FOREST PEST CONTROL

Montana Department of Agriculture

FOREST PEST CONTROL

A Study Manual for Commercial and Governmental Pesticide Applicators

This manual is intended for applicators that apply chemicals (pesticides) to conifer forests, forest nurseries and forest seed producing areas. Forest Pest Control applicators need to demonstrate a practical knowledge of the types of forests, pests involved, and pest management strategies used in forestry production. They should also possess practical knowledge of the cyclic occurrence of certain pests and specific population dynamics as a basis for planning pesticide applications.

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MONTANA STATE UNIVERSITY EXTENSION

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I. INTRODUCTION

The forestlands of Montana form the headwaters for a number of major river basins. These river systems supply large quantities of high quality water that nurtures some of the West's best fisheries and is used for irrigation and livestock water, as well as for domestic, recreational and industrial purposes. These same lands supply the logs that sustain the forest products industry, an important component of Montana's economy.

Montana's water quality protection program for forestry involves a combination of regulatory and non-regulatory approaches. Since the 1970's, forestry Best Management Practices (BMPs) have provided guidance for water quality protection for forestry operations. One forestry BMP is to use an integrated approach to pest control, including manual, biological, mechanical, preventive and chemical means.

Commercial and governmental applicators that use or supervise the use of pesticides in forests, forest nurseries, and forest seed producing areas are placed under the forest pest control category. These applicators have a detailed list of responsibilities:

> Applicators shall demonstrate practical knowledge of types of forests, forest nurseries, and seed production in their state and the pests involved. They shall possess practical knowledge of the cyclic occurrence of certain pests and specific population dynamics as a basis for programming pesticide applications. A practical knowledge is required of the relative biotic agents and their vulnerability to the pesticides to be applied. The applicator shall demonstrate practical knowledge of control methods and the possibility of secondary problems such as unintended effects on wildlife. Proper use of specialized equipment shall be demonstrated, especially as it may relate to meteorological factors and adjacent land use.

Identifying and managing the pests that infest Montana's forests, forest nurseries, and seed orchards can be difficult and time consuming. There are more than 1,300 diseases and insect pests common on conifer trees in the northern and central Rocky Mountains. Of these, only about 10 percent account for most of the reported cases of damage. In addition, there is animal damage, noxious weeds, and abiotic injuries that are often encountered. This manual will focus only on the most commonly encountered Montana forest pests.

FORESTS

A tree can be defined as a woody plant that is at least 20 feet tall at maturity, has a single trunk, is un-branched for at least several feet above the ground and has a definite crown. Trees are divided into two biological categories: **softwoods** and **hardwoods**.

The terms softwood and hardwood do not refer to the hardness or density of the wood. Softwoods are not always soft, nor are hardwoods always hard. For example, mountain-grown Douglas fir produces an extremely hard wood although it is classified as "softwood," and balsawood, so useful in making toy models, is classified a "hardwood" although it is very soft.

In biological terms, softwoods are called **gymnosperms**, which are trees that produce "naked seeds." The most important group of softwoods are the conifers or cone-bearing trees, which have seeds that are usually visible inside opened cones. All species of pine, spruce, hemlock, fir, cedar, redwood and larch are softwoods. Nearly all softwood trees have another common characteristic: their leaves are actually needles or scales and they remain on the tree throughout the winter, which is why they are also called evergreen trees. Exceptions are larch (or tamarack) and cypress whose needles drop in the fall, leaving the tree bare during winter.

Hardwoods are called **angiosperms**; trees that produce seeds enclosed in a fruit or nut. The hardwood category includes the oaks, ashes, elms, maples, birches, beeches and cottonwoods. In contrast to softwoods, hardwood trees have broad leaves and nearly all North American hardwoods are deciduous, which means they drop their leaves in the fall.

