse, brown, dying grass, caused by lack of water penetration. Weed invasion is common. All grasses are susceptible. Fairy ring develops most frequently in soils high in undecomposed organic matter. Apply adequate nitrogen and aerate the soil for better water penetration.

Algae

Algae (*Oedogonium* and *Ulothrix* species) probably do not parasitize plants, but they

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grow where grass is sparse, appearing as a dark-green scum on the soil surface. When the scum dries, penetration of water may be impaired. All grasses are susceptible. Algae growth is favored by poorly growing grass and wet conditions. *Pythium* root rot is frequently associated with the presence of algae. Provide better turfgrass growing conditions to control algae.

Disease control

The following suggestions are some of the most effective means of disease control.

Good seed or plants

Use seed from healthy plants of a good variety. Bulbs and tubers should be as free as possible of rots and other diseases.

Rotation and sanitation

Rotation is an important method of control of any plant disease that can live in the soil or on dead plant parts. In the case of annual plants in a landscape, a separation of even a few feet in placement of a given plant from year to year will make considerable difference in disease control. When plants succumb to disease they should not be replaced with a plant susceptible to the disease for a suitable period. The length of rotation needed depends on the specific disease or diseases, but in general three or more years should assist greatly in control.

Removal and destruction of diseased leaves and other parts will help control many diseases.

Because many diseases are transmitted mechanically, all tools, benches, and work areas should be carefully decontaminated with a chlorine solution or by hot water treatment.

Thinning

Young, crowded plants are prone to diseases. Thinning as early as possible will help to cut down on disease occurrence and spread. Thinning allows better air circulation and quicker drying and gives pathogens less chance to become established. Damping-off disease can often be avoided in this way. Thinning of excessively thick foliage on larger plants also promotes drying and reduces disease problems.

Resistant varieties

Where disease-resistant varieties are available and satisfactory for the desired purpose and area, their use is recommended. This is one of the most desirable methods of preventing plant diseases, as no other control measures are needed.

Spraying and dusting

Spraying or dusting pesticides is one of the most common methods used to control diseases. *It should be stressed that this is a method of prevention not a cure*. If the plants are to be protected, the spray must be on the plant or plant parts before and not after the disease strikes.

Soil treatment

Some diseases, primarily those that are soil-borne root diseases and wilts, can be controlled by soil treatment before planting. Soil treatment by heat or pesticides is the most effective method of protecting plants from nematodes.

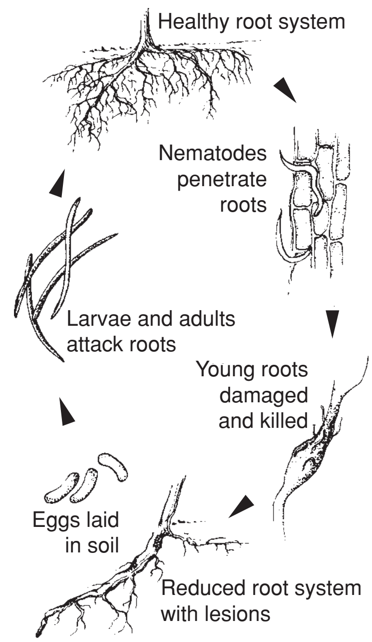
Quarantine and certification

Quarantines normally involve absolute or limited exclusion of diseases or potentially dangerous plant materials. Quarantines and certification may require specific treatments of plant materials and soil. Such requirements may include hot water treatments, pesticide applications, fumigation of plant materials, and chemical or steam sterilization of soil.

Nematodes

Plant-parasitic nematodes possess a protrusible stylet or spear that is used to puncture plant tissues. Free-living nematodes either lack a stylet or use it primarily for killing prey and not for piercing plant tissues. Nematodes may be either endoparasitic or ectoparasitic, i.e., they either live within the plant or externally on the plant. Nematodes are also designated as migratory or sedentary, depending upon their mobility during parasitism. Some are migratory in the immature or juvenile stage and sedentary in the adult stage. Not all nematodes damage plants. Several species have been developed as biocontrol agents because they feed on insect and weed pests.

Plant-parasitic nematodes may cause mechanical injury, chemical injury, or inject pathogenic bacteria and fungi. Injury may be manifested as lesions, knots, galls, root rots, excessive root branching, and injured root tips. These root symptoms are usually accompanied by symptoms in the above-ground parts of the plants that resemble those from various other causes, such as reduced growth, yellowing of foliage, excessive wilting in hot or dry weather, reduced yields, and poor plant quality.



Nematode disease cycle

Identification and sampling

Because of their small size, semitransparent bodies, and the fact that they are obscured from view in soil particles and plant tissue, field identification of nematodes is nearly impossible. Lacking characteristic symptoms such as root galling, laboratory assay is generally required. Because other plant pathogens and cultural conditions often produce symptoms that resemble those caused by nematodes, it is not advisable to attempt diagnosis of nematode diseases by symptoms alone. However, plant symptoms often give clues as to the nature of the problem and are valuable aids to people who have the training to correctly identify nematodes.

Soil samples for laboratory diagnosis must be carefully collected and handled. Samples must be kept moist, but not wet. They should not be left where they would be exposed to the sun or heat. Collecting and shipping samples in plastic bags will reduce the possibility of their drying in transit. Plant samples should be handled and shipped like soil samples. If possible, plant samples should include the entire root system, or as much as is practical to ship. Sampling tools should be cleaned between samples.

Control of nematodes

The most serious obstacle to an effective control program is often the lack of recognition that plant-parasitic nematodes are seriously limiting the potential growth of the host plant. Generally, acceptable growth can be achieved by reducing the nematode population through

- cultural practices including crop rotation, resistant varieties, and fallowing,
- biological methods utilizing parasites and predators
- mechanical or physical methods
- chemical control.

The method selected depends on many factors including the value of the plant, the type of equipment available, weather conditions, the soil, and the biology of the pest.

Chemicals used for control of nematodes are called nematicides. Some act as soil fumigants. Nonvolatile nematicides are often termed contact or systemic nematicides, depending upon their mode of action. Some nematicides are highly toxic to all forms of life including plants. These should only be applied by a properly trained applicator on the advice of a nematologist.

The effects of high populations of nematodes on turf has not been established in Hawaii. Although there are some nematicides that may be used either before planting or after the turf has been established, it is advisable to ascertain that symptoms are not due to another factor, such as cultural practices, pathogenic microorganisms, or herbicide residues.

The use of nematicides on potted ornamentals may be required if those ornamentals are shipped between the islands, to the U.S. mainland, or to foreign countries. Pesticide applicators and others should avoid unnecessary contact with recently treated potted plants. Most nematicides are highly toxic. All cautions on the label should be carefully read and followed.

Weeds

A weed is a plant growing out of place

Weeds are usually described as plants growing where they are not wanted. Any undesirable grass or broadleaf plant species, from a small herbaceous plant to a woody shrub, vine, or tree, may be considered a weed if it is growing in a turf planting. Broadleaf plants are those that have two cotyledons (dicot) in each seed. Most weeds in turf have little or no woody tissue and are herbaceous (e.g., plantains, dandelion).

Weedy areas provide habitat for desirable wildlife and beneficial insects, but they can also harbor rodents and arthropods such as ticks, mites, and fleas that might attack humans and domestic animals or carry diseases that may infect humans and domestic animals. Weeds can also serve as alternate hosts for some fungal pathogens and insects that might attack desirable plants.

