FOREST PEST CONTROL

PESTICIDE APPLICATION
AND
SAFETY TRAINING
STUDY GUIDE

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STUDY GUIDE FOR
FOREST PEST CONTROL

The educational material in this study guide is practical information to prepare you to meet the written test requirements. It doesn't include all the things you need to know about this pest-control subject or your pest-control profession. It will, however, help you prepare for your tests.

Contributors include the Utah Department of Agriculture and Utah State University Extension Service. This study guide is based on a similar one published by the Colorado Department of Agriculture. Materials for that guide were prepared by Colorado State University Extension Service. Other contributors include: University Cooperative Extension Service personnel of California, Kansas, New York, Oregon, Pacific Northwest, Pennsylvania, and Wyoming. The U.S. Department of Agriculture -- Forest Service, the U.S. Environmental Protection Agency (Region VIII Office), and the Department of Interior -- Bureau of Reclamation, and Metro Pest Management.

The information and recommendations contained in this study guide are based on data believed to be correct. However, no endorsement, guarantee or warranty of any kind, expressed or implied, is made with respect to the information contained herein.

Other topics that may be covered in your examinations include First Aid, Personal Protective Equipment (PPE), Protecting the Environment, Pesticide Movement, Groundwater, Endangered Species, Application Methods and Equipment, Equipment Calibration, Insecticide Use, Application, Area Measurements, and Weights and Measures. Information on these topics can be found in the following books:

1. **National Pesticide Applicator Certification Core Manual,** Published by the National Association of State Departments of Agriculture Research Foundation.

2. **The Workers Protection Standard for Agricultural Pesticides – How to Comply: What Employers Need to Know.** U.S. EPA, Revised September 2005, Publication EPA/735-B-05-002.

These books can be obtained from the Utah Department of Agriculture or Utah State University Extension Service. Please contact your local Utah Department of Agriculture field representative or Utah State University extension agent.

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INTRODUCTION

The forest is a fragile environment. Management of it is a major concern to many people, including forest and wildlife managers, lumber companies, recreational-area managers, and homeowners.

Insects and mites are always present in forests. They play a role that is nearly always subtle but at times very turbulent. Insects are known mostly for their destruction, yet their equally beneficial role often goes unnoticed.

A disease is a condition that alters or prevents the normal expected growth and function of the affected trees. A disease may be caused by both non-infectious factors (such as drought, excessive moisture, lack of nutrients, and chemical injuries) and infectious factors (including fungi, bacteria, viruses and nematodes). Growth abnormalities caused by insects, mites and animals are usually considered distinct from "disease," even though symptoms may be similar.

Besides insects and diseases, the third area of concern is the vegetative cover of forests. It directly or indirectly affects productivity, watersheds, wildlife, and the aesthetic values of these resources. The proper management of unwanted vegetation is a major concern of many people involved in forest management.

FOREST INSECT CONTROL

GENERAL OVERVIEW

Dealing with insect pests on plants involves a carefully planned procedure, just as it should be with any other pest problem being considered. You should have some knowledge about the situation, then use this knowledge in the proper sequence to achieve the best results. In general, the procedure for dealing with insect and mite problems is as follows:

EXAMINATION OF THE SITUATION

Know what the normal or healthy condition of the plant looks like. If the plant deviates too far from this condition, look for possible causes.

IDENTIFICATION AND ASSESSMENT

If insects or mites, or conditions apparently caused by them, are found, determine what the pest is and the seriousness of the problem. Not all insects on plants are pests. Some may be incidental visitors and some may be beneficial. On the other hand, some pests may be causing little damage at the moment, but the problem may become serious in a short time. Even if the plant is healthy, it may be vulnerable to attack from pests, and thus it’s important to know which insects or mites are likely to be pests.

PRESCRIPTION

This may involve preventive action, curative action, or no action at all, depending on the identification and assessment of the situation.

Preventive action often involves maintaining tree vigor by proper site selection. The sanitary practices of pruning out dead or unhealthy plant parts and cleaning up ground litter that may harbor pest insects are also helpful.

Other cultural (non-chemical) practices may be useful against some pests. In some cases, insecticides are used to protect plants from becoming infested.

Curative action involves restoring infested plants to a healthy condition. Sometimes natural controls are sufficient to give the plant an advantage to overcome the pest attack.

In other cases, control with pesticides may be necessary. The most common of the points to consider when selecting and using an insecticide or miticide are these:

- Is the use of this pesticide safe to you and others in the situation in which you want to use it?
- Is the pesticide likely to harm the plant you want to protect? If so, under what conditions?
- Will the pesticide also kill beneficial insects or other beneficial animals in this situation?
- Are there clear label directions for using the pesticide for this purpose?
- When is the proper time to use this pesticide for this particular pest?

- How and to what parts of the plant is the pesticide applied?

- Is the pesticide registered with EPA for this use?

No action might be prescribed when the pest isn't a serious one or when the corrective action would give rise to problems more serious than the one at hand. Sometimes a pest may be causing extensive damage, but there are no practical methods of control during this stage of the insect's development. Taking no action might be prescribed until the insect is in a vulnerable stage.

APPLICATION

Knowing what the problem is and what to do about it doesn't solve the problem until you carry out the prescription properly. Some of the common problems are:

- Calibration errors.
- Inadequate coverage of the plant with the spray solution. Plants usually should be thoroughly wetted.
- Tendency of the spray to separate or settle out unless the spray solution is kept agitated. If the spray solution is allowed to settle during spraying, some plants will be overdosed and others under-dosed.
- Improper timing of sprays. If applied too early, the effect of the insecticide may have disappeared by the time the main insect population is present. If the spray is delayed, the insects may have developed to a more resistant stage or may have bored in where the spray can't reach them.
- Adverse effects due to weather conditions. Rains following spraying may wash off the pesticide before it has accomplished its full effects. Temperature extremes may injure the plant, reduce toxicity of the pesticide, increase pest resistance, or volatilize the pesticide.

EVALUATION

Did the prescription work? This should be based on the considerations discussed under prescription.

SIGNS OF INSECT AND MITE PRESENCE

The insect or mite causing damage may not be present or visible when its damage is discovered. However, there may be evidence of its presence. The following are some general signs to look for:

Silk shelters: Made entirely from silk; usually don't enclose foliage, except an occasional leaf. The caterpillars feed outside the shelter and use it only for protection from predators, weather, etc.

Scale and aphid coverings: Most scale and some aphids excrete a protective waxy covering.

Insect and mite remains: Includes egg shells; shed nymphal, larval, and pupal skins; cocoons; frass; and trails of silk.

Honeydew: Sticky liquid sugar excreted by scales and aphids. A black, sooty mold may grow on the honeydew.

Sawdust, wood chips, and pitch balls: Usually found on or below the host plant. Mostly the result of feeding by bark beetles, wood borers, and shoot borers.

FOREST INSECTS AND MITES

There are several kinds of insects and mites that you should recognize. They can be grouped according to the part of the plant they feed on (leaves, twigs, trunks and roots) and the kind of injury they cause (chewing or sucking).

LEAF FEEDERS -- CHEWING INJURY

Defoliators

Defoliators attack leaves in a variety of ways, but all have chewing mouthparts and damage the foliage directly and visibly. There are three basic groups of defoliators, classified according to the type of damage each causes:

1. Leaf chewers feed on and destroy the entire leaf.
2. Leaf skeletonizers feed on the surface and eat only the tissue between the veins, leaving the veins and midribs.
3. Leaf miners feed between the epidermal layers of the leaf.

Although some insects may be leaf miners during one part of their life cycle and leaf chewers later, most usually remain consistent in feeding habits throughout

their life. The majority of defoliators come from the two orders Lepidoptera (butterflies and moths) and Hymenoptera (sawflies, parasitic wasps, ants, wasps and bees), but some members of the Coleoptera (beetles), Orthoptera (grasshoppers, crickets and katydids) and Diptera (flies) are also defoliators.

Defoliation affects trees in a number of ways, but the result is always to reduce or stop growth. A tree can withstand substantial defoliation, but loss of leaves reduces photosynthesis (the source of energy) and interferes with transpiration and transport of nutrients. Unless a very high percentage of the leaf surface is destroyed, the tree will generally survive, but it may be weakened. As a general rule of thumb, if a tree loses more than 60 percent of its foliage for two to three consecutive years, the tree may die or become highly susceptible to other pests.