Though there are many more hardwood species than there are softwoods, the softwoods produce a larger share of commercial wood products, particularly those used for structural applications. This is evident by the dominant use of a few softwood species such as Douglas fir, hemlocks, spruces, pines and true firs, all of which play crucial roles in home construction.

Tree Biology

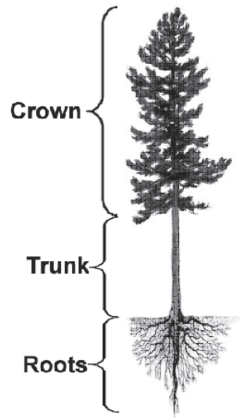


Figure 1-1.

The **crown** consists of the leaves and branches **(Fig. 1-1)**. The leaves contain cells called chloroplasts that have chlorophyll, the substance that gives leaves their green color. In the presence of sunlight, the leaves use the carbon dioxide from the air to produce glucose and oxygen. The oxygen is released to the atmosphere and the glucose is stored in the trunk and roots. This process is called photosynthesis.

The **trunk**, or main stem, of the tree supports the crown and contains the vascular tissue that runs between the roots and the leaves **(Fig. 1-1)**. This tissue allows the movement of raw materials up to the leaves and the return of manufactured food to the woodland root systems for growth and storage.

The **root system** is the most important part of a tree because the roots absorb nutrients and water, store food, and support and anchor the tree **(Fig. 1-1)**. The majority of the root system is located in the upper 12 to 18 inches of soil because of the high levels of oxygen that the roots require.

Monoecious plants have male flowers (or staminate flowers) and female flowers (or pistillate flowers) on the same plant. Therefore, if favorable environmental conditions occur the plant will bear fruit from some of the female flowers scattered throughout its growth. Examples include American Beech and Black Walnut.

Dioecious plants have male flowers (or staminate flowers) on one plant, and female flowers (or pistillate flowers) on another plant. Therefore, if pollination and favorable environmental conditions occur, a pollinating male plant bears no fruits or seeds, whereas a female plant may have fruits. Examples include Green Ash and Osage Orange. An advantage of dioecious trees is that seedless males can be selected and propagated.

Water and nutrients are absorbed by roots and transported from the soil up to the leaves through hollow cells found in the sapwood. Leaves absorb carbon dioxide from the air, which they combine with water through the use of chlorophyll and sunlight to manufacture food (various sugars) for the tree's use. This process is called photosynthesis. A by-product of this process is the release of oxygen. In fact, without the production of oxygen by trees and other green plants on our planet, humans and other animals could not survive. The nutrients (sugar solutions) manufactured by the leaves are conducted through the inner bark (**phloem**) to branch terminals, roots and the **cambium** layer **(Fig. 1-1** and **1-2)**. The cambium is the layer of reproductive cells found between the inner bark and **sapwood** portions of a tree. This narrow layer of cells creates new sapwood cells toward the inside and new phloem cells toward the outside of the cambium. This process adds a layer of new wood in the cambium layer every year, which is between the old wood and the bark. As rings are added, the tree trunk and branches grow in diameter.

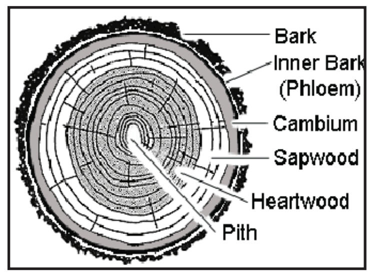


Figure 1-2.

As a tree gets bigger around, phloem cells get older; they are pushed farther away from the cambium (toward the outside) and gradually die. Their water transporting function is then taken over by younger phloem cells produced by the cambium. Dead phloem cells become part of the outer protective layer of trees that we call bark. Bark is important in protecting the tender cells in and near the cambium. Without bark, these cells would be under continual attack from insects, forest animals, fungi and birds and susceptible to physical damage from frost, wind and fire.