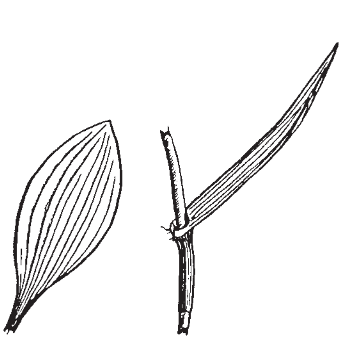
Many weed species possess efficient methods of seed dispersal, such as wind dissemination of winged or hairy seeds or the ability to spread rapidly by rhizomes, runners, or tubers.

Weeds may be classified based on their morphology and life cycle.

Weed classification based on morphology

Morphologically, most weeds are classified as grasses, broadleafs, and sedges.

Grasses



Parallel veins

True grass weeds have hollow, rounded stems and nodes (joints) that are closed and hard. The leaf blades have parallel veins, are much longer than they are wide, and arise alternately on each side of the stem. Grass weeds in turf include crabgrass, goosegrass, sandbur, and annual bluegrass. These weeds are annuals, completing the life cycle in one year. Some perennial grasses such as Hilograss and Wainaku grass are familiar weeds of many turf areas in Hawaii.

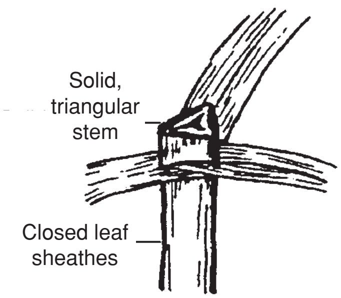
One of the frequent grass weed problems in turf is the presence of an undesirable turf species growing with the dominant or desirable turfgrass. For example, turf managers frequently wish to control St. Augustinegrass in a bermudagrass turf, or common bermudagrass may be present as a contaminant in a hybrid bermudagrass. It is possible in some cases to selectively control the undesirable or weedy turf species by proper management and herbicide selection.

Broadleaf weeds

This highly variable group of plants mostly have showy flowers and leaves with netlike veins. They are easy to separate from grasses due to their leaf structure and habits of growth. Their presence causes a visual change in the overall texture of a turfgrass. Many broadleaf weeds can adapt to the close mowing culture of turf and appear quite different from the pictures and descriptions given of mature specimens in identification guides. Important broadleaf weeds found in turf include spurges, pennywort, kaimi clover, and portulaca. Most broadleaf weeds are summer annuals.

Sedges

These important "grasslike" weeds of turf are not true grasses but are characterized by a solid, triangular stem with leaves extending from each side in three directions. There are annual sedges (water grass) and the predominant, difficult-to-control sedges such as yellow nutsedge (found only on the island of Hawaii). Rhizomes radiate from the plant and bear a single bulb or tuber at the end, which may produce new plants. Purple nutsedge is usually smaller than yellow nutsedge, has reddish-purple seedheads, and produces a series of bulbs on the radiating rhizomes called "tuber chains."



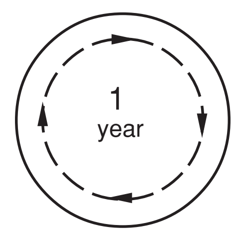
Sedge stem

Weed classification based on life cycle

Plants may also be classified by their life cycle: annual, biennial, or perennial. Understanding plant life cycles helps determine the best time to use different management techniques, or whether management is even necessary.

Annuals

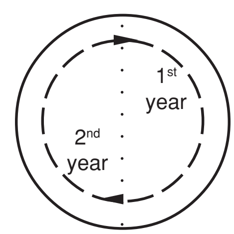
An annual plant germinates from seed, reaches full growth, and produces seed within a year. Most annuals in Hawaii are summer annuals. Those classified as annuals in temperate areas may grow throughout the year in Hawaii because of insufficient cold to kill off the weeds in the fall. Examples of annuals include goosegrass and spiny amaranth.



Annuals

Biennials

Biennial plants live for two growing seasons. They germinate from seed in spring or summer and produce a cluster of leaves and a large root system. In the second year they flower, produce seed, and die. These plants are few and relatively unimportant in Hawaii.



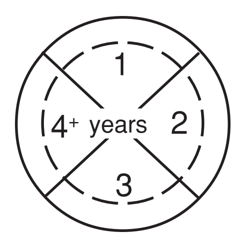
Biennials

Perennials

Weeds that live more than two years are perennials. They may reproduce from tubers, bulbs, rhizomes (underground stems), or stolons (above-ground stems). Some also produce seed in addition to vegetative reproductive organs. During cooler seasons, they may enter a dormant state and lose their foliage or stems. With the beginning of warm weather, they regenerate from food reserves in their root systems. Hilograss, nutsedge, and various vines are perennials.

Perennial weeds may be further divided into groups based on the type of root system and reproductive process.

- Simple perennials reproduce from seeds, but root pieces disturbed by cultivation or other mechanical means will produce new plants. Trees and shrubs are characteristic of this group.
- Bulbous perennials, such as yellow nutsedge, reproduce by underground bulbs.
- Creeping perennials may produce seed, rhizomes, or stolons. Bermudagrass, torpedograss and purple nutsedge produce these specialized stems (rhizomes and stolons) that act as food storage organs and can initiate growth at each node (joint) along the stem.



Perennials

NOTES . . .

Obviously, the perennial weeds are the most difficult to control because of their great reproductive potential and persistence. Control methods for woody plants are timed to the yearly growth cycle, much like herbaceous perennials.

Control of weeds is based on proper identification. For the most accurate identification, consult weed identification guides such as *Handbook of Hawaiian Weeds* or a local authority.

Weeds in turf

Weeds growing in turf are found where soil has been exposed or disturbed by compaction, planting activities, or maintenance activities such as sidewalk edging. For example, goosegrass and knotweed readily colonize heat-stressed and compacted soil sites along sidewalks or on athletic fields. They also occur where turf is weakened by drought, thatch accumulation, diseases, or insects. Fertilizer spills, chemical spills, and dog urine can also leave bare spots in which weeds will grow. Weeds are usually common where the grass species being grown is not well adapted to its environment.

In Hawaii, weeds constantly compete throughout the year with turfgrasses for space, water, nutrients, and light. These unwanted plants increase maintenance costs, may act as alternate hosts for insects and diseases, and may cause discomfort to man and animals through the production of allergy-causing pollen, skin irritants, toxic substances, and spines or burrs. The most obvious impact of weeds in turfgrass is a general lack of neatness, leading to a loss of visual appeal, turf quality, and real estate value. The variable leaf width, color, and growth habit of weeds disrupt the uniformity of texture associated with high-quality turf.

Monitoring for weeds

Monitoring for actively growing weeds should be done periodically. It is essential that all monitoring results are reported completely and accurately by site and date so that future surveys will cover the same areas. Recorded weed information allows the manager to develop a weed history of an area. This will result in a more accurate prediction of future weed management needs.

Regular visual inspections of turfgrass areas should be conducted to look for actively growing weeds as well as newly germinated weed seedlings. Weeds are most likely to be found in areas where some type of disturbance has taken place.

Certain weed species tend to be found in certain habitats, so monitoring for a particular weed should be based on knowledge of its biology. For example, crabgrass is an annual weed that needs light to germinate. Crabgrass seedlings are also most likely to be found in bare or thinning areas. If they are not found in areas such as this, it is unlikely that they will be found in a shaded area of denser turf.

Monitoring large areas of turf for weeds can be very time-consuming, so certain techniques should be employed to make the monitoring process more efficient. One commonly used technique in weed monitoring is to lay out 50-foot lines over turf and then count and identify all weeds that touch the line. The lines should be randomly placed in areas that represent the various turf species, habitats (e.g., sun vs. shade), and different use areas that may be present.