Deciduous trees and shrubs usually can tolerate considerable defoliation without affecting tree vigor. Evergreens, on the other hand, can be seriously affected by heavy defoliation. This is because evergreens replace only a portion of their total amount of foliage each year. (Pines, for example, replace about one-third, and if the new needles are eaten, the tree will be missing about one-third of its needles for three consecutive years.) Also, evergreens usually use their leaves or needles to produce growth regulators (hormones) and to store food reserves for the next year. If these leaves or needles are eaten, so are sites for growth-regulator production and food storage. New foliage is the most efficient producer of plant food. If this foliage is lost to defoliators, the current year's food production can be reduced considerably.

Generally, late-season defoliation of deciduous trees and shrubs is less important than early-season defoliation because food necessary for growth has been produced and stored. Late-season defoliation of evergreens can be important because of the factors discussed above.

The ultimate effect of defoliation is that it generally weakens the tree, making it much more susceptible to the attack of other insects, especially bark beetles or borers. These beetles usually attack only trees weakened by drought, fire, defoliation or other causes.

Resistance to defoliation depends on a number of factors, including type and species of tree. Hardwoods are relatively resistant and can successfully withstand three or more years of successive defoliation. Such hardiness is attributable to their ability to store large amounts of food and to replace the destroyed tissue almost immediately. Deciduous conifers such as larch are also relatively resistant, whereas evergreen conifers such as fir and spruce are quite easily killed.

The two most common types of leaf-chewing insects are caterpillars and leaf beetles.

TYPES OF CATERPILLARS

BAGWORM (*Thyridopteryx ephemeraeformis)*

Size: Larva 25 to 34mm long; adult 25.4mm wingspan.
Appearance: Larva is a light brown worm with a brown head and thorax. Adult female is a soft, wingless, yellowish-white moth with ring of woolly hairs around rear end. Adult male is a densely hairy, black moth.
Life cycle: One generation per year. Over-winters as pale, whitish eggs that hatch in late spring after trees have leafed out. Young larvae develop and pupate in bags. In the fall, males emerge, fly to the females (still in bags), and mate. Females protrude only their abdomens during mating, then withdraw into the bag, deposit eggs, wriggle out of the bag, drop to ground and die.
Host: Shade trees and ornamental shrubs, especially conifers.
Habits: Larvae feed on needles and spin bags, using foliage, and enlarge them as worms develop and pupate. Eggs are laid and over-winter inside bags. Adults don't feed.
Damage: Heavy infestation defoliates and eventually kills tree.
Control: Several species of flies and wasp-like parasites attack worms, but bags protect larvae and eggs from birds.

DOUGLAS FIR TUSSOCK MOTH
(Orgyia pseudostugata)

Size: Larva 19 to 25mm long; adult female 19 mm long and wingless; adult male 25 to 31 mm long, 25mm wingspan.
Appearance: Mature larvae are gray or light brown caterpillars with brightly colored tooth-brush-like tufts of hair along body; two long brush-like tufts behind shiny black head suggest horns; similar, longer tuft at rear end; many red spots and orange stripes along body.

Adults are dull, brownish-gray moths; females are wingless.
Life cycle: One generation per year. Over-winter as eggs that hatch in early spring as small, hairy caterpillars (larvae) that migrate (often windblown) before settling to feed on new foliage in June. Larvae mature in August, then pupate. Adults emerge in late August, mate; females lay eggs; adults die.
Host: Douglas fir, Colorado blue spruce, and all true firs.
Habits: During feeding, larvae drop from branch to branch on long silken strands, often blown by wind. Pupate in brownish, spindle-shaped cocoons attached to trunk and larger branches. Eggs are laid on top of old cocoons, covered with frothy, white substance mixed with mother's hair. **Eggs are one of the primary identification factors.**

Damage: Larvae defoliate tree, beginning at top and continuing downward. If unchecked, defoliation is rapid, and trees die if defoliated two to three years in a row or succumb to attack by bark beetles.
Control: Tachinid fly larvae live and feed inside caterpillars. The small, wasp-like *Trichogramma minutum* feed on the eggs. Epidemics can be controlled by a viral disease introduced into past populations.

WESTERN SPRUCE BUDWORM
(Choristoneura occidentalis)

Size: Larva 25 to 38mm long; adults l2mm long, 25mm wingspan
Appearance: Mature larva is olive-brown or reddish-brown caterpillar with ivory-colored splotches and tan or light chestnut-brown head and collar. Adult moths have gray-brown or orange-brown fore-wings that are somewhat mottled, with a white dot on the margin. Eggs are oval, light green, and about 1.2mm long.
Life cycle: One generation per year. Over-winter as young larvae that begin feeding on needles in the spring, then move to swelling buds. After destroying budding foliage, they move back to feed on old needles. Larvae mature 30 to 40 days after attacking buds, then pupate. Adults emerge in July and early August and mate; females lay eggs and die. Eggs hatch in about ten days; larvae don't feed but spin hibernaculae for winter shelters.
Host: Fir and spruce, occasionally ponderosa and lodgepole pine.
Habits: Larvae feed on buds and needles, over-winter in protective cases in silken hibernaculae among lichen or under bark scales; pupate in either new or existing webs. Each female lays about 150 eggs, in overlapping masses of 25 to 40, on the undersides of needles.
Damage: Larval feeding destroys new-growth buds, which causes stems to fork; tree appears as though singed with crown fire. Heavy infestation may destroy nearly all new needles, buds and shoots. Young and weakened trees are especially susceptible to defoliation; four to five years of sustained attack kills tree, starting at the top.
Control: About 40 species of wasps and flies are primary parasites of larva. Predators include spiders, ants, snake flies, true bugs, some beetle larvae, and some birds.

FALL WEBWORM *(Hyphantria cunea*)

Size: Larva is a pale yellow to brown, sometimes greenish caterpillar. Has dark strip down back and yellowish stripes down each side of body covered with tufts of long, silky, gray hairs sprouting from blackish-orange tubercles. Adults are winged, satiny-white moths, sometimes with brown or black spots.

Life cycle: Two generations per year. Over-winter as pupae in cocoons on the ground or in bark. Moths emerge during the spring and early summer and lay eggs from May to July. Eggs soon hatch; larvae feed about four weeks, then crawl down the tree and pupate. Adults emerge in late summer and lay eggs for a second generation in the early fall. This generation develops to pupal stage, and then spins cocoons for over-wintering.
Host: More than 100 species of forest and shade trees.
Habits: Larvae spin lightly woven webs, sometimes covering several branches, which are more unsightly than damaging; pupate in cocoons on or just below soil surface or on bark. Adults don't feed.

Damage: Larvae feed on leaves; heavy infestation can defoliate tree.

Control: Remove webs by hand before moths emerge in spring (first generation), late summer (second generation).

GYPSY MOTH (*Lymantria dispar)*

Isolated gypsy-moth infestations have occurred in the West. From 1989 to 1994, several state and federal agencies worked together to eradicate an infestation along Utah's Wasatch Front. Although gypsy moths have been eradicated from Utah, it's important to

understand some basic facts about this serious forest defoliator, its biology, and how to recognize it so that newly developing infestations can be identified.

Historically, the gypsy moth was purposely introduced into the United States in 1869 by a French scientist who had hoped to crossbreed this species with the silkworm moth. Escaping larvae became well-established throughout the New England states. Severe tree defoliation now occurs on hundreds of thousands of acres each year. New infestations outside of the New England states are being discovered with alarming frequency. Long-distance spread has been attributable to man and his activities, such as moving infested material (trailers, recreational vehicles, etc.) containing egg masses or other life stages.

Gypsy moth is a nuisance to people in addition to being a forest pest. Larvae are normally very numerous and interfere with acceptable outside activities such as camping, picnicking, or merely enjoying one's own home grounds. Trees may be killed by two or more years of complete defoliation; however, this mortality is highly variable. Factors such as tree type, age, growing site, amount of defoliation, and environmental conditions will influence the impact on the tree.

Life cycle: The gypsy moth over-winters as masses of up to 1,000 eggs covered with buff or yellowish hairs from the abdomen of the female. Masses, about 1-1/2 inches long and 3/4 inch wide, are laid on the bark of trees, under stones, in hollow trees, or on buildings or any other solid material affording protection from the weather. During April or early May, eggs hatch, and young larvae move to the tops of trees, where they spin down on silken threads, allowing air currents to blow them considerable distances. This is the principal means of natural dissemination. Larvae feed on most hardwood species, but oak, poplar, apple, birch and willow are preferred hosts.

