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

Rights-of-Way Weed Control

A Guide for Commercial Pesticide Applicators

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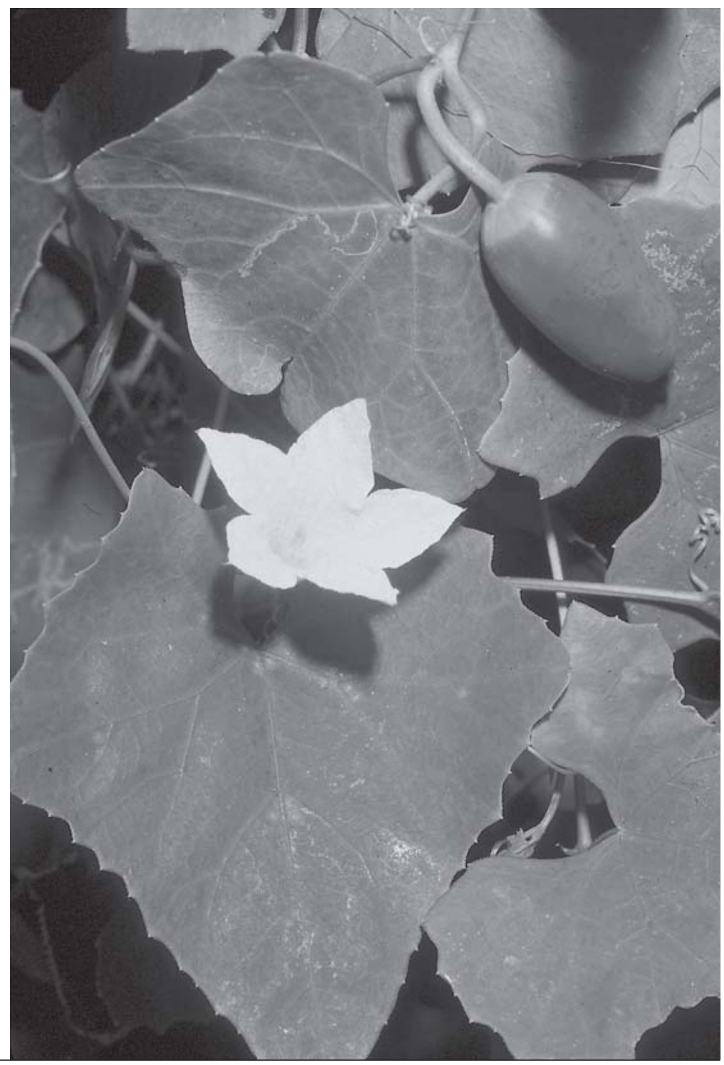

Pesticide Risk Reduction Education
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Cover photo of ivy gourd, *Coccinea grandis*, a serious weed pest in Hawaii, is from *Wayside Plants of the Islands* by Art Whistler; copyright Isle Botanica, Honolulu, Hawaii; used with permission.

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Rights-of-Way Weed Control

A Guide for Commercial Pesticide Applicators

Foreword and Acknowledgment

This publication contains basic information to help you meet the standards of the Hawaii Department of Agriculture and the Environmental Protection Agency for pesticide certification and to engage in rights-of-way weed 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.

We sincerely thank Dr. Phil S. Motooka, CTAHR Department of Natural Resources and Environmental Management, for his assistance.

Portions of this publication were adapted from Chapter 24 of the Military Pest Management Training Manual. Additional materials were adapted sections from other manuals and publications, which are thankfully acknowledged:

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.

Environmental Protection Agency, EPA 735F99024. Spray drift of pesticides.

Fech, J.C. Why herbicides fail. *Turf West*, August 2000, pp. B2–B7.

Marer, P.J., M. Grimes and R. Cromwell. 1995. Forest and right-of way pest control. Publication 3336, University of California.

Nagamine, C. Pesticide drift, Parts I–III. *The Pesticide Label*, July–December 1999, January–July 2000. College of Tropical Agriculture and Human Resources, University of Hawaii

Wixted, D., C. Boerboom, R. Flashinski and J. Wedberg. 1998. Training manual for the private pesticide applicator, 4th edition. University of Wisconsin.

Wood, M. 2000. Curbing pests in Hawaii's ornamental paradise, *Agricultural Research*. Agricultural Research Service, USDA, pp. 4–7.

Learning Objectives

After studying this publication on rights-of-way weed control, the vegetation manager should be able to:

- Recognize sensitive areas and organisms affected by herbicide applications, drift, and run-off
- Distinguish between annual, biennial, and perennial weeds
- Define the effectiveness and limits of cultural and mechanical management practices for weeds
- Differentiate among preplant, preemergence, and postemergence herbicide applications
- Explain the effects of soil texture, organic matter, and pH on herbicide activity
- Distinguish between grasses, sedges, and broadleaf plants
- Explain why stage of growth affects weed management
- Develop a vegetation management plan for nutsedge, goosegrass, and other common weeds
- Explain nonchemical and chemical management methods for aquatic weeds.

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.

NOTES . . .

Table of Contents

Rights-of-Way Weed Control

A Guide for Commercial Pesticide Applicators

Hawaii has some of the most beautiful scenery in the world. Residents and tourists alike reach our scenic lookouts, beaches, resorts, and other destinations in vehicles, by bicycle, and on foot. All of these destinations and all of our businesses and homes are connected by hundreds of miles of streets, highways, roads, and trails. For both safety and aesthetic reasons, it is important to maintain these rights-of-way free of obstructions.

Importance of good rights-of-way management

Most rights-of-way have been maintained with herbicides, but concern has been expressed in many communities and in the legislature that improper application has resulted in contamination of streams, soil erosion, and herbicide drift to adjacent homes or farms. Perhaps more importantly, schoolchildren walking barefoot along recently sprayed roads and highways may be exposed to herbicide residues. Clearly, this is a concern that needs to be taken seriously, because a legislative ban on herbicide use could lead to dependence on more costly weed management efforts, more injuries to rights-of-way workers, and a reduction in drivers' visibility. Such a ban could, ironically, lead to a loss of walking space for schoolchildren and their increased exposure to highway traffic.

Rights-of-way are the areas involved in common transport; they include highways and roads, bikeways, airports, electric utilities (including transformer stations and substations), pipelines and pumping stations, water reservoirs, parking lots, and public paths and trails. The goal of vegetation management is to ensure that rights-of-way are safe, usable, attractive, inexpensive to maintain, and not harmful to the environment. By following a well planned maintenance program, this goal can be achieved in a safe, efficient, and economical manner. A well planned maintenance program also supports a "good neighbor" policy. Controlling noxious weeds reduces allergy-causing pollen and the spread of seeds onto private property.

Rights-of-way management practices include cultural, mechanical, and biological controls as well as careful use of pesticides, particularly herbicides. The optimal control methods are often referred to as "best management practices" (BMPs). The management methods selected will be determined by the pest, the environment, and funding. The goal of vegetation management plans is to integrate BMPs into a long-range, low-cost maintenance plan. One of the purposes of this publication is to help you understand how to develop appropriate rights-of-way maintenance plans and carry them out effectively.

Herbicide applicators must be aware of the impact their activities have on the environment. Some results are expected and easily seen, such as dry, brown leaves following applications. Other consequences such as groundwater contamination are more serious, but for applicators these cannot be seen or go unnoticed. Government regulations may restrict certain herbicide uses to minimize unsightly "brownout" and protect natural resources. Use of herbicides is closely controlled because of their potential for adversely affecting human health, groundwater, nontarget plants, and animals.

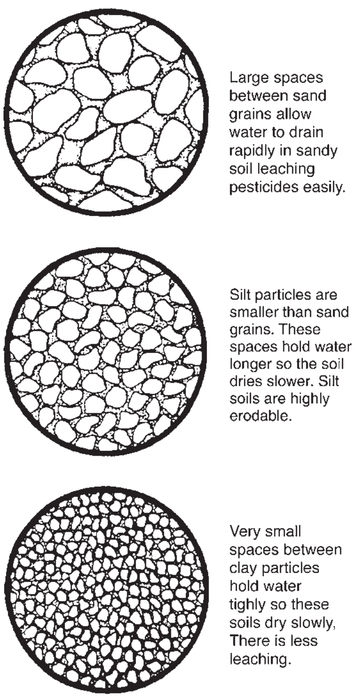
Vegetation Management Plans

Successful vegetation management begins with stating specific, reasonable goals. Applicators should understand the growth requirements of both desirable plants and weeds. All available control methods must be identified in order to select methods that minimize risks to workers, nontarget organisms, and natural resources. A good vegetation management program is designed with equal consideration of economics, effectiveness, the environment, and public relations. Long-range planning can greatly reduce cost. Sustained funding is needed to provide reliable support for successful maintenance programs. Infrequent or poorly planned maintenance plans can cost up to 10 times more than properly developed long-range plans. For example, letting a minor vegetation problem develop into a severe one can require extensive herbicide use, special equipment, and increased labor.