Crabgrass (*Digitaria*)

Action thresholds for weeds

Action thresholds are population levels at which pest management efforts must be instituted. It is extremely difficult to set specific action thresholds for weeds because the problems caused by weeds are largely aesthetic rather than medical or economic. Turfgrass or landscape managers should establish action thresholds for the area by maintaining records and scouting weed populations. Action levels will be lower in high-use areas such as around buildings and picnic or rest areas than they will be in large, unused, or parking areas. Vigorous weed competitors such as crabgrass, white clover, and quackgrass should have a lower action threshold than other weeds.

Some important weeds of turf in Hawaii

Pesticide applicators should be able to recognize common weeds found in Hawaii. Incorrect identification can result in control application mistakes. Such mistakes may have minor consequences, or they may lead to regulatory enforcement actions. It is impossible to include all weedy plants here—only representative weeds causing problems in Hawaii are discussed. Applicators are encouraged to consult weed or plant guides such as the *Handbook of Hawaiian Weeds* or similar references.

Bristly foxtail

Crabgrass

Crabgrasses (*Digitaria* species) include both annuals and perennials. They are easily recognized by the seedheads, which consist of several slender spikes that spread out like the fingers of a hand. Young seedlings have erect stems. Older stems bend at the nodes, which gives plants a spreading, messy look.

The large crabgrass (*D. sanguinalis*) has densely hairy leaves and branching stems that root at the nodes. Smooth crabgrass (*D. ischaemum*) lacks hair on the leaves and does not root at the nodes. Several species of *Digitaria* are established in Hawaii: *D. sanguinalis, D. violascens, D. setigera,* and *D. adscendens.*

Foxtails

The upright stems of these annual grasses (*Setaria* species) are over 1 foot tall and are topped by dense seedheads with numerous, long bristles. Yellow foxtail (*S. glauca*) and palm grass (*S. palmaefolia*) are common species in Hawaii. Bristly foxtail (*S. verticillata*) has barbed bristles around the fruiting bodies that stubbornly cling to clothing and fur.

Goosegrass

Goosegrass

Also called wiregrass, this annual weed (*Eleusine indica*) thrives in full sun and disturbed soil. The stems, leaf blades, and seedheads lie flat on the ground in a rosette pattern. It can tolerate close mowing. The flowering heads have from two to six flattened, fingerlike branches. This grass is widely distributed in Hawaii. It is a problem weed in cultivated areas, lawns, pastures, and unused places.

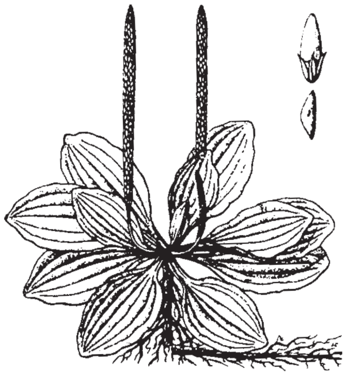
Nutsedge

This aggressive weed (*Cyperus* species) spreads by underground, nutlike tubers. Its leaves are attached at the base of a single fruiting stem. Several seed clusters on stalks of different lengths arise from three bracts, leafy structures at the base of fruiting stems that may or may not look like leaves. The decision to control nutsedge will depend on the severity of the weed problem and the soil moisture conditions. Yellow nutsedge (*C. esculentus*) is native to North America and probably an accidental introduction to the Hawaii. Another *Cyperus* species established in Hawaii is purple nutsedge, *C. rotundus*, one of the world's most difficult-to-manage weeds.

Purple nutsedge

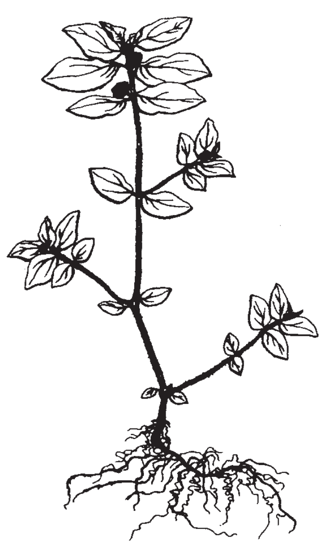
Broadleaf plantain

This widespread weed (*Plantago major*) is a stemless perennial herb with fibrous roots. The basal rosette of oval leaves is often unnoticed until flower spikes appear from the center. Its leaves are smooth with several prominent parallel veins. It is common in lawns and pastures as well as disturbed rainforests in Hawaii. The leaves and seeds are used in traditional Hawaiian remedies. Birds eat the seeds and help spread the plant to other sites.



Broadleaf plantain

Green kyllingia



Garden spurge

Bull thistle

This weed (*Cirsium vulgare*) can be a major problem in lawns and gardens. The leaves are deeply indented, dark green on top and paler on the lower surface, and each lobe is spine-tipped. The other plant parts are also armed with spines. The flower heads are large, rosy purple, and few in number.

Ivy gourd

This weed (*Coccinea grandis*) is abundant in the lowlands of the Hawaiian islands. It climbs over fences, low vegetation, and even into tall trees, often entirely suffocating them. It is considered a serious problem in both urban and forest areas. This herbaceous vine is recognized by its alternate, broadly ovate, five-lobed leaves, showy white bell-shaped flowers, and smooth red, ovoid to ellipsoid fruit. Birds feed on the fruits, helping to spread the seeds to other areas.

Spiny amaranth

This erect, annual herb (*Amaranthus spinosus*) is a troublesome weed in pastures, cultivated areas, and disturbed lowland places such as roadsides and abandoned cultivated or disturbed areas. Its stout stem has alternate leaves, and at the base of each leaf is a pair of sharp spines and small, shiny, dark brown seeds. This plant is a prolific seeder and crowds out other plants. Their long, sharp spines protect it from livestock.

Haole koa

This relatively small, thornless shrub or upright tree 10–30 feet high (*Leucaena leucocephala*) is common in dry and moist areas of Hawaii. It grows from sea level to 2600 feet elevation. It has alternate, bipinnate compound leaves, round white flower heads, and clusters of brown, strap-shaped pods. In some areas, the leaves are collected for cattle fodder.

Beggar's tick

Also known as Spanish needle, this weed (*Bidens alba, B. pilosa*) is widespread in the tropics and subtropics. It is one of the most abundant weed pests in Hawaii and a serious weed of disturbed roadsides, lawns, and abandoned plantations and cultivated areas. It occurs from sea level to 3900 ft elevation, spreading by means of barbed fruits that adhere to clothing, feathers, and fur. Its fruits are also dispersed by flowing water. Beggar's tick is recognized by its opposite, simple, or trifoliate leaves with serrated edges and many whitish hairs. The flower head is yellow.

Green and white kyllingia

Kyllingias (*Kyllinga brevifolia, K. nemoralis*) are perennial sedges native to the tropics; they spread both by seeds and creeping, underground stems. Both species have flower stems surrounded by one to four leaves, and they may have three to four narrow, leafy bracts at the top. Kyllingias are bothersome weeds in open spaces such as pastures, rangelands, and lawns.

Garden spurge

Garden spurge (*Chamaescye hirta*) is an upright annual broadleaf 6–8 inches high. Its stems are somewhat hairy, with opposite leaves. This plant is a weed in both moist and dry areas. Another spurge pest of turf is the prostrate spurge, *C. prostrata*, which is widely established in Hawaii.

Turfgrass weed control

"An ounce of prevention is worth a pound of cure" in controlling weeds in turf. A dense, vigorously growing turf is the most effective approach to lawn weed control. Any management practice that helps produce a thick turf will discourage weeds. Herbicides should be used as supplemental tools, not as substitutes for good cultural practices in turfgrass maintenance.