Newly hatched larvae feed on the leaf bases, then leaf surfaces, where they chew holes in the leaves. The older larvae feed inward from the leaf edges, completely consuming the leaves and leaving only midribs and larger veins.

Larvae are hairy caterpillars about two inches long with blue spots on the first five body segments; the last six are brick-red. They mature in late June and pupate. Pupae are normally located on the bark of trees or in a place protected from the weather. Adults emerge about mid-July; both males and females are winged, but only the males can fly. Females, white moths with a buff or yellowish abdomen and a wingspan of two inches, lay their eggs near the pupal case from which they emerged. Males, dark brown moths with a wing expanse of 1-1/2 inches, find females by means of a pheromone (sex lure produced by the female). This scent or odor, which attracts males up to 3/4 of a mile, has been chemically duplicated. This chemical, known as Disparlure, is used to bait sticky traps to detect new infestations or determine the extent of old ones by trapping males.

Gypsy moth was successfully eradicated in Utah using the Bt virus as a control agent.

SPIDER MITES

Spider mites, tiny creatures having eight legs instead of six, are close relatives of insects. Their mouthparts consist of tiny, needlelike stylets that pierce leaf cells, causing a fine stripping or flecking on leaves and needles. These tiny pest vary from 0.25 to one mm in size and attack evergreens and deciduous trees and shrubs.

In heavy infestations, the foliage becomes yellowed or bronzed, sometimes resulting in lost leaves or needles. All spider mites spin some webbing on affected plant parts; this webbing serves as protection for mites feeding beneath. Presence of dust on foliage seems to encourage mite infestations.

The mites go through a six-legged larval stage, then through two nymphal stages before becoming adults. Males tend to be smaller in size and somewhat more slender in body. Many generations are produced during warm summer months.

SCALE INSECTS

Scales are small, usually dark-colored, motionless insects that are often difficult to spot. Hence, the damage they inflict is perhaps the best clue to their presence. Infested plants appear unhealthy, grow poorly, and have stunted and yellowed foliage. Infestations will often appear as gray or brownish encrustations on the bark of twigs and branches. One characteristic often used for quick identification divides scales into two groups, armored and soft or unarmored.

Armored scales are the most common and are found on trees and shrubs. These scales secrete a hard, waxy covering (armor) over their bodies, which may be

circular, oblong, or pear-shaped. Armored scales vary from four to 13mm in size.

The waxy secretion of the soft, **unarmored scales** is part of the scale's body rather than an external coating. These scales may be flattened, slightly convex, or hemispherical and vary from two to 13mm in length. The young, mobile stage of some species (crawlers) feed on leaves during the summer, then move to twigs in the fall. Most species produce honeydew.

Life cycle: The scale insects most commonly found in Utah over-winter either as eggs or immatures. In most species, the female deposits eggs under her shell or scale. When the crawlers settle and begin to feed, the characteristic soft or armored scale covering is developed.

Damage: Scale insects feed by sucking sap from trees and shrubs and are capable of killing the entire plant or parts of the plant. Scale-insect feeding can also reduce the plant's vigor, which will make the infested plant more susceptible to injury caused by drought, severe winters, attack by other insects (especially borers), or infection by diseases. Plants are often covered by a sooty mold that grows in the honeydew secreted by scale insects. The sooty mold gives the plant a blackish appearance. Most species of trees and shrubs are subject to scale-insect attack.

Control: A thorough application of a superior dormant oil according to label instruction just prior to "bud break" will effectively control all of the common soft and armored scales found in Utah. It can be applied to most evergreen and broadleaf woody plants. Bud break will vary with the species of plant and the severity of the spring season, but superior dormant-oil sprays usually should not be applied after early April in Utah. Dormant-oil sprays kill scale insects by suffocation.

Sprays: Insecticides applied thoroughly according to label instructions are effective in controlling the common soft and armored scales found in Utah. However, since these sprays won't penetrate the waxy scale covering, spraying must be timed to coincide with the presence of the crawlers. Timing of the presence of the crawler stage will vary with the species.

BORING INSECTS

(Bark beetles, borers and leaf miners)

BORERS: Some beetle and moth larvae attack trees by boring into the wood of limbs or trunks. These pests are commonly called borers, and they may attack conifers as well as deciduous trees and shrubs. A few species of borers work in sapwood; others may tunnel into heartwood. A few species of borers will attack healthy trees, but most attack trees already weakened or injured from such things as drought, mechanical injury, improper root systems, transplant shock, and sun scald.

Prevention, where it can be practiced in campgrounds and picnic areas, is more satisfactory than control measures.

1. Keep trees adequately watered.
2. Don't crowd root systems with concrete walks, driveways or patios.
3. Wrap trunks of young trees during the winter to prevent sun scald.
4. Keep dead branches pruned out.

BARK BEETLES: Bark beetles are tiny insects that attack trees by tunneling under the bark and into the cambium area of trees. Some of these beetles will attack trees in sound condition, but many attack trees that are weakened or dying. Some of the bark beetles aid in the transmission of certain fungus diseases, hastening the death of trees. Both coniferous and deciduous trees may be affected by bark beetles.

LEAF AND NEEDLE MINERS: The larva of certain moths and flies feed by tunneling between the upper and lower leaf surfaces. These tunnels may be straight, twisted or blotchy. Some will mine into needles of conifers.

WOOD BORERS – BEETLES

This order of insects contains a large number of injurious species. Members are easily recognized, because the adult insect body is hard, and the wing covers meet in a straight line down the middle of the back.

FLATHEAD APPLE-TREE BORER

Adults of the flatheaded wood borers generally are brightly metallic-colored, boat-shaped, and one-third to one inch long. Adults are commonly called metallic wood-boring beetles because of their color. These borers are destructive to newly transplanted trees.

Visible Signs of Borer Activity

Sawdust-like material at the base of the tree. This material comes from the tunnel made by the borer. If sawdust is present, further examine the tree for small punctures in the branches and trunk. Generally there is a discharge of sap from the tunnel opening that wets and discolors the bark below it.

NOTE: DON'T CONFUSE BIRD DAMAGE WITH INSECT DAMAGE. Certain birds known as sapsuckers cause damage that is often attributed to wood-boring insects. Holes made by sapsucker damage are typically in an organized row or pattern.

Control: Borer control in forest situations isn't practical. Insecticides may be used in shelterbelts and Christmas-tree plantings to kill newly emerged larvae. Timing of egg hatch should be accurately determined.

BARK BEETLES

Bark beetles are so named because most of them live and mine between the bark and wood of trees and shrubs.

Adult beetles make tunnels between the bark and wood, in which they lay their eggs. After the eggs hatch, the larvae mine the area, making mines that radiate out from the egg tunnels. Larval tunnels are always packed with their feces. Extensive tunneling of this kind can girdle and thus kill trees and shrubs When adults bore out through the bark, they leave the surface as though riddled by buckshot. Don't confuse these bark-beetle exit holes with sapsucker damage.

Adults arc small, cylindrical beetles reddish to dark brown or black and from 1/16 to 1/4 inch long. The larvae are grub-like, thick-bodied, legless, generally broadly C-shaped, white- or cream-colored, and have a distinct head. Adult egg-laying habits and life cycles vary extensively with the different species.

Control: Some chemical insecticides can be applied to the host tree prior to bark-beetle attack to kill bark beetles as they attempt to bore into the tree. Insecticides vary depending on which beetle is present.

ENGRAVER BEETLES *(Ips spp.)*

Size: Larva four to six mm long; adults 3.5 to six mm long.
Appearance: Mature larva are white to dirty gray in color, legless, with a dark head. Adults are small beetles, reddish brown to black in color with a pronounced cavity at the rear end and with three to six pairs of tooth-like spines.
Life cycle: Attacks are made by these bark beetles after the arrival of warm weather in the spring. From two to five generations of these beetles may develop during the summer. The winter is usually spent in the adult stage.
Host: Various conifers according to species of beetle.
Habits: Adult beetles bore into cambium, where they excavate egg galleries. This group of beetles normally attacks only recently felled trees or those in a weakened condition. Outbreaks in standing and healthy trees are just sporadic.
Damage: The first evidence of attack by Ips beetles is yellowish or reddish boring dust in bark crevices around the base of trees. This group of beetles has egg galleries free of boring dust. Weakened trees attacked by Ips beetles may be destroyed.