The woody portion of a tree is called **xylem** and it includes both the sapwood and heartwood. **Heartwood** is the darker-colored (caused by tannins) inner part of a trunk. This portion of a tree is composed of dead cells, which contribute to the overall strength of the tree trunk. In many ways heartwood is similar to sapwood, but they differ in their chemical and physical properties.

Unlike animals, trees have no way to get rid of by-products produced by the chemical changes that take place in their living tissues. Some of these by-products could be harmful to the tree, so a tree moves these substances toward its heartwood center. Therefore, heartwood is basically just sapwood in which waste substances have accumulated. This leads to two major differences in the properties of heartwood and sapwood. Because of the presence of by-products and other substances, heartwood, usually has: **1)** Greater resistance to insect attack and decay by fungi, and **2)** Reduced permeability, which can affect timber treatment because the natural cellular channels of heartwood can become clogged with extractive deposits.

How Forests Develop

Vegetation follows established patterns of regrowth and change after disturbances by farming, timber harvesting or fire. This process of patterned regrowth and change is called **plant succession**. The rate of succession and the species present at various stages depend on the type and degrees of disturbance, the environment of the particular sites and the species available to occupy the site.

Even in the absence of human activity, forest ecosystems are dynamic and change in response to variations in climate and to disturbances from natural sources. For example, when a fire caused by a lightning strike occurs, the ecosystem goes through a sequence of changes. There is a quick flourishing of "pioneer species." These species are usually quick-growing grasses and broad-leaved plants, often including weeds, followed by a steady advance of slower-growing shrubs and bushes, and trees. This process begins quickly but it can take decades or even hundreds of years for a forest ecosystem to move from its early "pioneer" stage to its "climax" stage. The different species of a stage in forest growth depend on the environmental characteristics of the site in which the disturbance has occurred. For example, average moisture and temperature, soil types, elevation, slope, aspect and latitude as well as the seed bank available all play a role in what species will begin to grow after a disturbance.

MONTANA'S FORESTS

Of Montana's total land area (93 million acres), 17 coniferous tree species cover about 22.5 million acres. Of these 17 species, there are 11 conifer species of commercial value:

1. Douglas fir - *Pseudotsuga menziesii*
2. Lodgepole pine - *Pinus contorta*
3. Ponderosa pine - *Pinus ponderosa*
4. Western white pine - *Pinus monticola*
5. Grand fir - *Abies grandis*
6. Subalpine fir - *Abies lasiocarpa*
7. White spruce - *Picea glauca*
8. Engelmann spruce - *Picea engelmannii*
9. Western hemlock - *Tsuga heterophylla*
10. Western red cedar - *Thuja plicata*
11. Western larch (Tamarack) - *Larix occidentalis*

Forests on the east side of the Continental Divide are dominated by ponderosa pine and Douglas fir and are associated with the many isolated mountain ranges like the Snowies, Belt, and Bears Paw mountains.

West of the Continental Divide, in western Montana, many more species are present including western larch, lodgepole pine, western white pine, grand fir, subalpine fir, Engelmann spruce, western hemlock and western red cedar. This abundance of species is mostly due to Pacific weather systems that are intercepted by high mountains that in turn deliver enough moisture for tree growth.

Generally, forests across Montana can be separated into four basic forest species zones:

- Douglas fir (32 percent of forestlands)
- Lodgepole pine (21 percent of forestlands)
- Spruce and fir (15 percent of forestlands)
- Ponderosa pine (12 percent of forestlands)

These zones are created by differences in temperature, moisture, elevation, and soil. Tree species are adapted to specific conditions, although some tree species have a greater ability to adapt to varying conditions and disturbances.

Pine Trees

Pine trees (Pinaceae: *Pinus*) have uncovered seeds borne in pairs on the bracts of (female) cones (as do other genera of the Pinaceae family) and needles arranged in bundles of 2 to 5 and with a permanent or deciduous sheath at their bases (**fascicles**) (**Fig. 1-3**). Pines usually are among the first trees to establish after fire or other disturbance and often occur in pure even-age stands.