Select a well adapted plant and avoid problems later

After identifying the weed species, turfgrass managers must identify and correct any basic cultural problems and properly identify and control any insects, nematodes, snails, and diseases. Only after correcting the weaknesses in basic requirements of turfgrass culture that permitted the establishment of weeds should the use of herbicides be considered. The discussion on why weeds are present in turf and the initial corrective procedures is an exercise in cultural or preventive control. Consider further that if only a few weeds occasionally emerge or if weeds appear that are resistant to herbicides and other methods of control, hand removal or mechanical control would be the preferred approach.

Nonchemical control of turfgrass weeds

Turfgrass managers should plant only turfgrass species and cultivars that are adapted to the growing area and, if possible, are resistant to diseases and insects. Even though it is more expensive, certified seed free of noxious weed seeds should be used. Renovation and new plantings should be done at the times of year that are most appropriate for the particular plant, i.e., fall for cool-season grasses and late spring for warm-season grasses. When preparing the area for planting, allow weed seeds to germinate and then cultivate or apply a nonselective herbicide to kill the young plants. Cultivation without also using nonselective herbicide is generally not suitable for weeds that produce rhizomes, stolons, or bulblets because it breaks these structures into smaller pieces and may therefore result in dispersal rather than control of the weed.

Test, don't guess—have the soil analyzed

During turfgrass establishment, inspect regularly for weeds. Mechanically remove weeds found in small populations, or spot-treat areas with a concentrated weed population with appropriate herbicides. Always check the herbicide label for information on seedling tolerance.

Employ sound cultural practices that include regular soil testing, appropriate fertilizer applications at the correct times, mowing at the appropriate height and frequency, and deep irrigation when needed. Frequent, shallow watering discourages root growth and can encourage weed seed germination and some turfgrass diseases. Mow no shorter than 2½ inches for cool-season grasses such as Kentucky bluegrass, tall and fine-leaf fescues, and perennial ryegrass to prevent weakening of grass and encouragement of weed seed germination. High mowing of these species will promote a dense turf that can more effectively compete with weeds. Frequent mowing will prevent or reduce seed production in some weed species. Lower mowing is desirable for species such as bermudagrasses and zoysiagrasses. However, despite proper mowing, weeds may still become a problem in turfgrasses.

Turf management practices that increase the health, density, and general vigor of grass will discourage weeds through competition. It is essential to use turfgrasses that are adapted for the specific planting area (i.e., region, climate, light intensity) and type of use (e.g., heavy traffic). This will promote the best possible sod development. When turf is established or renovated, grass seed, sod, topsoil, and mulches that are free of weed seeds should be used.

Turf maintenance practices should stress appropriate fertilization and liming based on the results of soil tests. The amount of nitrogen and the timing of application are extremely important factors for maintaining turf density and discouraging weed en-

Weeds are easiest to control when they are small

croachment. Deep watering to wet soil to a depth of 5–8 inches when grass begins to show signs of wilting will prevent the development of shallow root systems and weak turf and will help to reduce weed, disease, and insect problems. Frequent, shallow watering encourages the germination of some weed seeds and should be avoided.

It is also important to remove leaves or other accumulated debris from turf, since this can smother or shade the grass, allowing weeds to grow in its place. Heavy thatch produced by some turfgrasses is reduced by a combination of core aerification, maintenance of soil pH between 6.0 and 7.0, and use of balanced fertilizers with slow-release nitrogen. Thatch also can be avoided through the use of tall fescue or other bunch-type grasses (where adapted) and by avoiding excessive nitrogen fertilization.

No biological control agents for weed control have been approved for use in turf.

Chemical control of turfgrass weeds

Generally, chemical weed control measures should be considered only if cultural practices to promote a dense, vigorous turf cover fail to provide the degree of weed control desired. Herbicides can be useful tools for weed control and very helpful overall in a turf management plan.

Herbicides are commonly classified on the basis of their target plant pest type (broadleaf, grass, or sedge), their selectivity in affecting different plants, the appropriate timing of their application, and their mode of action.

Selective herbicides

Selective herbicides kill some plants while having little effect on others. The selective nature of some herbicides allows applicators to use them to eliminate weeds without damaging desirable plants in the same location. To properly use selective herbicides, applicators need to know whether the weed is a grass, broadleaf, sedge, or woody plant and whether it is an annual, biennial, or perennial. Most selective herbicides will state on their label what they are intended to control, e.g., "For control of broadleaf seeds," or "For control of perennial grasses." An example of a selective herbicide is 2,4-D, which kills broadleaf weeds but leaves grasses unaffected.

Nonselective herbicides

Nonselective herbicides kill vegetation without regard to type or species. Paraquat, glyphosate, dinoseb, and bromacil are examples of nonselective herbicides. Selective herbicides may act as nonselective herbicides if used at high concentrations, so caution is advised to keep spray mixes within the dilution range specified on the product label. Likewise, some nonselectives may be selective when applied at low concentrations.

Modes of herbicidal action

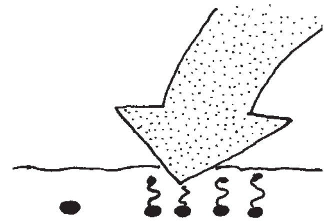
There are basically three modes by which herbicides affect vegetation: contact, translocation, and growth regulation. Turf managers need to understand the mode of herbicidal action needed to get the desired results.

Contact herbicides kill only plant tissues they actually contact. They are normally applied in liquid form. Effective control depends on whether a plant's growing points are protected from or exposed to the herbicide. For example, perennials with underground buds are not completely killed by a contact spray that reaches only top growth. As a result, pesticide applicators can expect new growth to occur soon after they apply a contact herbicide to a perennial plant. Paraquat is an example of one of the most commonly used contact herbicides.

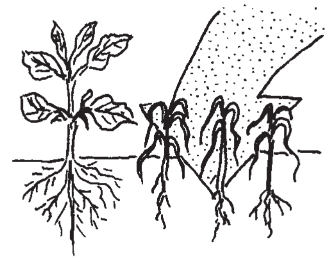
Soil sterilants also act as contact herbicides by making treated soil incapable of supporting higher plant life. However, they do not necessarily kill all life in the soil, such as fungi, bacteria, and other microorganisms. Toxic effects may remain for only a short time or for years.

Translocated herbicides, also referred to as systemic herbicides, are absorbed by the leaves, stems, or roots and move through the vascular system to other leaves, buds, and root tips. When absorbed by the leaves and stems, the herbicide is commonly moved with food materials as they are synthesized in the leaves and stems. When absorbed by the roots, the herbicide moves into water-conducting plant tissues. The herbicides then build up in rapidly dividing cells, upsetting the normal metabolism of the plant and causing death. Foliage application of translocated herbicides can be of practical value, as small amounts are usually effective, and they can be applied in small amounts of diluent. The most commonly used translocated herbicide is glyphosate (Roundup®).

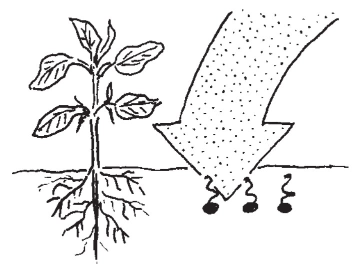
Plant growth regulators (PGRs) are chemicals that induce growth changes in plants. PGRs mimic the normal plant hormones that control flowering, fruit development, and dormancy. They are used to control growth, enhance fruit production, remove foliage, and destroy undesirable plants. Gibberellic acid (Pro-Gibb®) is an example of a PGR used on both ornamentals and other vegetation.