MOUNTAIN PINE BEETLE
(Dendroctonus ponderosae)

Size: Larva six to seven mm long: adults four to seven mm.
Appearance: Mature larva is a yellowish-white, legless grub with dark head. Adults are cylindrical, stout-bodied beetles, brown to black in color. Eggs are pearly white.

Life cycle: One generation per year. Over-winter as larvae under bark; begin feeding in spring, then pupate. Adults emerge during July and August (some stragglers emerge as late as September), fly to other trees, bore in and lay eggs.
Host: Ponderosa and lodgepole pines.
Habits: Adult beetles bore through the bark to the cambium, where they excavate egg galleries. Eggs are laid individually along each side of the gallery. Larvae feed on the winter bark and mature inside galleries. Adults migrate to other trees to begin new generation.
Damage: Attacks may extend from near ground level to treetop. Infested trees usually die, but weakened trees

are most susceptible to attack; saplings are usually spared. A blue-staining fungus is associated with this beetle, because it carries fungal spores from infested to un-infested trees.

Other types of bark beetles include Douglas fir beetle, spruce beetle, western balsam bark beetle, and fir engraver beetle. Host trees attacked and life cycles vary by beetle.

SHOOT BORERS

Insects in this category feed on the surface or inside of shoots, causing shoot malformations and death. Moths and beetles cause most of the damage.

LODGEPOLE-PINE TERMINAL WEEVIL
(*Pissodes terminalis)*

This is a common insect in lodgepole-pine stands of Utah. Their larvae range in size from four to five mm, and the adults range in size from five to six mm. The adults are a red-brown color. This weevil produces one generation per year. Small larvae mine and pupate in the cambium layer of open-grown trees. Mature larvae mine and pupate in the pith of terminal shoots.
Host: Lodgepole pine.
Damage: The developing terminals are attacked and killed, down to the uppermost whorl of branches.

POPLAR BORER *(Saperda calcarata)*

In ornamental settings, a common borer of poplar species is the poplar borer. Adults are about 20 to 30 mm in length, elongate, robust, gray in color with yellow stripes on their thorax, and yellow spots on their wings. Adults emerge in late July and August. The female borer chews a slit in the bark and lays one to two eggs. Larvae develop in the sapwood and heartwood for two years before maturing. In July of the third year, the new adults emerge through the holes used by the larvae to expel sawdust (frass).

Host: Poplar species, aspen.
Damage: Sap mixed with frass will ooze out of slits in the tree stem. Split bark will occur where eggs were laid. Borer holes create weak spots in the tree and allow other diseases to enter the tree.
Control: Apply an insecticide recommended for boring insects to kill adults in the spring.

FOREST DISEASE CONTROL

GENERAL OVERVIEW

The common causes of infectious diseases of trees are fungi, bacteria and viruses. Fungi cause the greatest amount of damage to trees and are the most common target for control with pesticides (fungicides). Chemicals used to control fungi generally aren't effective on bacteria. Viruses aren't controlled directly by pesticides but are controlled by eliminating vectors and by cultural methods (non-chemical) that protect susceptible trees from infection. Pesticides have very limited use for forest disease problems.

The proper diagnosis of a plant disease is as important to the management of the problem as any other factor.

The diagnosis includes identification of the pest organism and any contributing factors. The professional help of a plant pathologist is advised for many cases. Contact Utah State University Extension plant pathology personnel for specific information about a problem. Some plant disease organisms can't be isolated and identified accurately without a laboratory diagnosis.

JUNIPER TWIG BLIGHT

Juniper twig blight is a fungus disease more specifically referred to as Phomopsis blight. It usually affects young plants or the new growth on older plants. Species and varieties within the species vary in their susceptibility to the fungus.

Symptoms

Young needles are susceptible to infection throughout the growing season. When the causal fungus penetrates these needles, small yellow spots appear three to five days after invasion. The fungus advances throughout the needles and grows into young stem tissues. Terminals and branches begin to fade in color, then become reddish-brown and finally ashen gray.

Lesions on older stems often develop into cankers. Stems one to two years old are often girdled. Stems more than one-third inch in diameter usually aren't

girdled. Extensive girdling of small stems in individual shrubs causes an unsightly appearance because of numerous dead branch tips.

The disease may be confused with drought damage, because in both cases the tips of the branches may be killed. The easiest way to differentiate between juniper blight and drought damage is to observe the demarcation between the healthy and dead stem tissue. In juniper blight, a sharp demarcation exists between green and dead tissue. In tips affected by drought, the transition is gradual.

Juniper blight might also be confused with winter injury or winter drought. However, winter injury is likely to affect almost all of the branches on one side of the shrub, especially if the shrub has a south or southwest exposure.

Cause

Juniper blight is incited by the fungus *Phomopsis juniperovera*. This fungus is active throughout the growing season, especially during moist weather. It survives as specialized, flask-shaped fruiting bodies (called pycnidia) on dead, infected plant tissue. These bodies are black and extremely small. They can be seen only with the aid of a hand lens or magnifying glass. They are most commonly found on tissues that have turned ashen gray.

The fungus spreads when spores produced in the pycnidia are extruded from an opening at the top. The spores are splashed to healthy needles and stems of the shrub or adjacent shrubs. In the presence of moisture, the spores germinate and penetrate the host. Germination of the spores and subsequent infection occurs best when the temperature is around 75 degrees F., with moisture supplied by rain or sprinklers.

The pycnidia develop within three to four weeks after infection but usually are not well-developed until the infected tissues have dried considerably. Therefore, symptoms of the disease may not become visible to the homeowner until June, July, or even August, depending on the area of the state.

Control

Prune out and destroy affected twigs, because the fungus lives on these structures. Avoid the use of overhead sprinklers as a means of applying water. The foliage can remain wet several hours after the sprinklers are turned off. This is especially true if overhead irrigation is applied in the evening. Drip- irrigation systems installed at the base of shrubs is a water-saving alternative.

Spray with a copper-containing compound such as an 8-8-100 Bordeaux mixture or tribasic copper (fixed copper). Apply the first spray as new growth starts in the spring. Repeat the spray at two-week intervals until dry weather prevails. Follow label instructions carefully to avoid burning of sensitive plants nearby.

CERCOSPORA NEEDLE BLIGHT OF JUNIPERS

Eastern red cedar, Rocky Mountain juniper, and other junipers planted in Utah for ornamental or windbreak use are susceptible to several needle-disease fungi. The most damaging needle blight is caused by *Cercospora sequoiae* var. *juniperi*. Foliage on the lower branches is usually infected first. All foliage dies except that on the branch tips as the disease progresses. Severe infections over three or more years can result in trees dying. **This isn't a serious problem in Utah**

Symptoms

An applicator can easily tell Cercospora needle blight from other juniper diseases, because older foliage becomes infected first, rather than the newer foliage at branch tips.

Initial needle infection occurs during late June and early July. Infected needles first turn brown at the leaf tips, then gradually become completely brown. Smaller shoots and branchlets of the inner tree crown are usually infected first. Affected branchlets will often fall from the tree during late autumn.

The disease slowly progresses from the interior of the tree crown outward, and from the lower branches to the younger, higher branches. Severely infected trees may have only a small tuft of green foliage on the branch tips.

The fruiting bodies (sporodochia) of the fungus will form under the right environmental conditions. The tiny sporodochia are dark grey-green and inconspicuous, so they aren't usually seen. Close examination of the foliage with a hand lens is necessary to spot fruiting bodies. Spores of the fungus develop in the sporodochia

and are spread to nearby branches and trees during rainy periods.

Disease Development

Junipers have three recognized needle types. These types differ in their susceptibility to infection. Juvenile needles are sharply pointed and characteristic of seedling junipers. All juvenile needles are susceptible to infection. Spur needles are the flattened, blunt needles most abundant on older trees. Current-year spur needles are resistant, but older needles are susceptible. Whip foliage is the elongated shoot extremities of side branches. Whip foliage apparently isn't susceptible to Cercospora needle blight.

Spores of the fungus may be dispersed from late April through October, but significant spore release doesn't occur until mid- to late June. Spores spread by rainfall infect susceptible foliage as early as late June or early July. Shoots and small branchlets eventually die after all the leaves have been killed by the fungus.

Control

Bordeaux mixture (4 lbs. hydrated lime and 4 lbs. copper sulfate in 50 gal. water [1.8 kg/1.8 kg/190 l.]) effectively controls the disease. At least two applications are necessary for best control.