A good management plan provides equal consideration of economics, effectiveness, the environment, and public relations.

Levels of maintenance

The goal of some rights-of-way maintenance plans may call for total elimination of vegetation, for example, in parking lots, airport runways, and electrical transformer sites. The location of these sites influences the methods that can be used. For example, special care must be used near residential areas to protect desirable vegetation from damage by pesticide drift or runoff. In such areas, nonchemical control methods may be preferred. Other rights-of-way maintenance plans may call for weed management only if the vegetation poses a threat to public safety (for example, if it blocks views at highway or street intersections).



Soil types and leaching

Environmental concerns

Environmental factors must be considered when developing vegetation management plans. Plans should consider rainfall, soil texture, depth to groundwater, surface waters, and presence of threatened or endangered species. These factors influence the types of BMPs that can be used, and they must be given special attention when planning the use of herbicides.

It is important to understand what happens to pesticides after they are applied. Applicators need to know how long before the general public can enter treated areas. Generally, this information is found on the herbicide label. Knowing how persistent (or stable) a herbicide is also helps assess its potential for leaching into groundwater or accumulating in nontarget organisms, including humans.

Herbicides applied to landscapes, around buildings, on golf courses, or along rights-of-way may move off target during or after application. On occasion, these pesticides may contaminate surface waters or groundwater or adversely affect nontarget organisms such as birds, bees, fish, and humans. To avoid an unreasonable level of environmental problems, careful consideration must be given to selection of the herbicide, its formulation, the timing and technique of application, and the equipment used. Weather conditions, particularly wind strength and direction, must be considered before applications are made.

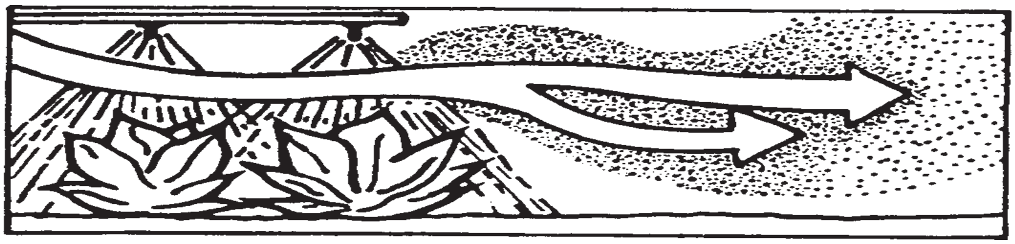
Special consideration is needed for sensitive areas

Local conditions and application techniques

Applicators must be aware of several factors when making herbicide applications in or near sensitive areas such as hospitals, schools, and residential areas where there are children, pets, and other domestic animals, and where desirable plants are also being grown. Past, present, and future conditions and practices affect all phases of a pest management program. These conditions include pest populations and the effectiveness of previous nonchemical and chemical pest management practices. Any vegetation management technique, including herbicide use, can have effects other than intended.

Select management measures that will maximize beneficial effects and minimize harmful ones

The essence of sound vegetation management is to select those management measures that will maximize beneficial effects and minimize harmful ones. To do this, applicators must be aware of the specific environment where operations are conducted. Applicators may want to use a checklist to help assess potential problems. The example in Appendix 1 shows some of the many considerations involved in safely applying pesticides. The goal should be to understand the impact of pesticides in the environment and select those that do not accumulate or persist to the degree that they threaten human health or environmental quality.



Use caution to keep pesticides on target: control spray drift and vapor drift

Drift management

With rights-of-way near sensitive areas such as schools and residential areas, herbicide drift is of major concern if it reaches nontarget areas or if humans, pets, or domestic livestock are exposed.

Pesticide drift is defined as the physical movement of pesticide particles and vapor, blown during or soon after application to any site other than that intended. When pesticide solutions are sprayed, droplets are produced. Many of these droplets are so small that they stay suspended in the air to be carried by wind until they evaporate, contact something, or drop to the ground.

The most common pesticide drift is movement of spray droplets or, in the case of dry formulations, dust particles. Spray drift is directly influenced by the weather conditions, topography, crop or area being sprayed, application equipment and methods, and decisions of the applicator.

Drift of a chemical with low vapor pressure is called vapor drift. Vapors or gases can drift in harmful concentrations, even in the absence of wind. Some pesticide products are volatile or capable of vaporizing from soil and leaf surfaces in potentially harmful concentrations after application. Vapor of some herbicides can severely damage and even kill desirable plants.

Nontarget organisms

Application sites should be cleared of things such as toys, pet food dishes, bird feeders, clothing, and other articles likely to be contacted by people or animals. Herbicide residues on these articles can be a hazard.

People and animals should be kept away from the area during herbicide application. They should also be kept from the area of potential drift and runoff until the spray has dried or the dust has settled. Some pesticides, other than herbicides, are potentially hazardous for a long time. Therefore, label directions concerning reentry to the sprayed area should be followed. The effects of herbicides on nontarget organisms such as fish, birds, and beneficial insects must be considered. Applicators should *read the precautionary statements* on the pesticide label before applying the product.

Keep people and animals away from application areas

NOTES . . .

Careful implementation of vegetation management plans will . . .

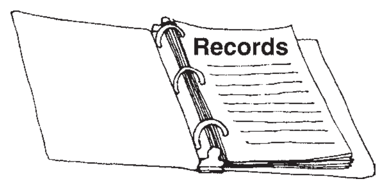
- reduce application errors
- reduce maintenance cost
- reduce risk of legal action
- reduce risk of regulatory action
- reduce operational interruptions
- reduce erosion
- reduce water pollution
- improve public relations
- more effectively utilize equipment and labor
- increase safety to workers
- improve cost planning.

Recordkeeping

Avoid liability—keep detailed records

Records provide valuable information for the applicator. Keeping complete and accurate records is the best way to evaluate previous activity, improve future control measures, and to maintain accurate information in case of lawsuits or regulatory actions. Such records may include

- areas treated and date
- pesticide amount, concentration, and time applied
- environmental conditions
- equipment and crew
- evaluation of effectiveness
- problems encountered
- damage claims.



Plant Basics

The key to good control is to know the weed

A comprehensive, long-range vegetation management plan requires a basic knowledge of plant morphology and an understanding of how plants grow and reproduce. Understanding how environmental factors affect plant growth is also helpful in selecting BMPs.

Weeds are plants growing out of place. In rights-of-way they may be a safety hazard, a nuisance, or unsightly. They may impede the use and maintenance of the right-of-way, cause injury to man or animals, crowd out desired plants, or damage structures such as road surfaces. Many weeds have been legally declared “noxious.”

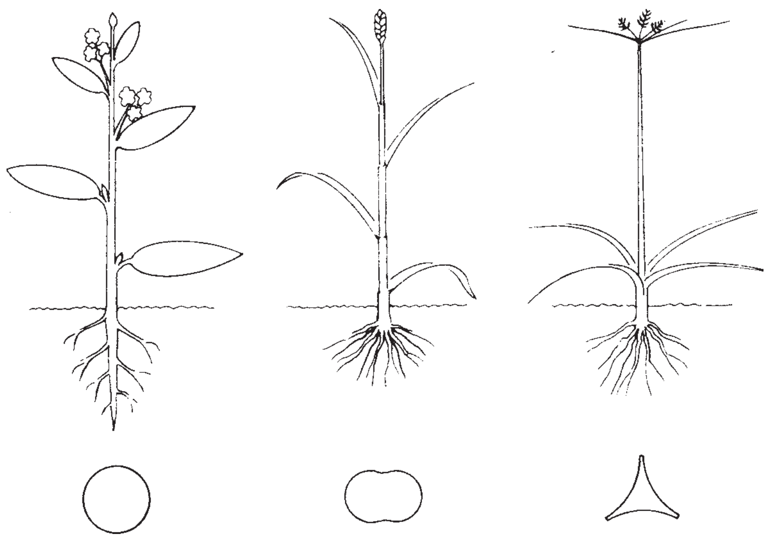
Weeds succeed because they are superior competitors. Their success may be due to persistent or aggressive root systems (e.g., banyan trees, purple nutsedge), resistance to herbicides, or because they produce many seeds (e.g., ragweeds).