Preemergence



Postemergence

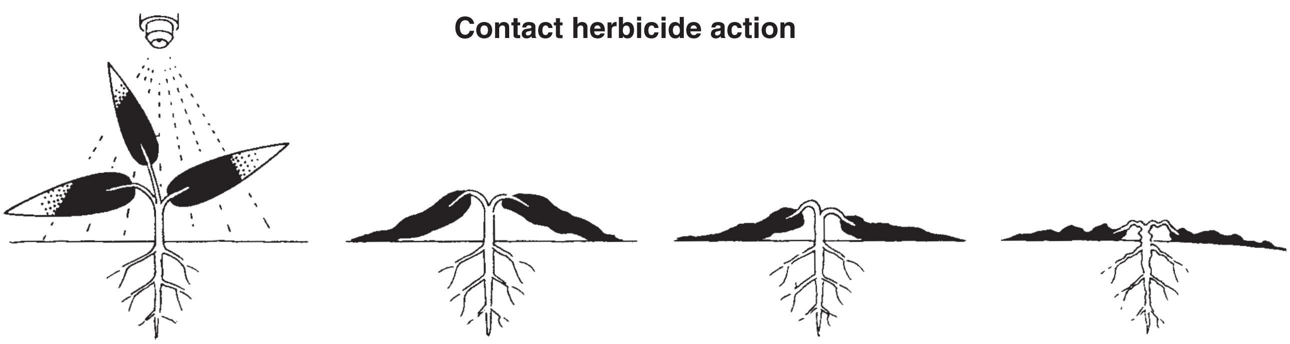


Postplant preemergence

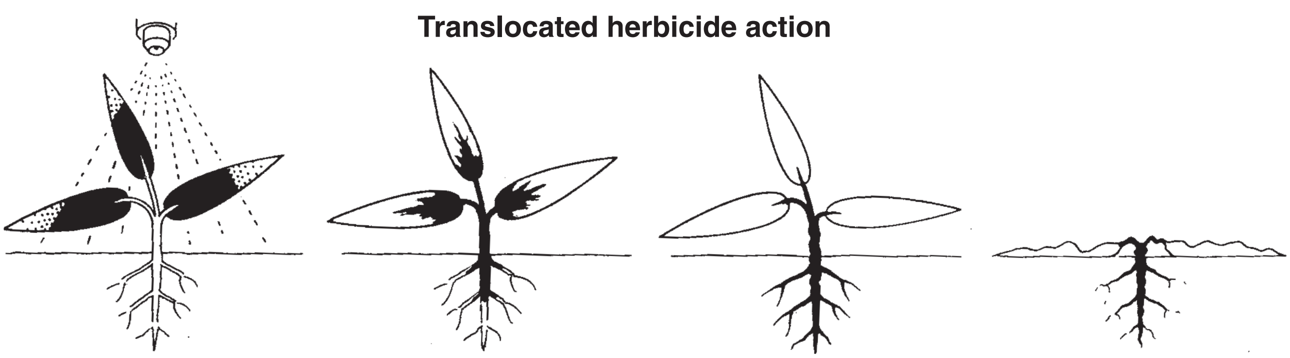
Timing of application

Herbicides can be classified according to the timing of their application with regard to weed life cycles. Preemergence herbicides prevent or retard the growth of germinated weed seeds. Postemergence herbicides are used to control actively growing weeds. Most postemergence herbicides remain active in the soil for a short period of time, so repeated applications are often required. Preplant herbicides are incorporated into the soil before planting crop seeds.

Contact herbicide action



Translocated herbicide action



Read the label

Herbicide longevity

Herbicides vary in their rate of disappearance because of volatility (which is affected by temperature), solubility, and susceptibility to decomposition by soil microorganisms. For example, certain soil microorganisms effectively decompose the herbicide 2,4-D. Some water-soluble herbicides are readily leached from the soil, while others are tightly bound to soil particles and are subject to removal in run-off during soil erosion. Other pesticides also have variable longevity; for example, some carbamate insecticides are volatile at high temperatures and rapidly lose their toxic effect during the summer months.

The best source of information on the use of a particular herbicide is the label. ***Read the label*** before buying, storing, mixing, applying, and disposing of herbicides.

Lateral movement

Caution must be exercised in use of herbicides on slopes, sandy soils, and soils that are subject to erosion in heavy rains. All soil-active herbicides can move laterally, causing excessive destruction of vegetation and subsequent soil erosion. In areas where complete destruction of vegetation would be an undesirable effect of herbicide treatments, apply contact or translocated herbicides as spot treatments to weeds, or use selective herbicides rather than nonselective herbicides.

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Basics of chemical weed control

When chemical weed management is necessary, start by using spot applications to areas with concentrated weed populations. Apply broadleaf herbicides to mature turfgrass stands. Annual grass weeds are best controlled with preemergence herbicides applied before the weed seeds germinate.

In sites with extremely persistent, perennial weeds such as quackgrass or bermudagrass, a nonselective herbicide such as glyphosate should be applied twice, 30 days apart. This is ideally done first about a week before tilling and then a few weeks afterward. The first application will kill existing weeds, while the second will kill weeds that have germinated from seeds that were dormant in the soil. Being nonselective, glyphosate also will injure or kill desirable turfgrasses, flowers, and other herbaceous plants, but this herbicide has no significant residual soil effect, and treated areas can be re-seeded within 24 hours of glyphosate application.

When new areas of turf are being established, shallow cultivation will bring many buried weed seeds to the surface to germinate. Applying nitrogen fertilizer and irrigating the soil helps encourage weed germination, and then a nonselective herbicide such as glyphosate can be applied to control these weeds.

Perennial broadleaf weeds can generally be controlled or reduced below threshold levels with a single application of a selective herbicide. Do not use these herbicides unless there is sufficient soil moisture to support active growth of weeds. Air temperatures should range from 65° to 85°F, and there should be no wind when these herbicides are applied. Liquid or sprayable herbicide formulations provide superior control to granular formulations but are susceptible to drift. Read the pesticide label carefully and follow all its directions.

Annual grass weeds such as crabgrass and goosegrass are serious weeds because they can effectively compete with turfgrasses and can significantly reduce turf stand density. When monitoring indicates increasing populations of annual grasses, an application of preemergence herbicide must be planned for new adjacent turf areas. To be effective, the herbicide must be applied before weed seed germination, and the soil must be moistened by rainfall or irrigation within three to five days of herbicide application.

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Phytotoxicity

Phytotoxicity, or pesticide damage to plants, may result in abnormal growth, leaf drop, and discolored, curled, or spotted leaves. If phytotoxicity is severe, the plant may die. Phytotoxicity often mimics such things as insect damage, plant disease, and response to poor growing conditions such as insufficient moisture and improper fertilizer application.

Pesticides that are safe for both target and nontarget plants should be selected, if possible. It may be necessary to place a barrier around the target plant or remove susceptible plants from the area (such as removing susceptible potted plants from a greenhouse). Finally, if the benefit from using the pesticides does not justify the hazard to nearby plants, do not apply it. The following are especially relevant to phytotoxicity:

- variety of plant material
- pesticide drift
- pesticide persistence beyond the intended period of pest control
- incompatibility
- formulation
- application method.

Plant material

Ornamental plants vary from herbaceous to semi-woody and distinctly woody species. Generally, herbaceous plants (chrysanthemums, petunias, turfgrasses, etc.) are more susceptible to pesticide damage than woody ones. Woody plants are more susceptible when growth is young and tender.

Plant damage is more likely to occur with herbicides. Insecticides and fungicides, except those applied as smokes, tend to be less hazardous to plants than herbicides. The pesticide label is the best guide to the safe use of pesticides on a specific ornamental plant. If the pesticide is not known to be safe for use on a specific ornamental plant, it should not be used. Where different plants are rotated in the same soil, a pesticide used to control some pests on one plant may leave residues in the soil that will damage or kill another plant. This is especially true of some herbicides.