The first fungicide treatment should be applied during the second or third week in June, just prior to the initial infection period. The second treatment should be applied about the third week in July. The second application will prevent infections for the remainder of the season. A drip- irrigation system installed at the base of shrubs is water- saving alternative.

Additional applications may be necessary during periods of frequent rains. Rain will favor disease development as well as reduce fungicide longevity.

Handle all pesticides safely. Read all label instructions before using any pesticide. Store all pesticides safely, away from children, pets and livestock.

CYTOSPORA CANKER OF POPLARS, WILLOWS AND ASPENS

Cytospora chrysosperma is one of several cankers on hardwood trees. This fungus is most damaging to aspens, poplars, willows, and mountain ash, but other trees such as silver maple and Siberian elm can also be attacked.

Cytospora canker is associated with the decline (dieback) or death of valuable shade and ornamental trees in landscapes and recreational areas. It also occurs in native tree stands and in field windbreaks. The disease was especially widespread and severe throughout the Great Plains during the drought years of the 1930s.

Symptoms

The disease appears as slightly sunken or depressed cankers on trunks and limbs. In cottonwoods, the bark sometimes splits vertically along the canker margin. Cankers develop by gradually killing the diseased bark and sapwood in a more-or-less elongated pattern, enlarging until the stem is girdled. Discoloration of outer bark varies, depending on host species affected and stage of disease development. Infected bark may be yellow, brown, red-brown to gray, or black. Diseased inner bark and cambium turn orange to reddish-brown to black as these tissues deteriorate.

Infected twigs are quickly girdled and killed without formation of a definite canker. This stage is called stem or branch dieback, or simply dieback. On white poplar and mountain ash, the disease usually occurs as a branch-by-branch dieback. Highly susceptible trees (Lombardy poplar and Siouxland cottonwood) may die within two to five years following infection. Rapidly killed trees often produce sprouts around the base of the trunk. These sprouts also become infected and die.

Causal Agent and Disease Cycle

Cytospora chrysosperma is generally considered a weak parasite and is commonly found on dead branches. It assumes a parasitic role on trees that are in poor vigor. Thus, the disease is most severe on trees weakened by stresses such as fire injury, drought, frost, sun scald, severe pruning, insect or mechanical damage, or herbicides.

The fungus enters bark wounds, dead tips of twigs, or stubs of broken branches and gradually advances to the trunk. Small, raised, pimple-like fruiting structures appear in infected bark. These structures exude long, thin, coiled tendrils called "spore horns" during warm,

moist weather. The spore horns, yellowish to reddish brown, consist of masses of spores (fungus seeds) in a sticky exudate. As the tendrils dry, spores are released and spread by wind, insects or birds to other trees.

Deep watering, especially late in the season, will greatly reduce the severity of the disease.

DWARF MISTLETOE (*Arceuthobium spp*.)

Dwarf mistletoes are a major problem in Utah forests on ponderosa and lodgepole pine. Other members of the pine family -- Douglas fir, pinion, and limber pine -- are damaged occasionally. Nursery and ornamental plantings seldom arc attacked; however, this parasite can be introduced into an area by the planting of collected stock infected with dwarf mistletoe.

Dwarf mistletoes are small, leafless, parasitic flowering plants. The seeds, explosively discharged from the fruit, are very sticky and adhere to any surface they strike. Seeds that adhere to young branches of susceptible trees germinate, and the mistletoe plant penetrates the bark. These seeds generally are dispersed in August and early September.

This parasite is easily identifiable by the yellow to green or brownish-green segmented shoots that protrude from the infected part of the tree. These perennial shoots are two to six inches long and one-eighth to one-fourth inch in diameter.

The "roots" of the dwarf mistletoe are imbedded in the bark and phloem of the tree. The parasite produces secondary root-like structures called "sinkers" that become imbedded deeper in the wood as the twig adds its annual growth rings. These "roots" provide the parasite with nutrients obtained from the living tissues of the host.

Symptoms

The first symptom of dwarf mistletoe infection is a slight swelling of the bark at the site of infection. As the "roots" of the parasite become more extensive in the host, a distorted branching habit, called a witches'-broom, may form. The witches'-broom diverts food from uninfected parts of the tree, subsequently reducing vigor and causing premature death of the tree. Infected trees that don't develop witches'-brooms usually have visible mistletoe shoots protruding from the infected area; however, shoots are not formed until two or three years after infection.

Control

Pruning is the best control measure available for reducing or eliminating dwarf mistletoe infestations in ornamental trees or urban forests. Trees severely infected in the upper branches or those with only a few live branches should be cut. Trees with high, unreachable mistletoe infections will continue to rain seeds on nearby trees if not cut down.

Pruning Dwarf Mistletoe -- Dwarf mistletoe in lightly to moderately infected trees can be removed by pruning. All infected branches and two whorls above the highest infected branch should be pruned using proper pruning techniques. This procedure will remove all currently visible infections and should remove most of the latent and immature infections. Treated trees should be re-examined two to three years afterward, and any newly visible infections should be removed. If removing the infected branches and two whorls above them leaves less than 30 percent live crowns, the tree is unlikely to survive the pruning treatment. Then the tree should be removed to prevent spread of the parasite to neighboring susceptible trees.

If the mistletoe on a branch is close to the bole, the parasite may enter the bole. This is unlikely, however, and most bole infections produce little seed.

POPLAR LEAF SPOTS -- Fungi in the genus *Massonina* often cause leaf spots and blight in many trees in the Populus genus, including aspen and cottonwood. These fungi cause brown lesions on foliage that are typically surrounded by a yellow halo. Moist weather in the spring favors repeating cycles of the fungus, often defoliating the infected trees. Repeated instances of defoliation can kill the tree.

Control

Control is only necessary if spring weather is very moist. For isolated cottonwood and aspen away from natural sources of infection, sanitation can reduce spread. Sanitation involves raking and disposing of infected leaves and twigs. This disease is spread primarily by splashing water, and free moisture on the leaves is required for infections. Therefore, watering by overhead sprinklers should be avoided.

Protective fungicides may be applied at bud break and repeated at ten- to 14-day intervals if wet weather continues. These treatments are usually unnecessary unless the trees have been defoliated in at least one proceeding year. Benomyl (Benlate) and chlorothalonil (Daconil 2787) are registered for spray on shade trees and will control leaf spots.

POWDERY MILDEW -- Powdery mildews are fungal diseases that are very common in dry climates. They form superficial mycelium (a mat of fungal tissues) over the surface of foliage. This mat has structures called haustoria that absorb water and food from the host plants. The characteristic fruiting structure of this group of fungi is the cleistothecium, a tiny sphere about 0.1 to 0.2 mm in diameter. These tiny spheres form in the mycelium on the leaf surface and are usually black at maturity, giving a "salt and pepper" appearance to the leaf surface.

This disease is most common in Utah on maple, cottonwoods, apple trees and roses. Apple trees and roses are most susceptible while new shoots and fruits are developing, but in some hosts, the mature foliage is most susceptible.

Control

Often these fungi can be washed off with a garden hose if infections are light. Chemical sprays can control these diseases if necessary. Triflourine (Funginex) and Dinocap (Kerathane) are registered for powdery mildew control and are effective on all powder mildew hosts.

BRANCH DIAMETER (Outside bark)	DISTANCE OF INFECTION ON BRANCH FROM TRUNK
Under 1.0 inch	6 inches
1.1-2.0 inches	8 inches
2.1-3.0 inches	10 inches
3.1-4.0 inches	12 inches

In heavily infested areas, non-susceptible trees can be planted to replace cut trees. Ponderosa pine areas can be replanted to:

- Douglas fir
- Pinion pine
- White fir
- Limber pine
- Blue spruce
- Rocky Mountain juniper

In lodgepole pine areas, the following trees can be substituted:

- Englemann spruce
- Subalpine fir
- Douglas fir

Hardwoods such as ash, birch and aspen also can be planted in affected areas, because dwarf mistletoes don't attack hardwood trees.

FOREST WEED CONTROL AND VEGETATIVE MANAGEMENT

GENERAL OVERVIEW

No single chemical or method of application is suitable for all forest or site conditions. Planning your program in advance of application will provide the best control at the least cost per acre. One must assess a given site according to tree or brush size and number of stems to be treated, then choose the proper chemical and carrier, select the right method of application, and later evaluate the results accurately. The use of herbicides is most often recommended because they are economical, environmentally safe, effective, and versatile in application. These are the basic considerations in a successful program of chemical application in the manipulation of forest vegetation.