Plant classification based on morphology

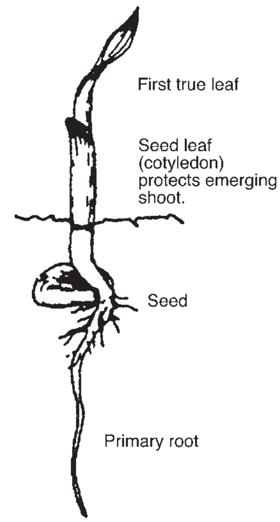
For the purposes of weed control, plants may be classified as grass, sedge, broadleaf, or woody.

Grasses

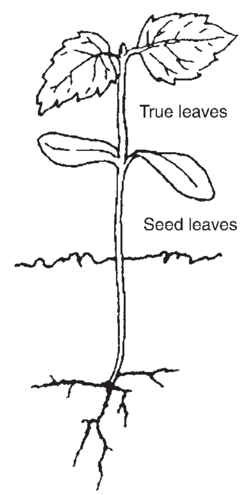
Grass seedlings start with one leaf coming from the seed (thus the broad plant category monocotyledon, or “monocots”). Grass leaves are generally narrow and upright with parallel veins. Grasses have round stems that are hollow between nodes. Each leaf consists of a sheath surrounding the stem and a blade; leaves are arranged along the stem in two rows, one on each side. Many grasses have fibrous, dense, compact root systems.



Broadleaf **Grass** **Sedge**



Monocot seedling



Dicot seedling

Sedges

Sedges resemble grasses, but their stems are solid and often triangular, with no obvious joints. The leaf sheath closes around the stem, and the leaves are arranged in three rows. Sedges are often associated with wetlands.

Broadleaf plants

Broadleaf plant seedlings have two leaves (thus the category dicotyledon, or "dicots"). They generally have broad leaves with veins in a branching pattern, but some have narrow leaves with less obvious venation. They have taproots and coarse, extensive root systems. The flowering reproductive phase of growth may not occur until late in the life cycle of the plant. Most broadleaf plants are considered undesirable in a right-of-way, but some low-growing legumes are tolerable because they enhance soil fertility by fixing nitrogen.

Woody plants

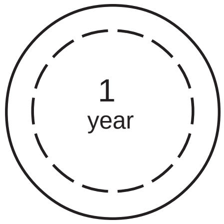
Plants with woody stems include brush, shrubs, and trees. Brush plants and shrubs have several stems and are less than 10 ft tall. When trees are present, brush or shrubs are considered the "understory." Trees usually have a single stem (trunk) and are over 10 ft tall.

Plant classification based on life cycle

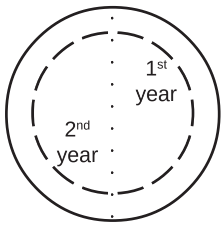
Plants may also be classified by their life cycle: annual, biennial, or perennial. Understanding plant life cycles helps in determining the best time to use particular management techniques—or, whether management is even necessary.

Annuals

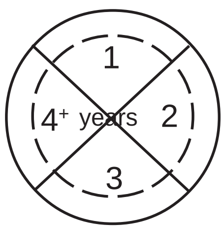
An annual plant germinates from seed, reaches full growth, and produces seed within a year. Most annuals in Hawaii are "summer annuals." Plants classified as annuals in temperate areas may grow throughout the year in Hawaii because of insufficient cold to kill them in the fall. Examples of annuals are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



Annuals



Biennials



Perennials

Biennials

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

Perennials

Perennial plants live more than two years. They usually have an extensive root system, which helps them overwinter in temperate areas. They may be grasses or broadleaf plants, herbaceous or woody, and their form may be forb, vine, shrub, or tree.

Perennials may germinate from seed but often they can also reproduce and spread using vegetative structures such as tubers, rhizomes, and stolons, which contain stored food. When these organs are present, the perennial seedling is generally harder to control. Two examples are purple nutsedge and Johnson grass.

Woody perennials have persistent stems above ground. The most obvious members of this group are trees, shrubs, and woody vines. Control methods for woody perennials are often timed to the yearly growth cycle.

Some Important Weeds in Hawaii

Rights-of-way herbicide applicators should be able to recognize common weeds found in Hawaii. Indiscriminate spraying and incorrect identification can result in application mistakes. Such mistakes might have minor consequences, but they could lead to regulatory action.

It is impossible to include all weedy plants in this publication. 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.

Crabgrass (*Digitaria*)

Crabgrass

Crabgrasses (*Digitaria* species) include both annuals and perennials. They are easily recognized by their seed heads, which consist of several slender spikes that spread out like fingers. Young seedlings have erect stems. Stems of the mature plant bend at the nodes, which gives crabgrass a spreading, messy look.

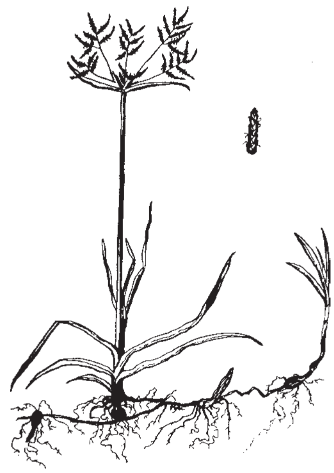
The large crabgrass (*D. sanguinalis*) has dense, hairy leaves and branching stems that root at the nodes. Smooth crabgrass (*D. ischaemum*) lacks hair on the leaves and does not root at the nodes. Several other species of *Digitaria* are established in Hawaii*: D. violascens*, *D. pruriens*, and *D.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

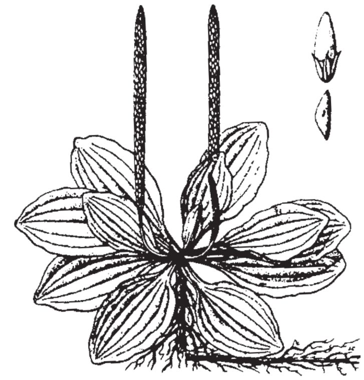
Foxtail

Foxtails (*Setaria* species) are annual grasses. Their upright stems reach over 1 foot and are topped by dense seed heads 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 animal fur.

Bristly foxtail


Goosegrass


Purple nutsedge


Broadleaf plantain

Goosegrass

Eleusine indica, also called wiregrass, is an annual weed that thrives in full sun and disturbed soil. The stems, leaf blades, and seed heads lie flat on the ground in a rosette pattern. It can tolerate close mowing. The flower heads have 2–6 flattened, fingerlike branches. This grass is widely distributed in Hawaii. It is a problem weed in cultivated areas, lawns, pastures, and unused places.

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Nutsedge

The *Cyperus* species are aggressive weeds that spread by underground, nutlike tubers, hence the name nutsedge, or the misnomer, nutgrass. The leaves are attached at the base of single fruiting stems. Several seed clusters on stalks of different lengths arise from bracts, leafy structures at the base of the fruiting stems. The bracts may or may not look like leaves.

The decision to control nutsedge will depend on the severity of the weed problem and soil moisture conditions. Yellow nutsedge (*C. esculentus*) is native to North America and is probably an accidental introduction to the Hawaiian Islands. Another *Cyperus* species established in Hawaii is purple nutsedge, *C. rotundus*.

Broadleaf plantain

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

Bull thistle

Cirsium vulgare can be a major problem along rights-of-way. The leaves are deeply indented, dark green on top and paler on the lower surface, and each lobe is spine-tipped. The plant parts are all spiny (“armed”). The flower heads are large, rosy purple, and few.

Ivy gourd

Coccinea grandis is abundant in the lowlands. It climbs over fences, low vegetation, and even into tall trees, often entirely smothering 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 it to other areas.

Ivy gourd

Spiny amaranth

Amaranthus spinosus is an annual herb that is a troublesome weed in pastures, cultivated areas, and disturbed lowland places such as roadsides and abandoned land. It has an erect, stout stem with alternate leaves. At the base of each leaf is a pair of sharp spines and small, shiny, dark brown seeds. The long, sharp spines protect them from livestock. This plant is a prolific seeder and crowds out other plants.

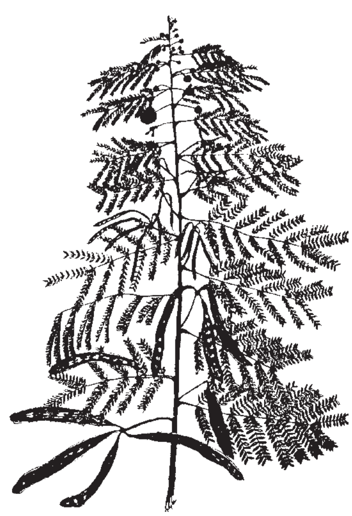
Haole koa

Leucaena leucocephala is a shrub or upright tree 10–30 feet high, common in both dry and moist areas of Hawaii. It grows from sea level to 2600 feet elevation. It is thornless, with alternate, bipinnate-compound leaves, white “puff-ball” flower heads, and clusters of brown, strap-shaped pods. While it is useful for some purposes, such as fodder for ruminant animals, it is an aggressive colonizer of rights-of-way and other disturbed areas.