Drift problems

The proximity of different plants with varying susceptibility to pesticide damage requires that pesticide applicators certified in the ornamental and turf category be especially aware of pesticide drift problems. Because pesticide drift can cause damage to nontarget sites, applications that result in drift could result in civil, criminal, or administrative penalties to the applicator in charge. There are several steps that can be taken to prevent damage to nontarget plants.

Factors affecting drift must be understood before the applicator can take appropriate steps to deal with them. They can be grouped into one of the following four categories:

- weather conditions at the time of application (wind speed and direction, temperature, relative humidity, and stability of air at the application site)
- spray characteristics, such as the volatility and viscosity of the pesticide formulation
- equipment and application techniques
- operator's care, attitude, and skill.

Weather conditions

Spraying only when weather conditions are favorable can reduce drift. Wind speed and direction are perhaps the most important factors to consider. The amount of pesticide lost from the target area and the distance the pesticide moves increase with wind speed. Time applications for early in the morning or early evening, when wind speeds are the lowest. Avoid spraying even in a light breeze if the wind is blowing toward a sensitive area.

NOTES . . .

Spray droplet size

Spray droplets smaller than 50 microns ($^{50}/_{1000}$ of an inch)—about the same diameter as a human hair—are highly susceptible to drift under normal conditions. The ideal range of droplet sizes for general ground applications is 80–150 microns. In general, droplet size can be affected by

- spray pressure—higher pressure decreases droplet size
- nozzle type—flood nozzles produce slightly larger droplets than flat fan nozzles, which in turn, produce droplets larger than hollow cone nozzles
- nozzle orifices—nozzles with large orifices and greater flow rates produce larger droplets than nozzles with smaller orifices
- using carriers and adjuvants; thickening agents, or drift-reduction agents, can reduce drift by 50–80 percent by minimizing formation of small droplets.

Equipment considerations

Spray drift is greater from mist blowers and aerial applications than from ground application. Low-pressure ground sprayers usually produce large spray droplets that are released closer to the target than aerial sprayers or mist blowers. Booms and nozzles should be kept as close to the ground as possible to get the proper spray coverage while reducing the effects of wind. Because nozzles are so important to maximizing coverage and minimizing drift, applicators should make an effort to keep current in nozzle technology.

Pesticide persistence

The period of pesticide residual activity varies greatly from one class of pesticides to another. Persistence is directly related to the rate of application, soil type or texture, temperature, moisture conditions, rainfall amounts, and other factors. Applicators must be familiar with the persistence of each pesticide that may be applied to ornamentals and turfgrasses, especially where adjacent areas may be affected, the soil treated is used to grow other plants, or humans and pets frequent the area. An example of persistence causing a problem in plant handling would be the use of a highly toxic systemic insecticide on plants grown for transplants. It is very possible that in the process of transplanting, the soil would be handled and the applicator would be exposed to the pesticide. In situations such as this, it is necessary to hold the plants until the chemical has lost its toxicity. Information on this interval can be found on the pesticide label.

Persistence is an important part of pest control. Successful pest control requires knowledge of the chemical's persistence. For example, herbicides used for preemergence weed control in turf persist for 60–90 days, and postemergence herbicides last from 1–2 days to 3–4 weeks, depending upon the specific herbicide involved.

Persistence can be an advantage to the applicator for long-term control of the pest. The use of a chemical to control *Pythium* (cottony blight) in turf or root rot in chrysanthemums is a situation in which pesticide persistence is desired. However, problems can develop when applications are made too frequently, which raises the level of the chemical in the soil to potentially phytotoxic levels.

Pesticide incompatibility

When two or more pesticides cannot be used in combination, they are said to be incompatible. Chemicals may be incompatible because they will not mix or because they do not produce the desired results. In some cases mixing two chemicals together may produce a third chemical with unknown or undesirable properties. Incompatibility may result in misapplications, excessive residue or runoff, or phytotoxicity. Applicators should refer to a compatibility chart if they are unsure.

NOTES . . .

Formulation

Pesticides may be purchased in many forms, e.g., dusts, granules, wettable powders, concentrates, and fumigants. Dusts usually are not very phytotoxic, and they may cake or become ineffective if they become moist during storage. Liquid concentrates may cause plant injury under certain weather conditions because of the solvents they contain. However, because only a small amount is normally needed to make an effective spray, they are often used. Wettable powders generally are less phytotoxic than concentrates, but they may leave unsightly residues, a disadvantage when marketing potted plants. Granules are only applied to the soil or potting media. They may cause “burn” to foliage if misapplied. Many highly toxic pesticides are formulated as granules to reduce the hazard associated with their application. Most oil solutions should not be used on actively growing plants because the oil will kill living tissues. “Summer oils” are sometimes used against sucking insects. Fumigants are generally of limited value on ornamentals. However, they may be used to treat ornamentals for export.

Application

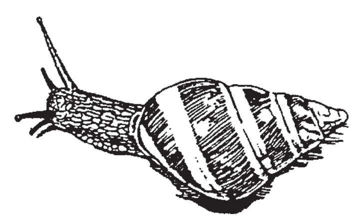
In general, pesticides should be applied during cooler parts of the day. Plants are less likely to be injured when protected by at least broken shade as opposed to being in direct sun. It is a good practice to irrigate ornamental plants 1–2 days before applying pesticides. Some materials injure plants when there is a shortage of moisture. If possible, spray plants in the early morning so the foliage will be dry before it is in full sun. Be sure to check the manufacturer’s label for plants that may be injured by the pesticide. Do not exceed the manufacturer’s recommended rate or frequency. If you are unsure if the pesticide will cause injury, spray a few plants and wait a suitable period of time (7–10 days, usually) do observe development of phytotoxicity. The period of time necessary will depend on several factors, the most important of which are the plant and the pesticide. Frequent calibration of equipment is absolutely essential to good pest control. Do not apply insecticides or fungicides with equipment previously used to apply herbicides.

Snails and slugs

Snails and slugs are not insects but are mentioned here because they often become pests in lawns and landscapes. They damage some plants by feeding on leaves, and they attack the surface roots of orchids. Aside from their economic importance, some freshwater snails are intermediate hosts of blood flukes, *Schistosoma* species, that cause schistosomiasis in humans and livestocks.

Snails and slugs are members of an animal group called mollusks (class Gastropoda). Snails are soft animals whose bodies are protected by a hard, coiled shell. Slugs are snail-like but lack the hard shell.

Several terrestrial snail species are native to Hawaii. They are mostly found in pristine habitats and do very little damage. Alien species such as the giant African snail and the predatory *Achatinella* species are very serious economic pests. The latter is even suspected to be a factor in the extinction of the native species. Introduction of snail species is under rigid quarantine.



Snail

Garden slug

Giant African snail

Description and biology

The calcium shells of snails are a simple spiral or helix. Snails have an air-breathing lung opened by a contractile pore. They are either bisexual or hermaphroditic (capable of changing sex). They reproduce by laying eggs.

Snails and slugs are found almost everywhere. They prefer sheltered habitats, adequate moisture, an abundant food supply, and—for snails—a source of lime. Snails are more adaptable than slugs to unfavorable environmental conditions. Because of their shell, snails are able to survive in fairly dry conditions. Some types are not as secretive as others, aestivating in hot seasons above ground on objects such as tree trunks, fence posts, and signposts,

Managing land snails and slugs

It is costly and sometimes impractical to manage introduced snail and slug species. However, it is possible to reduce their population and spread. Management methods include physical, cultural, biological, and chemical controls.