Recognition of the weed pest species is as important in forest weed control as it is with any other pest control problem.

WEEDS

Weeds are plants that interfere with land management objectives. Weeds cause more forest losses than all other pests combined. Inadequate control of forest weeds is causing a major shortage in future supplies of high-quality wood products. Weeds may be classed as:

- Weed trees
- Brush
- Vines
- Herbaceous weeds

Weed Trees

Weed trees often cause significant losses in forest production. They affect both young and old commercial trees within the stand. Included are:

- Non-commercial hardwood and conifer species.
- Deformed, defective, or undersized individuals of commercial species (such as crooked trees or those with heart rot).
- Off-site species (commercial species in a location where they can't develop well).

Some weed trees may be removed by mechanical methods. Some of these can be sold as pulp or fuel. Chemical control methods include:

- Broadcast foliar application of herbicides.
- Directed basal-cut application of herbicides to individual trees.
- Directed basal-bark application of herbicides.
- Broadcast soil application of herbicides.

Brush

Dense brush keeps light from tree seedlings. It also can deprive taller commercial species of water and nutrients. It interferes with planting and can create habitat for wildlife species that may damage tree seedlings. Brush includes:

- Woody shrubs
- Non-commercial stump sprouts

Broadcast applications of foliar herbicides are used for general or selective control of susceptible brush species. If the brush isn't more than 20 feet high, air-blast sprayers may be used for ground application. Aircraft are usually used on taller vegetation.

Application of chemicals to individual stems can be expensive if large numbers of stems per acre are treated. Basal-bark applications are effective but are costly in labor, chemicals, and fuel oil. Systemic brush-killing herbicides do the best job of controlling large, woody vegetation.

Common brush species in Utah include such plants as sagebrush (several species), rabbitbrush, chokecherry, snowberry, bitterbrush, buckbrush and kinnikinnick.

Vines

In some areas of the country, vines are serious pests, especially on better forest soils. They strangle trees, drag down branches and crowns, and compete for light and nutrients. Poison ivy is a human health hazard. Vines are hard weeds to control -- they have vigorous sprouting habits. Systemic herbicides kill their root systems.

Herbaceous Weeds

Herbaceous weeds compete with seedlings in new plantings. Tree and introduced grass seedlings may develop poorly or die, especially in time of drought. Herbaceous weeds also create favorable cover for tree-damaging animals such as mice, gophers and moles. Control herbaceous weeds with herbicides labeled for this forest use. Killing all ground cover for several years can cause soil damage, especially from loss of nutrients and from erosion. Use banded application in areas with summer rainfall. In dry-summer climates, short-residual herbicides permit winter ground cover to develop.

WEED-CONTROL METHODS

The methods used for weed control in forest sites depend on the weed situation and the manner in which the resource is being managed. Methods most often employed are:

- Hand-cutting
- Mechanical control
- Chemical control
- Biological control

HAND-CUTTING

Hand-cutting of brush and weed trees is rarely practical on a large scale. However, such operations may be applicable to small weed lots or commercial thinning of conifer stands. Many brush and weed-tree species readily sprout from stumps or roots following top removal, thus making the benefits of hand-cutting short-lived.

MECHANICAL CONTROL

Brush removal with a track-layer tractor fitted with a blade or brush rake is applicable where trees are grown in rows. Similar mechanical tools are used in site-preparation operations where brushes as well as any existing small conifers are removed. Unless roots and crowns are lifted free from the soil, most broadleaf woody species will readily re-establish.

CHEMICAL CONTROL

The chemical control of woody plants offers the land manager a more economical and effective method of managing undesirable vegetation than by laborious hand-cutting or mechanical methods.

Several factors have helped make herbicides a standard tool for the establishment and improvement of forests, wildlife habitats, and range pasture lands. One such factor is continuous advances in chemical formulation and application methods. Others include more knowledge about specific action and safety of various herbicides and the accumulation of years of practical experience.

Herbicides

The chemical response, or level of vegetation control obtained after application, will vary according a number of factors:

- Tree or brush size and density
- The kind of herbicide
- The volume applied
- Carrier and active ingredient
- Season and method of application
- Species susceptibility
- Equipment being used

It's imperative that the forest managers, herbicide applicators, and especially the crew foremen familiarize themselves with these factors before application. They can then select the most suitable method or methods for their particular set of conditions. READ THE LABEL again before applying the herbicides to be sure the correct formulation has been chosen and applied through proper equipment at the right place and at the right time.

Herbicides most commonly used for establishment and improvement of forest and rangelands are currently available under a variety of trade names. Many of these contain nearly the same chemical and concentration, but with varying amounts of inert ingredients and carriers. Therefore, it's better to become familiar with the common names of the chemicals themselves. The advantages of using herbicides are:

- Economy, compared to alternate control practices such as hand-cutting or mechanical methods.
- Time-saving: large areas can be covered in a relatively short time.
- Ease of application and low labor requirement.
- Fewer re-treatments to control re-sprouting of herbaceous and wood perennials.
- Selectivity of some herbicides to minimize or avoid damage to conifers.

The disadvantages or limitation of herbicides are these:

- Success of weed control programs depends on the selection of the proper type and formulation of herbicides or herbicide mixtures.
- Application timing is often critical in maximizing conifer tolerance and in gaining maximum weed control.
- Non-target plants in gardens or on farms may be adversely affected by spray or vapor drift or through root uptake, causing plant injury or residues.

Herbicides generally move very little in forest soils. They are broken down in place by micro-organisms, sunlight, and chemical reactions. A compound that has an effective life of several months will usually move less than a foot or two from the site of application. Therefore, herbicides are not a serious threat to water supplies or fish unless they are placed directly (especially by spillage) into forest streams or on areas that will become waterways during storm periods.

Biological Control

There are several examples of insects that have been introduced to control an undesirable weed. One example is weevil (*Rhinocyllos*) introduced to control musk thistle and canadian thistle. Biological controls are also very host-specific.

CHOOSING A PESTICIDE

Since the approved use of pesticides is subject to change, only general information about commonly used pesticides is given in this study guide.

REMEMBER:

- Before you choose a pesticide, get a positive identification of your target pest(s).
- Before you buy the pesticide, read the label to be sure it’s the correct chemical for your problem.
- Before you get too involved, be sure of your information. Contact such people as the Utah State Extension Service for professional advice.

PESTICIDE LABELING

Forest lands are considered to be cropland when a stand of commercial trees is present. This means that "non-cropland uses" listed on a pesticide label may not apply to forests. Pesticides used in forests, seed orchards, Christmas tree plantations, or nurseries must bear directions for use on the specific crop and pest species.

Some forestry uses are included on labels mainly devoted to other uses. For example, pesticides may be applied to Christmas trees, seed orchards, or nurseries if the label gives directions for use on ornamentals or shade trees, including conifers, and for the pest you need to control.

Herbicides registered for other crops, range or non-croplands may be used before crop trees are planted. Some pesticides registered for use in forestry may be tank-mixed. In mixtures of two or more products, the rate of each component may not exceed the rate prescribed on its label. Check labels or a recognized authority for details.

PROTECTING GROUNDWATER AND ENDANGERED SPECIES

INTRODUCTION

Federal and state efforts to protect groundwater and endangered species have resulted in special requirements and restrictions for pesticide handlers and applicators. Pesticides that are incorrectly or accidentally released into the environment can pose a threat to groundwater and endangered species. Whether pesticides are applied indoors or outdoors, in an urban area or in a rural area, the endangered species and groundwater must be protected and state and federal agencies rigidly enforce this requirement.

The need for special action by the pesticide handler/applicator depends on site location. Groundwater contamination is of special concern in release sites where groundwater is close to the surface or where the soil type or the geology allows contaminants to reach groundwater easily. In the case of endangered species, special action is normally required in locations where the species currently live or in locations where species are being reintroduced. The product labeling is the best source to determine if pesticide use is subject to groundwater or endangered species limitations.

The U.S. Environmental Protection Agency (EPA) establishes the specific limitations or instructions for pesticide users in locations where groundwater or endangered species are most at risk. These limitations and instructions may be too detailed for inclusion in pesticide labeling. In such cases the labeling will direct the applicator or handler to another source for instructions and restrictions. The legal responsibility for following instructions that are distributed separately is the same as it is for instructions that appear on the pesticide labeling.