Spiny amaranth

Beggar’s tick

The *Bidens* species (*B. alba* and *B. pilosa*), also known as Spanish needle, are widespread in the tropics and subtropics. Beggar’s tick is one of the most abundant weeds in Hawaii, a serious pest of disturbed roadsides, lawns, abandoned plantations, and cultivated areas. It grows from sea level to 3900 feet elevation. Beggar’s tick spreads by means of barbed fruits that adhere to clothing, feathers, and fur and can also be dispersed by water. Beggar’s tick has opposite leaves that are simple or trifoliate, with serrated edges. The leaves are covered with many whitish hairs. The flower head is yellow.



Haole koa

Beggar’s tick

Vegetation Management

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Vegetation management practices can be grouped in two basic categories: nonchemical and chemical. Nonchemical methods include cultural controls, mechanical controls, and biological controls. Weed management is often most successful when it involves all of these methods in an integrated approach.

Nonchemical practices

Cultural controls

Plants cannot grow without adequate sunlight. Placing a barrier over the ground to exclude light inhibits weed growth. Weed-control barriers include mulches of organic materials such as wood chips and inorganic materials such as crushed coral or gravel. Asphalt and cement can be considered weed-control barriers. The depth of mulch material needed to successfully prevent weed growth depends on its ability to block out light. Placing a layer of heavy plastic beneath any weed-control barrier provides better control. Even when cracks develop or mulches decompose or erode, the plastic layer will continue to control weeds.

Mechanical controls

Hand pulling or mechanically cutting weeds are expensive control methods in terms of time and labor. Use of motorized mowers and hand-held cutters also exposes operators to hazards such as highway traffic, broken bottles, stones, and other debris. However, the advantages of these weed control methods in terms of fire safety, appearance, and drainage often justify their use.

Many woody plants can be managed by cutting once each year. Unless treated with herbicide, woody perennial species will regrow, making annual cutting necessary. Herbicide applications made in conjunction with mechanical control methods must be properly timed for best results.

Biological control

Biological weed control involves the use of other living organisms such as insects, diseases, and parasitic plants. An example of biological weed control is the moth borer from Argentina used to destroy prickly pear cactus in Hawaii and Australia. Currently, the Hawaii Department of Agriculture is testing insects to control ivy gourd (*Coccinea grandis*) in urban and forest areas.

Chemical control

Many chemical control methods are available. Several factors should be considered when deciding which is best. Goals, funding limitations, proximity to sensitive areas, types of weeds, and stage of weed growth influence the choice of herbicide. It is also necessary to understand how various herbicides kill weeds, how to handle them safely, and what hazards they present. This understanding allows applicators to select products that provide the desired control while limiting health risks to themselves and others.

*Herbicide—
a pesticide used for killing plants or inhibiting their growth*

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

NOTES . . .

and whether it is an annual, biennial, or perennial. Most selective herbicides will state on their label what they are intended to control (for example, “for control of broadleaf weeds,” or “for control of perennial grasses”). An example of a selective herbicide is MCPA, which is used to control broadleaf weeds but leaves grasses unaffected. Some selective herbicides can be “nonselective” and kill untargeted plants when improperly applied at levels in excess of those specified on the product label.

Nonselective herbicides

Nonselective herbicides kill vegetation without regard to type or species. Paraquat, glyphosate, dinoseb, and bromacil are examples of nonselective herbicides. Nonselective herbicides may be “selective” when applied at low rates, in that they will kill sensitive plants but leave other plants only damaged, stunted, or unaffected, depending on the plant and the application rate. In general, application of a herbicide at rates other than those specified on the label may constitute a misuse of the product and may result in reduced efficacy.

Modes of herbicidal action

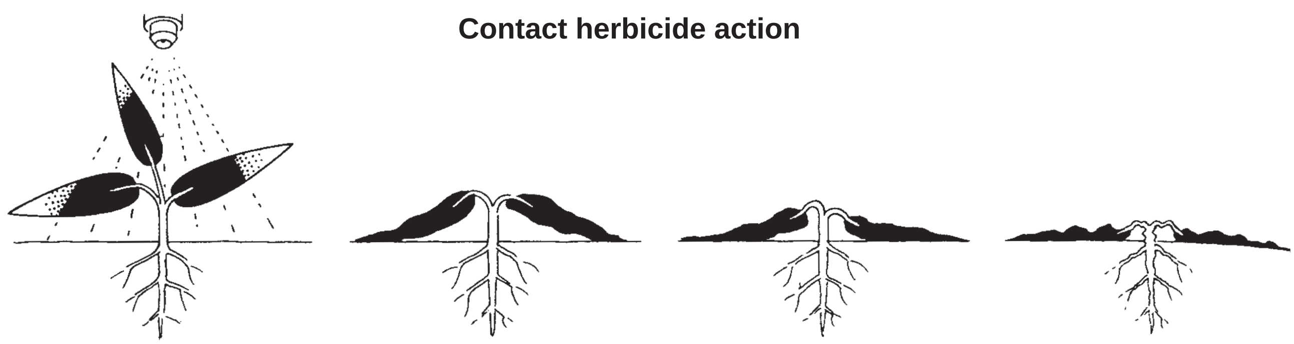
Modes of herbicide action: contact, translocation, growth regulation

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

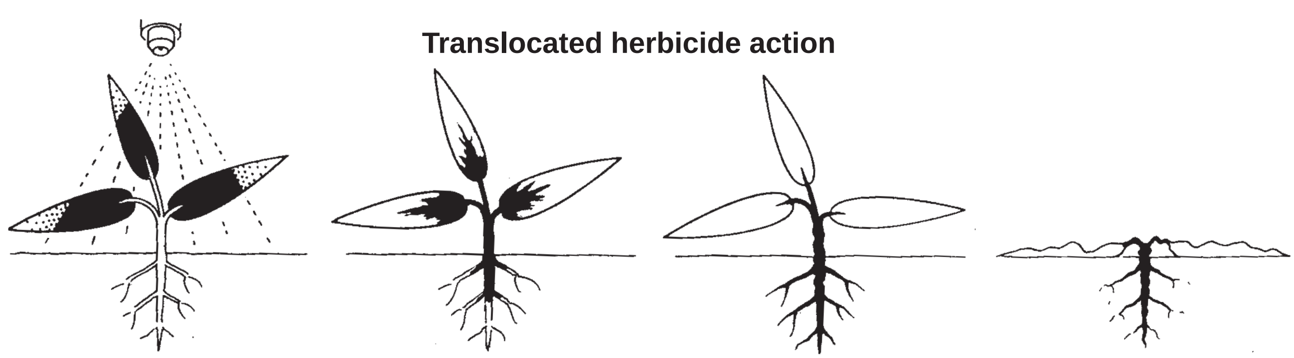
Contact herbicides

Contact herbicides kill only the plant tissues they are applied to. 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.

Contact herbicide action

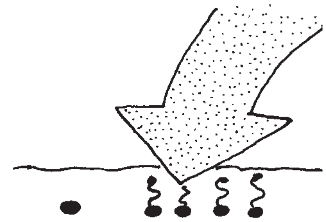


Translocated herbicide action



As a result, pesticide applicators can expect new growth to occur soon after they apply a contact herbicide to a perennial plant. Scythe® is one of the most commonly used contact herbicides.

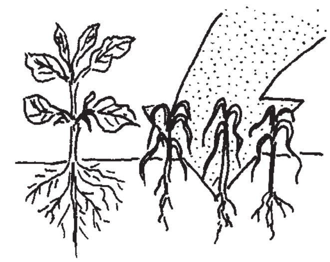
Soil sterilants also act as contact herbicides by making treated soil incapable of supporting plant life (as opposed to other life forms, such as fungi, bacteria, and other microorganisms, which soil sterilants do not necessarily kill). Toxic effects may remain for only a short time or for years, depending on the product and dose.



Preemergence

Translocated herbicides

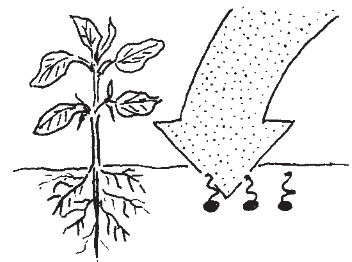
Translocated herbicides, also referred to as systemic herbicides, are absorbed by the leaves, stems, or roots and move through the plant's vascular system to other tissues such as leaves, buds, and root tips. When absorbed by leaves and stems, the herbicide is commonly moved with food materials synthesized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



Postemergence

Plant growth regulators

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.