Physical management involves searching for the pests and handpicking and destroying them. Avoid moving equipment, plants, and other material from an area known to be snail-infested to a noninfested area. Store snail-free supplies in well maintained storage areas.

Cultural management of snails and slugs can involve destroying their habitats. Clear underbrush and eliminate refuse piles, loose boards, and stones. Maintain grass and weed regularly to reduce the amount of food and limit their increase. Cultivate the soil of infested areas to destroy snails and their eggs. Heavily infested areas may have to be burned to kill snails.

Biological management is usually the deliberate introduction of predators or parasites. These introductions must be evaluated and approved by appropriate government agencies. Once the pest species has been successfully reduced, the introduced predator may prey on nontarget native species. Severe reduction or extinction of certain native species has been attributed to introduced predators. The risk of introducing a predator may actually be far greater than the intended benefit. For example, the introduction of *Achatinella*, a predatory snail, to control the giant African snail in Hawaii resulted in the reduction and possible extinction of some endemic Hawaiian terrestrial snails.

Chemical control options for slugs and snails include contact sprays, paints, irritating powders, poison baits, and repellents. Because snails must have lime to build their shells, applicators can paint or spray objects with a pesticide mixed with limewater as a lure. Some sprays are registered, but few effectively eliminate snails. Pesticides specific for snails and slugs are called molluscicides.

Repellents can be effective against snails and slugs. Frequency of their application depends on soil conditions, rainfall, and pest numbers. Protective barriers of soot, ash, lime, salt, and other substances can keep snails and slugs away from valuable plants. These materials should be used with caution because they may kill vegetation or degrade the soil.

Baits can often reduce snail and slug populations. Baits should be applied when the pests are active and feeding. Generally, baits are most effective in areas where vegetation is scant.

Terms To Know

Note: Definitions are given in a context that relates specifically to turf and ornamental pest management.

Abiotic—nonliving factors, such as wind, water, temperature, fertilizers, or soil type and texture.

Action threshold—the level of pest infestation at which control practices are justified.

Adsorption—the binding of a pesticide to surfaces of soil particles or organic matter in such a manner that the pesticide is slowly available.

Algicide—a chemical used to kill algae.

Annuals—plants that complete its life cycle in one year, i.e., germinates from seed, produces seed, and dies in the same season.

APHIS—Animal and Plant Health Inspection Service.

***Bacillus thuringiensis* (BT)**—a microbial pesticide used to control insect larvae.

Bactericide—any chemical used to kill bacteria.

Bacterium (plural: **bacteria**)—a unicellular, microscopic organism that lives in soil, water, organic matter or the bodies of plants and animals. Some bacteria cause plant or animal diseases.

Bait—food or foodlike substance used to attract and often poison pest animals.

Biennial—a plant that completes its life cycle in two years; the first year to produce leaves and store food, the second year to produce fruits and seeds.

Biological control—the action of parasites, predators, pathogens, or competitors in maintaining another organism's density at a lower average than would occur in their absence. Biological control may occur naturally in the field or be the result of human manipulation or introduction of biological control agents.

Biotic—pertaining to living organisms.

Blight—a disease characterized by general and rapid killing of leaves, flowers, and stems.

Broadleaf weeds—weeds that have broad, rounded or flattened leaves as opposed to narrow, bladelike leaves of grasses and sedges.

Chlorosis—yellowing of normally green tissue due to chlorophyll destruction or failure of chlorophyll formation.

Cotyledon—the first leaf or pair of leaves of a sprouted seed.

Crawler—the immature, active-moving stage of scale insects.

Dicot (dicotyledon)—a flowering plant that has two-seed leaf or cotyledons, the broadleaf plants.

Disease—a condition, caused by biotic or abiotic factors that impairs some or all of the normal functions of a living organism.

Environment—all of our physical, chemical, and biological surroundings such as climate, soil, water, and air and all species of plants, animals, and microorganisms.

Formulation—a mixture of active ingredients combined during manufacture with inert materials.

Fungus (plural: **fungi**)—uni- and multicellular living organisms which cause rot, mold and disease.

Fungicide—a pesticide used for the control of fungi.

Grass—a plant with bladelike leaves, parallel-veined leaves and round jointed stems, flowers on spikelets; a monocot.

Grubs—larvae of certain beetles, wasps, bees and ants.

Herbaceous—characteristic of a plant that is herblike, usually having little or no woody tissue.

Herbicide—a chemical compound used to kill or inhibit growth of weeds or unwanted plants.

Hermaphrodite—an organism with both male and female reproductive organs.

Honeydew—liquid discharged from the cornicles of some Homoptera, especially aphids; scale insects also discharge honeydew fed on by ants.

Hyphae—threadlike structures which make up the mycelium or vegetative body of a fungus.

Hypocotyl—the part of the stem of a seedling below the cotyledons or seed-leaf.

Infectious agent—the pathogen (e.g., bacteria) that causes the disease.

Integrated pest management (IPM)—a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health and environmental risks (Hawaii Department of Agriculture definition).

Insecticide—a pesticide used to kill insects. Some insecticides are also labeled for control of ticks, mites, spiders, and other arthropods.

Label—all printed material attached to or on a pesticide container.

Molluscicide—a compound used to kill snails and slugs.

Mollusks—an invertebrate animal group composed of snails and slugs.

Monitoring—a periodic system of keeping track of and checking up on weed growth and distribution.

Monocot (monocotyledon)—a plant with a single cotyledon or one leaf seed which include grasses.

Mycelium (plural, **mycelia**)—the vegetative part of a fungus; made of a mass or network of threadlike tubes.

Native—refers to plants and animals found only in one geographic area (e.g., native to Hawaii, native to the South Pacific).

Nematicide—a chemical compound or physical agent that kills or inhibits nematodes.

Nematodes—microscopic, wormlike animals that live as saprophytes in water or soil, or as parasites of plants and animals.

Node—a joint in a stem, where buds and leaves grow.

Nonselective herbicide—a herbicide that can be used to kill plants, generally without regard to species.

Nontarget organism—any organism other than the pest organism at which the pesticide is directed.

Nymph—the young of insects with gradual metamorphosis.

Right-of-way—an area or site involved in common transport such as highways and roads, bikeways, airports, electric utilities (including transformer stations and substations), pipelines (including pumping stations), water reservoirs, and parking lots.

Pathogen—a microorganism (e.g., fungus) that causes a disease.

Parasite—a plant or animal that derives all its nutrients from another organism.

Perennials—plants that continue to live from year to year. These plants are either herbaceous or woody.

Persistence—a measure of how long a pesticide remains in an active form at the application site or in the environment.

Pest—any organism that competes with people for food, fiber, or space; presents a threat to the health of people or domestic animals; or interferes with human activity (e.g., plants that obstruct a right-of-way).

Pesticide—any substance or mixture of substances, including biological control agents that may prevent, destroy, repel, or mitigate pests and are specifically labeled for use by the U.S. Environmental Protection Agency (EPA).

pH—a measure of the acidity or alkalinity of a solution, pH values below 7.0 indicate acidity; above 7.0 indicate alkalinity.

Pheromone—chemicals produced by insects and other animals to communicate with and influence the behavior of other animals of the same species.

Phytotoxicity—injury to plants due to exposure to a chemical.

Postemergence herbicide—a herbicide applied to a specified weed or crop after its emergence.

Predators—an insect or animal which attacks, feeds on, and kills other insects or animals.

Preemergence herbicide—a herbicide applied prior to emergence of a specific weed or crop.

Preplant herbicide—a herbicide applied prior to planting a crop.

Pupa—in insect development, pupa is the resting stage between larva (caterpillar or maggot) and adult.

Repellent—a chemical that is annoying to an organism, causing it to avoid a treated site.