PROTECTING GROUNDWATER

Groundwater is water located beneath the earth's surface. Many people think that groundwater occurs in vast underground lakes, rivers, or streams. Usually, however, it is located in rock and soil. It moves very slowly through irregular spaces within otherwise solid rock or seeps between particles of sand, clay, and gravel. An exception is in limestone areas, where groundwater may flow through large underground channels or caverns. Surface water may move several feet in a second or a minute. Groundwater may move only a few feet in a month or a year. If the groundwater is capable of providing significant quantities of water to a well or spring, it is called an aquifer. Pesticide contamination of aquifers is very troubling, because these are sources of drinking, washing, and irrigation water.

Utah has implemented a comprehensive and coordinated approach to protect groundwater from pesticide contamination. Formulation of the Utah Groundwater and Pesticide State Management Plan is a cooperative effort between federal, state, private agencies, producers, and user groups. It provides a basis for continuing future efforts to protect groundwater from contamination whenever possible. Furthermore, this plan provides agencies with direction for management policies, regulations, enforcement, and implementation of groundwater strategies.

Utah recognizes that the responsible and wise use of pesticides can have a positive economic impact, yield a higher quality of life, enhance outdoor activities, and give relief from annoying pests. The EPA has authorized the Utah Department of Agriculture and Food (UDAF) to enforce the protection of groundwater from pesticides.

The UDAF, in concert with cooperating agencies and entities, demands strict compliance with all pesticide labels, handling procedures, and usage to protect groundwater in the state.

Prevention of groundwater contamination is important, because once the water is polluted, it is very difficult and costly to correct the damage and in some instances impossible. City and urban areas contribute to pollution because water runoff can contain pesticides. Shallow aquifers or water tables are more susceptible to contamination than deeper aquifers or water tables. Sandy soils allow more pollution to move than clay or organic soils, because clays and organic matter adsorb many of the contaminants. For more information about what groundwater is and where it comes from, read the study

manual

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), as amended, establish a policy for determining the acceptability of a pesticide use or the continuation of that use, according to a risk/benefit assessment. As long as benefits outweigh adverse effects, the EPA can continue to register the pesticide. Although the intent of a pesticide application is to apply the pesticide to the target or pest, part of the pesticide will fall on the area around the target or pest. Rain or irrigation water then can pick up the part that is not degraded or broken down and carry it to the groundwater via leaching.

There are many factors that influence the amount of pesticide contamination that can get into groundwater. The major factors are the soil type, soil moisture, persistence in soil, placement of the pesticide, frequency of application, pesticide concentration and formulation, pesticide water solubility, and precipitation. Each of these factors will influence the amount of pesticide that can penetrate the soil surface, leave the root zone, and percolate into groundwater.

Although some pesticides may have a high adsorption quality, when they are applied to sandy soil, they may still migrate to the water table because there are few clay particles or little organic matter to bind them. The management and use of pesticides is up to the individual applicator and/or landowner as to whether safe practices are used. Groundwater is a very valuable resource and it must be protected from pesticide contamination.

PROTECTING ENDANGERED SPECIES

The Federal Endangered Species Act lists the three classifications as endangered, threatened, and experimental. Endangered has the highest level of protection. The phrase "endangered species" is used when referring to these classifications. This Act was passed by Congress to protect certain plants and wildlife that are in danger of becoming extinct. A portion of this Act requires EPA to ensure that these species are protected from pesticides.

EPA's goal is to remove or reduce the threat to endangered species that pesticides pose. Achieving this goal is a portion of the larger continuing effort to protect species at risk. Normally these restrictions apply to the habitat or range currently occupied by the species at risk. Occasionally the restrictions apply where endangered species are being reintroduced into a habitat previously occupied.

Habitats are the areas of land, water, and air space that an endangered species needs for survival. Such areas include breeding sites, sources of food, cover, and shelter, and the surrounding territory that provides space for normal population growth and behavior.

Utah's endangered species plan is a cooperative effort between federal, state, private agencies, producers, and user groups. This plan provides agency direction for regulations, enforcement, management policies, and implementation of threatened and endangered species protection strategies.

EPA launched a major project known as Endangered Species Labeling (ESL). The goal is to remove or reduce the threat to endangered species from pesticides. EPA has the responsibility to protect wildlife and the environment against hazards posed by pesticides. The ESL program is administered by the U.S. Fish and Wildlife Service (FWS) in the U.S. Department of Interior. The FWS reports to EPA concerning endangered species. EPA and FWS work cooperatively to ensure that there is consistency in the pesticide restriction information provided to agencies and pesticide users.

The UDAF acts under the direction and authority of EPA to carry out the ESL project as it relates to the use of pesticides in Utah. Utah's web sites with maps designating the habitat boundaries and listings of endangered plants and wildlife is: www.utahcdc.usu.edu

WORKER PROTECTION STANDARD

The U.S. Environmental Protection Agency's Worker Protection Standard (WPS), as revised in 1992, must be complied with when pesticides are used on agricultural establishments, including farms, forests, nurseries, and greenhouses, for the commercial or research production of agricultural plants. The WPS requires employers to provide agricultural workers and pesticide handlers with protections against possible harm from pesticides. Persons who must comply with these instructions include owners or operators of agricultural establishments and owners or operators of commercial businesses that are hired to apply pesticides on the agricultural establishment or to perform crop-advising tasks on such establishments. Family members who work on an agricultural or commercial pesticide establishment are considered employees in some situations.

WPS requirements for employers include:

- **Displaying information** about pesticide safety, emergency procedures, and recent pesticide applications on agricultural sites.
- **Training** workers and handlers about pesticide safety.
- Helping employees get **medical assistance** in case of a pesticide related emergency.
- Providing **decontamination sites** to wash pesticide residues off hands and body.
- Compliance with **restricted entry intervals** (REI) – the time after a pesticide application when workers may not enter the area.
- **Notifying** workers through posted and/or oral warnings about areas where pesticide applications are taking place and areas where REI are in effect.
- Allowing only **trained and equipped workers** to be present during a pesticide application.
- Providing **personal protective equipment** (PPE) for pesticide handlers and also for workers who enter pesticide treated areas before expiration of the REI.
- **Protecting pesticide handlers** by giving them safety instructions about the correct use of pesticide application equipment and PPE and monitoring workers and handlers in hazardous situations.

One of the provisions of the WPS is the requirement that employers provide handlers and workers with ample water, soap, and single use towels for washing and decontamination from pesticides and that emergency transportation be made available in the event of a pesticide poisoning or injury. The WPS also establishes REI and the requirements for PPE. PPE requirements are specified for all pesticides used on farms and in forests, greenhouses, and nurseries. Some pesticide products already carried REI and PPE directions. This rule raised the level of protection and requirements for all pesticide products.

Other major provisions require that employers inform workers and handlers about pesticide hazards through safety training. Handlers must have easy access to pesticide label safety information and a listing of treatment sites must be centrally located at the agricultural facility. Handlers are prohibited from applying a pesticide in a way that could expose workers or other people.

References: *The Worker Protection Standard for Agricultural Pesticides–How to Comply: What Employers Need to Know*. Web site <www.usda.gov/oce/oce/labor-affairs/wpspage.htm>.