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 germination of weed seeds. Postemergence herbicides control actively growing weeds. Most postemergence herbicides only remain active in the soil for a short period of time, and repeated applications are usually required. Preplant herbicides are incorporated into the soil prior to planting crop seeds. However, some herbicides are pre- and postemergence; e.g., tebuthiuron.

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

Herbicide longevity

Herbicides vary in their rate of disappearance from the soil because of volatility, susceptibility to decomposition by soil microorganisms, temperature, and solubility. For example, some carbamate insecticides are volatile at high temperatures and rapidly lose their toxic effect during the summer months. Certain soil microorganisms effectively decompose the herbicide 2,4-D. Some water-soluble herbicides are readily leached from the soil. Others are tightly bound to soil particles and are subject to runoff in soil erosion.

Lateral movement

Caution must be exercised in use of herbicides on slopes, sandy soils, and soils that may be subject to erosion. All soil-active herbicides can move laterally, causing destruction of the vegetation contacted. In sloping areas, only selective herbicides should be used, as loss of all vegetation will lead to soil erosion.

Read the label

Factors Affecting Chemical Management

Plant growth stages respond differently to chemical control

Grasses and broadleaf weeds go through four stages of growth:
- seedling
- vegetative
- flowering (reproduction)
- maturity.

Seedling (all plants affected)
In respect to control strategy, the seedling stage of growth is the same for all types of weeds. Because seedlings are small and tender, less effort is required for control at this stage of growth than at any other. This is true whether nonchemical or chemical control is used. Herbicides with either foliar contact or residual soil activity are usually very effective against seedlings.

NOTES . . .

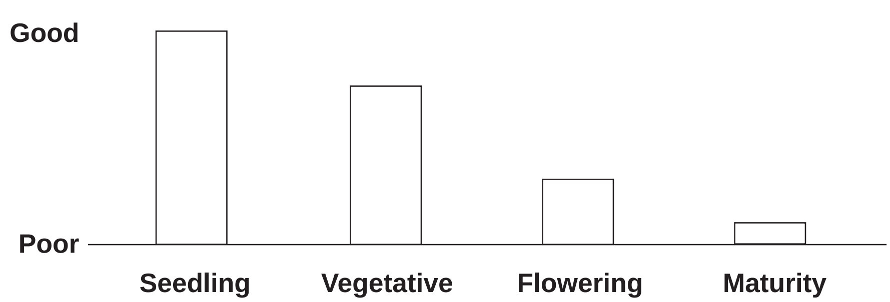
Vegetative—annuals
During the vegetative stage of growth, energy produced by the plant goes into the production of stems, leaves, and roots. Control at this stage is still possible but sometimes more difficult than at the seedling stage. Cultivation, mowing, and postemergence herbicides are effective controls.

Vegetative—perennials
When the plant is small, part of the energy used to produce stems and leaves comes from underground roots and stems. As the plant grows, more energy is produced in the plant's leaves. Some of this is moved to the underground parts for growth and storage. Translocated herbicides provide some control at this stage.

Flowering—annuals
When a plant changes from the vegetative to the flowering stage of growth, most of its energy goes into the production of seed. As plants reach this mature stage, they usually are much harder to control by either mechanical or chemical methods than at earlier growth stages.

Flowering—perennials
At this stage the plant's energy goes into the production of flowers and seeds. Food storage in the roots begins during these stages and continues through maturity. Chemical control is more effective at the flower-bud stage, just before flowering.

Control of annual weeds by the stage at which herbicide is applied



Maturity—annuals

Maturity and seed set complete the life cycle of annuals. Chemical control is usually not effective at this stage, because there is little or no movement of materials in the plant. Once the seeds are mature, mechanical and chemical controls are ineffective.

Maturity—perennials

Mature perennial plants are more difficult to control, in some cases because of their size. Only the above-ground parts are affected when they are sprayed with contact herbicide—the underground roots and stems remain alive and send up new plant growth. Control with translocated herbicide is less effective when mature perennials are not in a growth flush.

Woody plants go through the same four growth stages as other perennial plants. They do not die back to the ground but may lose their foliage during cooler months. Woody plants can be controlled with herbicides at any time, but control is easiest when the plants are small. Foliar treatments can be used at any time woody plants are actively producing leaves. They usually work best when the leaves are young.

Perennial weeds that have regrown after being controlled by chemical or mechanical methods should be treated on a regular basis. Herbicides reach underground plant parts through the natural translocation activities of the plant from leaves to underground storage parts. Underground growth must be killed to control these weeds.

NOTES . . .

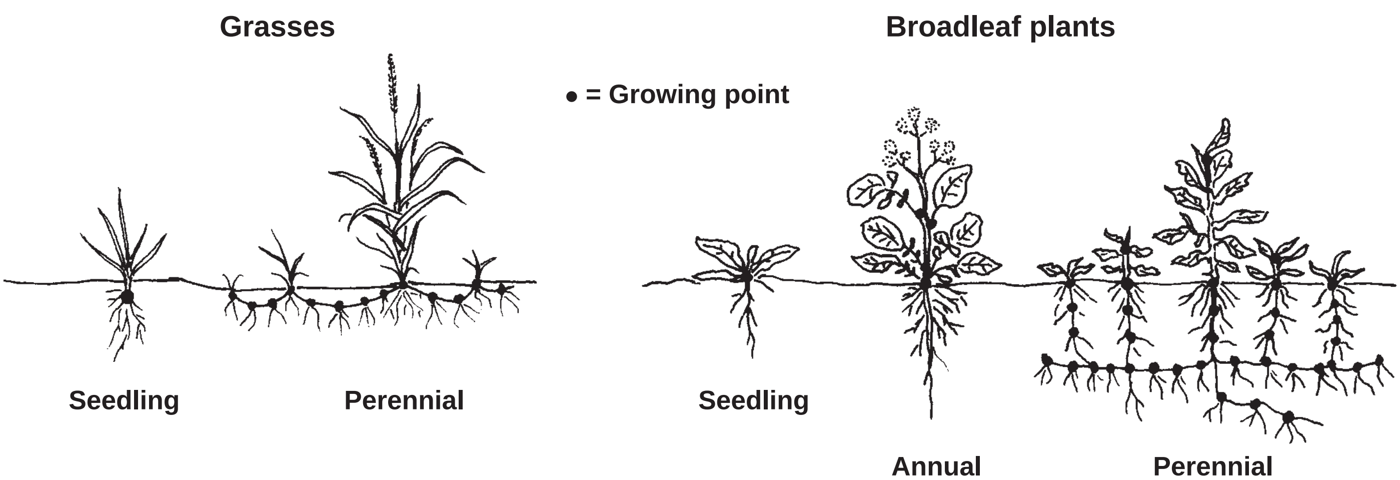
Factors Affecting the Effectiveness of Foliar Herbicide Applications

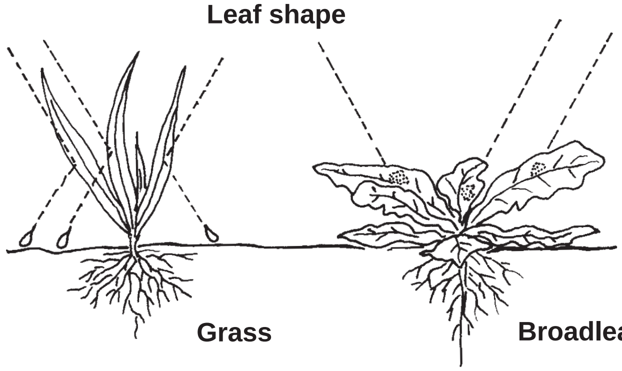
Location of growth points

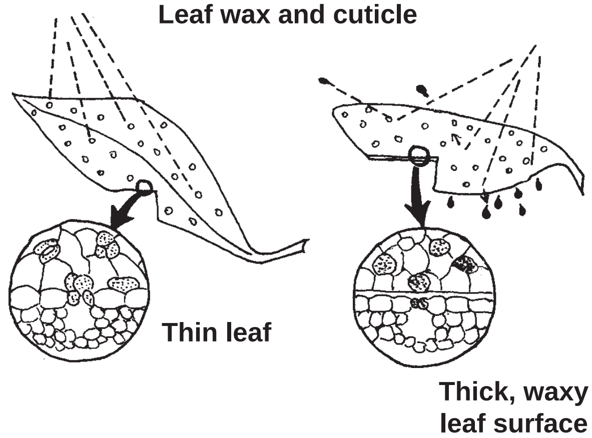
The growing point of seedling grasses is protected below the soil surface. The plants will grow back if a herbicide or cultivation does not reach the growing point. Creeping perennial grasses have buds below the soil surface.