Rhizome—an underground rooting structure of certain plant species.

Rosette—a cluster of closely arranged, radiating leaves at or close to the ground.

Scouting—checking a crop on a regular basis and in a prescribed manner to determine pest population levels and the extent of pest damage.

Sclerotia (singlular, **sclerotium**)—a hardened part of a fungus used for food storage; a black or reddish brown mass of threads; helps the fungus remain dormant for long periods.

Sedges—plants with solid stems, often triangular with three edges; leaves are arranged in three rows and leaf sheath is closed around the stem.

Selective herbicide—a herbicide which is effective only against certain species and is able to control unwanted plants without serious injury to desirable species.

Serrated—refers to a leaf with saw-toothed margin.

Spore—an inactive form of a microorganism resistant to destruction and capable of being active again.

Spray drift—the physical movement of a pesticide through air at the time of spray application or soon thereafter, to any site other than that intended for application.

Stolon—an above ground runner or rooting structure found in some plant species.

Susceptible host—a plant or animal that is capable of being injured, diseased, or poisoned by a pesticide, not immune.

Systemic pesticide—a pesticide which is absorbed by the plant and translocated within a plant. Also called translocated pesticide.

Target pest—the pest toward which control measures are being directed.

Translocated herbicide—otherwise called systemic herbicide, absorbed by plant parts and moves through the vascular system to other parts of plant.

Trifoliate—with three leaflets.

Virus—a submicroscopic pathogen that requires living cells for growth and is capable of causing disease in plants or animals. Plant viruses are often spread by insects.

Weed—an unwanted plant.

Wettable powder—a dry pesticide formulation consisting of an active ingredient that will not dissolve in water.

Woody plants—perennial plants that have a thick, tough stem or trunk covered with bark.

Review Questions

These review questions are not certification exam questions but the similar format (e.g, multiple choice, fill-in-the blanks) will help inform you of what to expect in a certification examination. Correct answers are given at the end of the list of questions.

1. Abiotic agents of plant disease ______.
   a. Cause a one-time, sudden change in plant
   b. Are often spread by insects
   c. Cannot be controlled with pesticides
   d. Are not known to occur in Hawaii

2. Many plant-pathogenic ______ can obtain their food from dead plant material.
   a. Fungi
   b. Viruses
   c. Bacteria
   d. All of the above

3. Plant disease management strategies are directed at ______.
   a. Controlling the pathogen directly
   b. Reducing host susceptibility
   c. Manipulating environmental conditions
   d. All of the above

4. ______ is the best method to detect insect problems.
   a. Pheromone trapping
   b. Soil sampling
   c. Irritant sampling
   d. Visual inspection

5. Adult ______have six legs and one pair of antennae.
   a. Insects
   b. Mites
   c. Spiders
   d. All of the above

6. A ______ looks like a miniature copy of the adult insect.
   a. Larva
   b. Nymph
   c. Pupa
   d. None of these

7. Cutworms and grasshoppers are pests with ______ mouthparts.
   a. Sucking
   b. Chewing
   c. Piercing-sucking
   d. Sponging-sucking

8. Insects that transmit disease-causing pathogens to plants or animals ______.
   a. Are called "hosts"
   b. Do so only in the larval stage
   c. Usually have piercing-sucking mouthparts
   d. All of the above

9. Some viruses may be spread by ______.
   a. Insects
   b. Infected seed
   c. Soil fungi
   d. All of the above

10. A plant's susceptibility to a pathogen ______.
   a. Does not change as the plant matures
   b. Depends solely on its genetics
   c. Tends to increase under nutrient stress
   d. Is unaffected by weather conditions

11. Symptoms of a plant disease caused by a pathogen ______.
   a. Tend to appear on all plants in a field at the same time
   b. Do not change over time
   c. Will be the same on each variety of crops
   d. May be confused with those caused by abiotic factors

12. Annual weeds are often a problem because ______.
   a. Few herbicides are effective against them
   b. Seeds can germinate years after they were produced
   c. They spread vegetatively
   d. None of these

13. Crop rotation is an effective weed management tool ______.
   a. Provided you can use the same herbicides in each crop
   b. Especially if the crops have different life cycles or growth habits
   c. But only for winter annuals
   d. In vegetable, but not grain crops

14. You generally need to apply soil herbicides at higher rates on finer soils because:
   a. Weed pressure is typically higher
   b. More pesticide is likely to be lost through leaching
   c. Clay adsorbs herbicides
   d. Soil incorporation is less effective

15. A postemergence contact herbicide:
   a. Is applied before weeds germinate
   b. Must be translocated in the plant to be effective
   c. Causes injury to any part of the weed it touches
   d. Is applied before the crop germinates

Answers: 1 c, 2 a, 3 a, 4 d, 5 a, 6 b, 7 b, 8 c, 9 d, 10 c, 11 d, 12 b, 13 b, 14 c, 15 c

Some Conversions for Pesticide Applicators

Length

1 mi	=	1760 yd	=	5280 ft	=	1609.3 m	=	1.6 km
1 yard	=	3 ft	=	36 in	=	91.44 cm	=	0.9144 m
1 foot	=	12 in	=	30.48 cm	=	0.3048 m		
1 in	=	2.54 cm						
1 km	=	1000 m	=	3280.8 ft	=	1093.6 yd	=	0.621 mi
1 m	=	100 cm	=	39.37 in	=	3.28 ft	=	1.09 yd
1 cm	=	0.39 in						

cm = centimeter(s); **ft** = foot (feet); **in** = inch(es); **km** = kilometer(s); **m** = meter(s); **mi** = mile(s); **yd** = yard(s)

Area

1 acre	=	4840 sq yd	=	43,560 sq ft	=	4046.9 sq m	=	0.40469 ha
1 hectare	=	10,000 sq m	=	107,639.1 sq ft	=	11,959.9 sq yd	=	2.471acres

ha = hectare(s); **sq ft** = square foot (feet); **sq m** = square meter(s); **sq yd** = square yard(s)

Volume

1 U.S. gal	=	4 qt	=	8 pt	=	16 c	=	128 fl oz	=	256 tbsp	=	768 tsp	=	3785.3 ml or cc		
		1 qt	=	2 pt	=	4 c	=	32 fl oz	=	64 tbsp	=	192 tsp	=	~ 946 ml or cc		
				1 pt	=	2 c	=	16 fl oz	=	32 tbsp	=	96 tsp	=	~ 473 ml or cc		
						1 c	=	8 fl oz	=	16 tbsp	=	48 tsp	=	~ 237 ml or cc		
								1 fl oz	=	2 tbsp	=	6 tsp	=	~ 30 ml or cc		
										1 tbsp	=	3 tsp	=	~ 15 ml or cc		
												1 tsp	=	~ 5 ml or cc		

1 liter	=	1000 ml or cc	=	0.264 gal	=	1.06 qt	=	2.11 pt
1 liter	=	4.23 c	=	33.81 fl oz	=	67.6 tbsp	=	202.9 tsp
1 liter	=	1 qt	+	1 fl oz	+	1 tbsp	+	~ 2 tsp

cc = cubic centimeter(s); **fl oz** = fluid ounce(s); **ml** = milliliter(s); **pt** = pint(s); **qt** = quart(s);
gal = gallon(s); **c** = cup(s); **tbsp** = tablespoon(s); **tsp** = teaspoon(s)

Weight

1 lb	=	16 oz	=	453.59 g	=	0.454 kg
1 oz	=	28.35 g				
1 kg	=	35.27 oz	=	2.2046 lb		

g = gram(s); **kg** = kilogram(s); **lb** = pound(s); **oz** = ounce(s)

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