CALIBRATION INFORMATION

Conversion:

Units

One acre = 43,560 square feet	**Example: ½ acre = 21,780 square feet**
One mile = 5,280 feet	Example: ¼ mile = 1320 feet
One gallon = 128 fluid ounces	Example: ½ gallon = 64 fluid ounces
One quart = 2 pints = 4 cups = 32 fluid ounces	Example: 2 quarts = 64 fluid ounces
One pint = 2 cups = 16 fluid ounces	Example: ½ pint = 1 cup = 8 fluid ounces
One tablespoon = 3 teaspoons = 0.5 fluid ounces	Example: 2 tablespoons = 1 fluid ounce
One pound = 16 ounces	Example: ¼ pound = 4 ounces
One gallon = 231 cubic inches	Example: 2 gallons = 462 cubic inches

Weights

1 ounce = 28.35 grams
16 ounces = 1 pound = 453.59 grams
1 gallon water = 8.34 pounds = 3.785 liters = 3.78 kilograms

Liquid Measures

1 fluid ounce = 2 tablespoons = 29.573 milliliters
16 fluid ounces = 1 pint = 0.473 liters
2 pints = 1 quart = 0.946 liters
8 pints = 4 quarts = 1 gallon = 3.785 liters

Lengths

1 foot = 30.48 centimeters
3 feet = 1 yard = 0.9144 meters
16 1/2 feet = 1 rod = 5.029 meters
5280 feet = 320 rods = 1 mile = 1.6 kilometers

Areas

1 square foot = 929.03 square centimeters
9 square feet = 1 square yard = 0.836 square meters
43560 square feet = 160 square rods = 1 acre = 0.405 hectares

Speeds

1.466 feet per second = 88 feet per minute = 1 mph = 1.6 kilometers per hour (kHz)

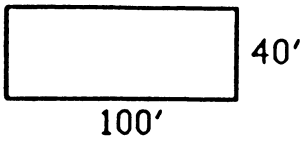
Volumes

27 cubic feet = 1 cubic yard = 0.765 cubic meters
1 cubic foot = 7.5 gallons = 28.317 cubic decimeters

Area and Volume Calculations:

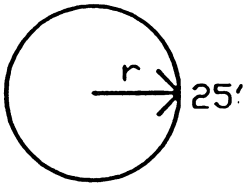
Area of Rectangular or Square Shapes

The area of a rectangle is found by multiplying the length (L) times the width (W).
(Length) x (Width) = Area
Example: (100 feet) x (40 feet) = 4000 square feet



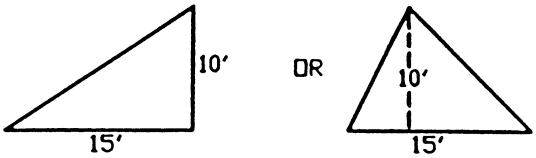
Area of Circles

The area of a circle is the radius (radius = one-half the diameter), times the radius, times 3.14.
(radius) x (radius) x (3.14) = Area
Example: (25 feet) x (25 feet) x (3.14) = 1962.5 square feet



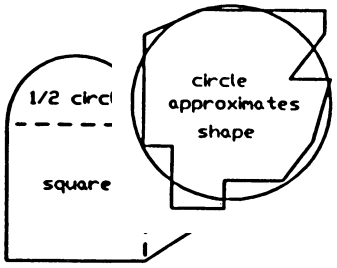
Area of Triangular Shapes

To find the area of a triangle, multiply ½ times the width of the triangle's base, times the height of the triangle.
(½) x (base width) x (height) = Area
Example: (½) x (15 feet) x (10 feet) = 75 square feet



Area of Irregular Shapes

Irregularly shaped sites can often be reduced to a combination of rectangles, circles, and triangles. Calculate the area of each shape and add the values together to obtain the total area.
Example: Calculate the area of the rectangle, triangle, square and one-half of a circle.

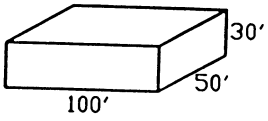


Another method is to convert the site into a circle. From a center point, measure the distance to the edge of the area in 10 or more increments. Average these measurements find the radius, and then calculate the area using the formula for a circle.
Example: Approximate the area by calculating the area of a similarly sized circle.

Volume of Cube and Box Shapes

The volume of a cube or box is found by multiplying the length, times the width, times the height.
(Length) x (Width) x (Height) = Volume

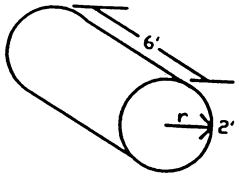
Example: (100 feet) x (50 feet) x (30 feet) = 150,000 cubic feet



Volume of Cylindrical Shapes

The volume of a cylinder is found by calculating the area of the round end (see formula for circle) and multiplying this area times the length or height.

Example: (radius) x (radius) x (3.14) = Area of Circle
(Area of Circle) x (Length) = Volume of Cylinder
(2 feet) x (2 feet) x (3.14) x (6 feet) = 75.36 cubic feet



Sprayer Calibration Formulas:

To Calculate Travel Speed in Miles Per Hour

The travel speed of a sprayer is determined by measuring the time (seconds) required to travel a know distance (such as 200 feet). Insert the values in the following formula to determine the miles per hour.

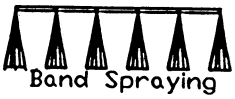
$$\frac{\text{Distance in Feet x 60}}{\text{Time in Seconds x 88}} = \text{Miles Per Hour}$$

Example: $\frac{\text{(200 feet) x (60)}}{\text{(30 seconds) x (88)}} = \frac{12{,}000}{2640} = 4.55 \text{ mph}$

To Calculate the Gallons Per Minute Applied During Broadcast Spraying

The application rate in gallons per minute (GPM) for each nozzle is calculated by multiplying the gallons per acre (GPA), times the miles per hour (MPH), times the nozzle spacing in inches (W); then dividing the answer by 5940. For small adjustments in GPM sprayed, operating pressure is changed. For large adjustments in GPM sprayed, travel speed (miles per hour) is changed or nozzle size is changed.

$$\frac{\text{GPA x MPH x W}}{5940} = \text{GPM}$$



Example: $\frac{\text{(12 GPA) x (4.5 MPH) x (24”)}}{5940} = \frac{1296}{5940} = 0.22 \text{ GPM}$

To Calculate the Gallons Per Minute Applied During Band Spraying

Broadcast spraying applies chemicals to the entire area. Band spraying reduces the amount of area and chemicals sprayed per acre. To use the above formulas for band sprayer applications, use the band width (measured in inches) rather than nozzle spacing for the “W” value.

Pesticide Mixing:

Terminology

The ***active ingredients*** of a pesticide are the chemicals in a formulation that control the target pests. The ***formulation*** is the pesticide product as sold, usually a mixture of concentrated active ingredients and an inert material. Restricted use pesticides are purchased in formulations requiring ***dilution prior to application***. Formulations are diluted with inert substances such as water. The ***percentage of active ingredients*** in a pesticide formulation directly affects dilution and application rates. Given two pesticides, A = 50% active ingredients, B = 100% active ingredients; twice as much pesticide A formulation is required to equal pesticide B formulation.

To Determine the Total Amount of Pesticide Formulation Required Per Tank

To calculate the total amount of pesticide formulation needed per spray tank, multiply the recommended dilution, ounces/pints/cups/teaspoons/tablespoons/etc. of pesticide per gallon of liquid, times the total number of gallons to be mixed in the sprayer. A full or partial tank of pesticide spray may be mixed.

(Dilution Per Gallon) x (Number of Gallons Mixed) = Required Amount of Pesticide Formulation

Example: (3 ounces per gallon) x (75 gallons) = 225 ounces

Note: 1 gallon = 128 ounces; through unit conversion 225 ounces = 1.76 gallons

To Calculate the Amount of Pesticide Formulation Sprayed Per Acre

The calculate the total amount of pesticide formulation sprayed per acre is determined by multiplying the quantity of formulation (ounces/pounds/pints/cups/teaspoons/tablespoons/etc.) mixed per gallon of water, times the number of gallons sprayed per acre.

(Quantity of Formulation Per Gallon) x (Gallons Sprayed Per Acre) = Formulation Sprayed Per Acre

Example: (1/2 pound per gallon) x (12 gallons per acre) = 6 pounds per acre

To Calculate the Amount of Active Ingredients Sprayed Per Acre

The total amount of active ingredients (AI) applied per acre, multiply the amount (pounds, gallons, ounces, etc) of pesticide formulation required per acre, times the percentage of active ingredients in the formulation (100%, 75%, 50%, 25%, etc.), and divide the value by 100.

$$\frac{\text{(Amount of Formulation Required Per Acre) x (Percentage of AI)}}{100} = \text{Active Ingredients Per Acre}$$

Example: $\frac{\text{(4 pounds formulation sprayed per acre) x (75\% AI)}}{100}$ = 3 pounds of AI sprayed per acre

Note: 75 % = 0.75

To Calculate the Gallons of Pesticide Mixture Sprayed Per Acre

The total amount of pesticide mixture sprayed per acre is determined by dividing the number of gallons sprayed by the number of acres sprayed.

$$\frac{\text{Gallons Sprayed}}{\text{Acres Sprayed}} = \text{Gallons Sprayed Per Acre}$$

Example: $\frac{\text{200 Gallons Sprayed}}{\text{10 Acres Sprayed}}$ = 20 gallons of pesticide mixture sprayed per acre