Seedling broadleaf weeds have an exposed growing point at the top of the young plant. They also have growing points in the leaf axils. Herbicides and cultivation can reach these points easily. Established perennial broadleaf plants are hard to control because of the many buds on the creeping roots and stems.

Many woody plants, either cut or uncut, will sprout from the stem base or roots.





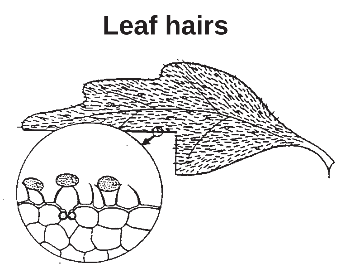


Leaf shape

Leaf shape influences the ease of control with herbicide sprays, which tend to bounce or run off plants with narrow, vertical leaves, whereas broadleaf plants tend to hold the spray. Adjuvants may be added to increase spray adhesion and retention if the label allows.

Leaf wax and cuticle

The thickness of leaf wax and cuticle affect the penetration of herbicides. A thin cuticle allows good contact of the spray solution with the leaf surface. On a leaf with a thick, waxy surface, the spray solution tends to bead up in droplets. The wax and cuticle are thinner on young weeds—a good reason for applying herbicides at earlier growth stages.



Leaf hairs

Like wax, hairs on the leaf surface also tend to keep spray droplets from contacting sensitive leaf tissues. Seedlings usually have fewer and shorter hairs, another reason for early control.

Plant size

Seedlings, being small and tender, are easier to control than established weeds.

Species

Species vary in growth habit and susceptibility to herbicides. In some cases this is due to the plant characteristics listed above. In other cases, it is related to the plant's ability to metabolize (break down) the herbicide.

Precipitation

Rainfall occurring soon after a foliar herbicide treatment may wash it off, decreasing its effectiveness.

Humidity

A foliar herbicide will enter the leaf more easily and rapidly at high humidity than at low humidity. At high humidity, the leaf is tender and has a thinner layer of wax and cuticle.

Temperature

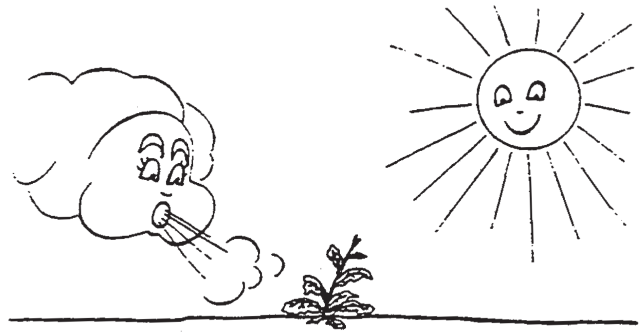
Temperature may affect the amount of time required for the herbicide to do its job. As the temperature increases, the herbicide may work more quickly. However, when the temperature is 90°F or above, even selective herbicides may cause leaf burn to sensitive, nontargeted plants.

Wind and temperature

Wind and temperature can also affect the weed. A hot, dry wind will cause

- the openings on the plant surface to close
- the leaf surface to become thicker
- the wax layer to harden.

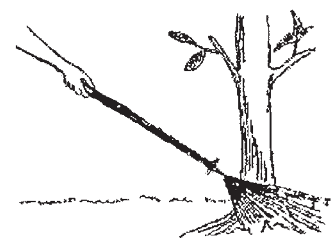
These factors make it harder for herbicides to penetrate the leaves.



Woody Plant Control

Controlling woody plants, whether shrubs, vines, or trees, presents a challenge to vegetation managers. All woody plants have extensive, persistent root systems, and many of them can resprout from their roots. Successful management programs combine mechanical and chemical methods to remove woody plants and prevent their regrowth. It is cheaper to manage woody species at early stages of their growth than later when they are large.

To control individual woody plants, the basal bark application method is to apply spray with an oil carrier to the lower 12–24 inches of the stem and allow run-off to drench the root collar area. To control either individual plants or groups of plants, foliar application is often faster and less labor-intensive than the basal bark method. Applications are more effective while the plants are growing actively.



Factors Affecting Soil-Applied Herbicides

Persistence

The persistence of n herbicide in the soil depends on the product's characteristics and rate of application, the soil's texture and organic matter content, the weather (precipitation and temperature), and the terrain as it affects surface flow. The herbicide effect can be lost when it

- remains concentrated at the soil surface
- partially leaches (diluting it)
- is flushed downward through the soil in a band, allowing new weeds to grow above.

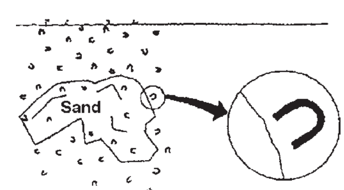
Three factors affect the movement of herbicide applied to soil:

- soil texture—how much sand, silt, and clay it contains
- soil organic matter level
- slope.

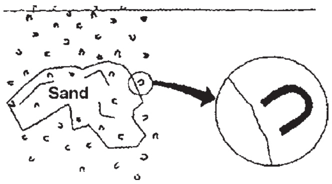
Texture

Herbicides are best retained by soils that have good "charge" characteristics—the ability to attract and hold chemical ions on the surfaces of the soil's particles.

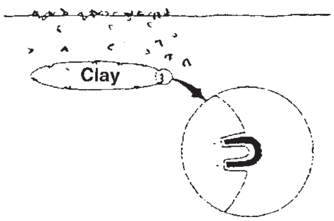
Sand has coarse particles and few charge sites. The drawing at right illustrates a magnified sand particle in the soil. Herbicide ions, depicted as magnet-shaped objects, are moving down through the soil. The magnified circle shows the herbicide ion moving past the sand surface. Because of the low chemical charge of the sand, the herbicide is not attracted to the sand particle.



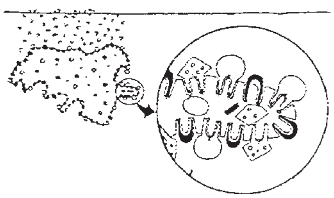
Sand



Clay



Organic matter



Clay particles are very fine compared to sand. Clay, therefore, has a large amount of surface area with many charge sites. The drawing shows a magnified clay particle. The positively charged herbicide ion fits into the negatively charged slots on the clay particle. The ion is thus “tied up” and will not continue moving through the soil.

Silt has more charge sites than sand but fewer than clay and organic matter.

Organic matter

Organic matter has many more negative charge sites than even the finest soil particles. The magnified drawing shows not only herbicide ions tied up on the organic matter but also other materials such as water and ions of sodium, calcium, and ammonium.

Soil moisture

Herbicides that are applied to the soil for uptake by plant roots must be applied to moist soil to be readily absorbed by the plants. This requires water in the form of rainfall (or irrigation, in agricultural situations). But too much rain may move the herbicide too deep, past the root zone. A hard rain may wash surface soil and herbicide away from the target area. This is especially true when the site is sloping or the soil surface is packed.

Factors Affecting Herbicide Application Failures

The most frequent reported cause of a herbicide application failure is the environment, either too much rain after an application or not enough moisture following an application of a herbicide that must be watered into the soil in order to be activated. One of the following factors or a combination of factors could be responsible when herbicide applications do not meet expectations (see box, below). Knowing what caused the failure can help applicators take necessary steps to prevent future problems.

Aside from *READING THE LABEL* first, applicators must follow guidelines for the the dilution, agitation, size of mesh screen, and timing of the application.

Causes of herbicide application failure

- *incorrect identification of the weed*
- *ineffective herbicide due to:*
  photo-decomposition
  volatilization
  leaching
  adsorption
  microbial degradation
  temperature
  late stage of weed development
- *improper timing of application*
- *spray drift*
- *application error*
- *residual effectiveness of product*
- *thickness of plant cuticle*
- *poor equipment calibration*
- *unsuitable cultural practices*
- *bad choice of herbicide*

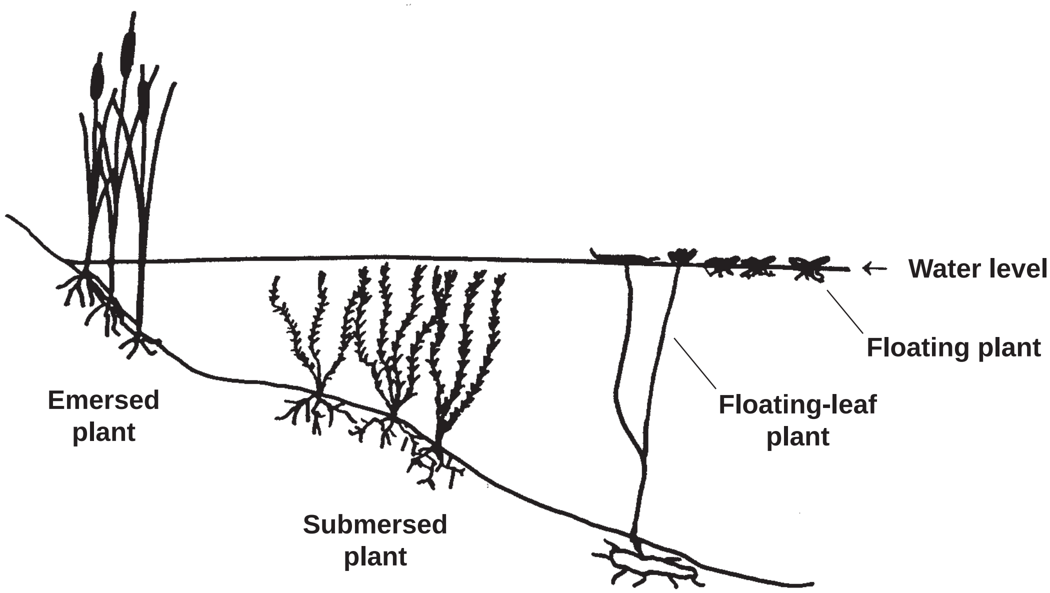
Managing Aquatic Weeds

NOTES . . .

Aquatic weeds do not pose a big problem in Hawaii. If they occur in water reservoirs they are mostly localized, and mechanical control measures can often be used. If a herbicide is used, applicators are responsible for verifying that the site of intended application (e.g., reservoirs, canals, or wetlands) is listed on the product's label. The information that follows is brief and intended to provide only an overview of the subject. Applicators should consult the Hawaii Department of Land and Natural Resources for more specific information on managing aquatic weeds, and the Department of Health regarding the need for discharge permits.

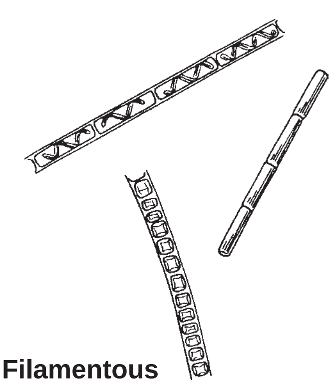
Nonvascular plants (e.g., algae) and vascular plants (e.g., water hyacinth) found in channels, ponds, water reservoirs, and lakes may physically interfere with recreation, navigation, and water distribution systems. Drinking water obtained from these sources may have an unpleasant taste or odor.

Correct pest identification is essential for managing aquatic weeds. The major groups of aquatic weeds are algae, ferns, and flowering plants. Aquatic plants may also be described according to their growth habits. *Submersed plants* grow completely below the water surface and depend on the surrounding water for support of the plant body. *Emersed* plants are rooted in the bottom but extend above the water surface and are self-supporting. *Floating plants* are not attached to the bottom and float on the water surface. *Floating-leaf plants* are attached to the bottom but have leaves that float on the surface. These plants may or may not be self-supporting and can be emersed.

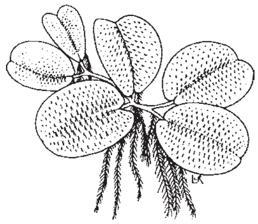


Algae

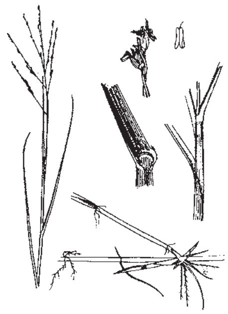
Algae are single- or multi-celled plants that lack supporting or conducting tissues. Algae are identified based on their life cycles, pigments, and growth form. Planktonic algae are single-celled and live in small colonies attached to each other. They are free-floating or suspended in the water. Filamentous algae are multicellular and are attached to each other end-to-end to form long chains. The two most important algae found in fresh water are the filamentous green algae and bluegreen algae.



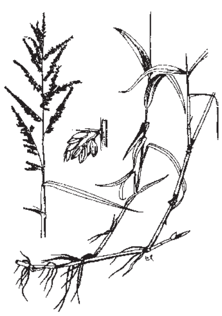
Filamentous algae



Water fern

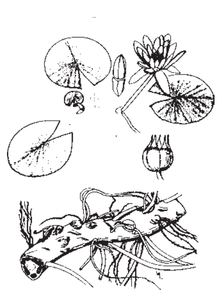


Torpedograss



Paragrass

Water hyacinth



Waterlily

Ferns

Although most ferns are terrestrial, there are a few aquatic ferns. They have supporting or conducting tissues and reproduce from spores. Examples of aquatic ferns are mosquito fern (*Azolla* species) and water fern.

Flowering plants

Aquatic flowering plants include both monocots (grasses and sedges) and dicots (broadleaf plants). Several important pest species are described below.

Torpedograss (*Panicum repens*) is an emersed, perennial grass that grows from extensive rhizomes (underground stems). The tips of the rhizomes are pointed, hard, and glossy-white. Its leaves are rolled and have fine hairs on the upper surface. The seedheads are branched sharply upwards, and the flowers are attached individually along the branches.

Paragrass (*Brachiaria mutica*) often forms stems that recline and root at the nodes. Its leaves are flat and have very fine hairs on the upper leaf surface. It can be identified by the presence of dense hairs that occur at the nodes and stiff hairs that occur along the collar or where the leaf sheath joins the leaf blades.

Water hyacinth (*Eichhornia crassipes*) is a floating plant. Mature plants are about 1–3 feet tall. When growing under uncrowded conditions, the leaf stalks are usually swollen, filled with spongy tissue, and act as floats. Its flowers are in spikes and are light blue to violet with showy yellow marking on the uppermost petal.

American eelgrass (*Vallisneria americana*) is a submersed weed with ribbonlike leaves that show definite veins and some crossveins but no veins visible at the margins. The veins are not raised and the leaf tips are blunt with few teeth on the margins. This grass produces rhizomes.

Nonchemical control of aquatic weeds

Pond and ditch design

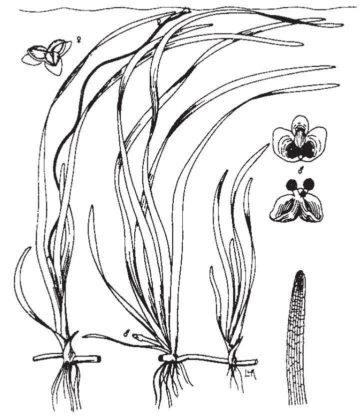
Proper design and construction of ponds is an important factor in preventing weeds. Shallow water at the margins of ponds provides an ideal habitat for seeds in water. Submersed weeds can easily become established there and then spread into deeper water. Banks should be sloped steeply so that there is very little water less than 2–3 feet deep. Lining canals can also help alleviate aquatic weed problems.

Mechanical control

Water in fishponds, drinking water reservoirs, or livestock watering ponds usually cannot be treated with pesticides. Weed-control personnel may want to consider using draglines to clean canals, reservoirs, and lake margins. Weed mowers may be used to cut weeds loose beneath the water surface. The weeds must then be collected and removed. Just chopping weeds can result in a greater problem if the weed is a type that can reproduce from the pieces. Mechanical control is usually slower and more costly than other methods.

Draining and drying

Some ponds, canals, and ditches can be drained so aquatic weeds dry up. Partial draining to expose weeds may be sufficient to kill certain species in shallow areas. However, it may require several months to adequately dry some ponds and lakes. Impacts on resident fish and birds must be considered before the decision to drain is made.



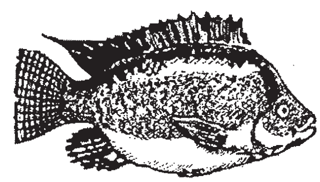
American eelgrass

Fertilization

The use of inorganic nutrients may stimulate growth of microscopic algae, which shades the bottom, preventing or reducing the growth of weeds. This method is more effective in deep water than in shallow water. If not done properly, the weed problem could become even more severe. Also, applications of fertilizer to some bodies of water may be in violation of the Clean Water Act.

Biological control

Biological control of aquatic weeds generally involves the use of plant-eating fish or insects. Tilapia can be used successfully if water temperatures remain relatively warm. Insects have been used with varying success to control water hyacinth. Although initial costs related to the introduction of biocontrol agents may be high, such introductions may be very cost-effective over the long run. Local governments strictly regulate the introduction of biocontrol agents because too many biocontrol agents have themselves become pests. Consult the Hawaii Department of Agriculture regarding use of biocontrol agents.



Tilapia

Chemical control of aquatic weeds

Describing specific herbicides to control aquatic weeds is beyond the scope of this publication. Applicators should consult the Hawaii Department of Land and Natural Resources, the Hawaii Department of Agriculture, or the University of Hawaii College of Tropical Agriculture and Human Resources for information needed to implement an aquatic pest management program. In general, before using herbicides or algicides applicators must be familiar with the following topics.

Formulations

Each herbicide formulation has advantages and disadvantages in various aquatic environments. Sprayed formulations may be effective in still or slow moving water. Some are sprayed directly on floating or immersed weeds or allowed to disperse evenly to contact underwater surfaces of weeds. Some granular formulations are intended to act as slow-release herbicides to give control of submersed weeds over an extended period of time.

Special cautions apply to herbicide applications in or near bodies of water

Application techniques

The application method selected will depend on the zone of water treated. The four zones are (1) surface, (2) total water volume, (3) bottom 1–3-foot layer of water, and (4) bottom soil surface. The selection of application technique will depend on the availability of equipment (aircraft, boats, application systems), water volume and characteristics (static, flowing), whether the pest is floating or submersed, and availability of herbicides or algicides approved for use. Just as important, the applicator must be trained in each technique.

Calculations

Two types of calculations must be made: water volume and amount of pesticide to use. Water volume calculations must take into consideration the surface area, depth, flow rate, and recharge. Calculations of total chemical needed differ for each of the four zones described above. When using herbicides or algicides in an aquatic environment, as in any other situation, applicators are advised to read the entire label to learn all relevant directions, precautions, and restrictions applying to the intended use.

Terms To Know

Note: Definitions are given in a context that relates to rights-of-way weed management only.

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

Algicide—a chemical used to kill algae.

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

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. Biennial plants are uncommon in Hawaii.

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.

BMP—Best management practices

Broadleaf weeds—weeds that have broad, rounded leaves as opposed to narrow, bladelike leaves of grasses and sedges (although some broadleaves have narrow leaves with less obvious venation).

Buffer zone—a "no spray" zone between the area to be treated and a nearby sensitive area. Because of its location, it would receive overspray or drift that would otherwise get into the sensitive area.

Degradation—the breakdown of a herbicide into simpler compounds by the action of microbes, water, air, sunlight, or other agents.

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

Diluent—any liquid or solid material serving to dilute an active ingredient in the preparation of a herbicide formulation.

Endangered species—plant or animal species of specific areas and so designated in the Federal Register as an endangered species.

Environment—all of our physical, chemical, and biological surroundings such as climate, soil, water, and air and all species of plants, animals, and microorganisms, and the interrelationships which exist among them.

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

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

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

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

Inert material—a material added to a formulation to improve the mixing and handling qualities of a herbicide.

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).

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

Labeling—the herbicide product label and other accompanying materials that contain directions herbicide users are legally required to follow, which may be manuals, leaflets or brochures issued by the manufacturers.

Leaching—the downward movement of a herbicide or other soluble material through the soil as a result of water movement.

Ligule—a thin, membranous outgrowth from the base of the leaf of most grasses.

Monocot (monocotyledon)—a plant with a single cotyledon or one seed leaf, e.g., grasses, usually with parallel leaf veins and fibrous roots.

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

Nontarget organism—any organism other than the weed organism at which the herbicide is directed.

Noxious weed—any plant species which is, or which may likely become injurious, harmful, or deleterious to agriculture, horticulture, aquaculture, the livestock industry, forest and recreational areas and conservation districts of the state of Hawaii, as determined and designated by the Department of Agriculture from time to time.

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

Persistence—a measure of how long a herbicide remains in an active form at the site of application 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 such 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.

Plant growth regulators (PGRs)—a substance that alters the normal growth and /or reproduction of a plant.

Postemergence application—application of a herbicide after the weeds or crops have emerged.

Postplant application—application of herbicide after planting a crop.

Precautionary statement—a pesticide label statement on hazards of a particular pesticide to humans and wildlife if not used as directed on the label.

Preemergence application—application of a herbicide to the soil before weeds or crops emerge.

Preplant application—application of a herbicide prior to planting a crop.

Rhizome—an underground rooting structure of certain plant species.

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.

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

Runoff—movement of pesticide away from the release site in water or other liquid flowing horizontally across the surface.

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

Selective herbicide—herbicides that kill or interrupt normal growth of particular plants and have little effect on others.

Sensitive areas—areas such as hospitals, schools, parks, streams and lakes that are vulnerable to harmful effects from pesticides.

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

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

Statement of Practical Treatment—pesticide label statement on first aid measures to help a pesticide exposure victim while waiting for medical help.

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

Systemic pesticide—a pesticide that is absorbed by and translocated within a plant or animal; also called translocated pesticide.

Taproot—the primary root from which smaller roots grow, usually stout and tapering.

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.

Tuber—a short thickened part, usually an enlarged end of an underground stem.

Vapor drift—the movement of vapors of a volatile chemical from the area of application.

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 on the next page.

1. Monocots ______.
   a. Have leaf veins in a netlike pattern
   b. Usually have taproots
   c. Have growing point typically at or below the soil surface
   d. Have 2 seed leaves

2. Mowing may not be fully effective in controlling perennial weeds because ______.
   a. It may not kill all the growing points
   b. Weeds in the rosette stage will not be harmed
   c. The weeds may re-sprout from the underground vegetative structures
   d. All of the above

3. The pest to which a pesticide is applied is called a ______.
   a. Target
   b. Use pattern
   c. Site
   d. Carrier

4. A significant amount of an applied pesticide never reaches the intended site because of misapplication, drift, or ______.
   a. Persistence
   b. Degradation
   c. Volatilization
   d. Leaching

5. ______ increases the likelihood that pesticides will reach groundwater at a given site.
   a. Fractured bedrock
   b. Soil with a high organic matter content
   c. Clay soil
   d. All of the above

6. The goal of vegetation management plans is ______:
   a. Plant new vegetation in rights-of-way
   b. Restrict use of herbicides
   c. Cut down weeds along schools and public properties
   d. Ensure that rights-of-way are safe, attractive, usable, and inexpensive to maintain

7. 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 the above

8. All ______ herbicides are absorbed by and move throughout the plant.
   a. Selective
   b. Nonselective
   c. Contact
   d. Translocated

9. Ivy gourd ______.
   a. Troublesome weed in pastures
   b. Vine suffocates trees, red fruits favored by birds
   c. Barbed fruits adhere to clothing, feathers, or fur
   d. Woody plant

10. BMP stands for ______.
   a. Best Management Practices
   b. Best Management Plans
   c. Best Marketable Pesticides
   d. Better Management Practices

11. A nonselective herbicide may act as a selective herbicide when used at ______ rates.
   a. Low
   b. High
   c. Frequent
   d. Infrequent

12. A foliar-spray of herbicide is more effective when applied ______.
   a. During dry, hot weather when humidity is low
   b. During warm, wet weather when humidity is high
   c. During windy weather
   d. After application of an insecticide

13. Which of the following is not a characteristic of weeds.
   a. Some weeds are noxious and endanger livestock
   b. Weeds interfere with the safety or use of roads, utilities, and waterways
   c. Most weeds produce large quantities of seeds, even under adverse conditions
   d. Weeds enhance the growth of agricultural crops

14. Perennial weeds are generally the most difficult to control because:
   a. They produce more seeds than other types of plants
   b. They can reproduce and spread from storage organs such as rhizomes and tubers
   c. Their seeds remain viable for more years than those of annual and biennial plant
   d. They produce deep taproots that resist mechanical control as well as herbicides

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

Vegetation Management Checklist

- Has the weed been properly identified? Is it a new problem? If yes, why?
- What are the nonchemical vegetable management options? List them. Have these been tried before? Did they work? Do they need to be modified?
- Are herbicides a viable option? Have they been tried before? Did they work? Does their use need to be modified?
- Is the proper application and personal protective equipment available?
- Is there a choice of more than one herbicide? If they are equally effective, which is least toxic? Which will have the least adverse effect on the environment?
- What sensitive areas need to be considered? (Check the following: schools, hospitals, parks, housing, well-heads, streams, lakes, reservoirs, endangered or threatened species, and nontarget organisms such as birds or bees)
- Will weather be a factor? (Check wind speed and direction, inversions, expected rainfall)
- Will other environmental factors affect application effectiveness? (Consider soil type, potential runoff, and depth to groundwater).
- Will applications have to be scheduled based on animal life cycles, nesting, or feeding habits to avoid undesirable effects on wildlife or beneficial insects?
- Is there a choice of formulations or dosage rates that may significantly affect the degree of hazard (e.g., granular formulations are generally less harmful to fish than emulsions or oil solutions, and baits are usually attractive only to the target pest).

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

Some Conversions for Pesticide Applicators

Length

1 mi	=	1760 yd	=	5,280 ft	=	1,609.3 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	=	3,280.8 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	=	4,840 sq yd	=	43,560 sq ft	=	4,046.9 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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