Figure 1-3.

Lodgepole pine (*Pinus contorta*) **(Fig. 1-4)** commonly grow in dense even-aged stands across Douglas fir, grand fir and subalpine fir sites where crown fires have occurred. With special heat resistant cones, these trees need severe disturbances to re-generate. This species is considered short-lived (150 years), as it is often killed by bark beetles once it reaches an age close to 100 years. At this age these trees can reach 70 to 110 feet tall and one to two feet in diameter. The small brown woody cones of lodgepole pine are egg-shaped and 1 to 2 inches long. They also have tiny, sharp prickles **(Fig. 1-5)**. In some areas, lodgepole cones are sealed by a resin and need heat to open (**serotinous**). Fires provide the heat to open the cones and free millions of lodgepole seeds. Most pure stands are therefore established on burned areas. Lodgepole pine needles grow one to three inches long and in groups of two needle-like bundles. Lodgepole bark is thin, gray-brown and flaky on older trees. The bark is very thin, rarely exceeding ½ inch, reducing the tree's resistance to fire.


Figure 1-4.


Figure 1-5.

Ponderosa pine (*Pinus ponderosa)* **(Fig. 1-6)** is a hard pine with varied grain coarseness that inhabits the warmest and driest of forest zones. The heat tolerance and taproot of ponderosa pine allows it to grow where few other native tree species can. This also allows it to colonize severely burned areas on wetter sites. Soil disturbances timed with a good cone crop result in prolific seedling production. It has a large crown, straight trunk and can live as long as 300 years. At 150 years of age it can reach 120 to 180 feet tall with trunk diameter of 2 ½ to 4 feet. This tree also has a long, deep root system that enables it to access deep water and keep the tree from blowing over. Ponderosa pine bark is black on young trees then yellow-brown, with large scaly plates on mature trees **(Fig. 1-7)**.


Figure 1-6.


Figure 1-7.

Ponderosa pine is generally found at lower elevations and dry southern slopes across the forest.

Needles of the ponderosa pine are five to ten inches long, in fascicles of 2 or 3. Cones are four to six inches long, conical or egg shaped, with outward pointed prickles **(Fig 1-8)**.


Figure 1-8.

Western white pine (*Pinus monticola*) **(Fig 1-9)** is an important timber tree because it has soft, light weight, non-resinous, straight-grained wood and rapidly grows to a large size. It is particularly valuable for sash, frames, doors, interior paneling, building construction, match wood and toothpicks. Western white pine requires fire or timber harvesting to become established as this removes competing conifers. This tree species is intermediate in fire resistance compared to other conifers because of its thin bark and moderately flammable foliage. As a result of fire protection and the lack of major fires, plus blister rust infection, the proportion of western white pine regeneration has decreased. The needles are flexible bluish green, 2 to 4 inches long and in clusters of five. The cones are typically found at the tops of the trees. They are 5 to 10 inches long and green before opening. They are light brown with thin scales **(Fig. 1-10).**

Figure 1-9.

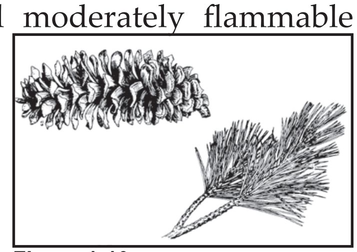


Figure 1-10.

Spruce Trees

In general, spruce trees (Pinaceae: *Picea*) are rugged evergreens that can withstand extreme winter cold. Engel-

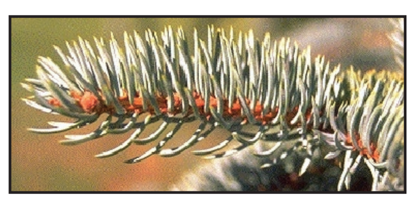


Figure 1-11.

mann spruce (*Picea engelmannii*) and to a lesser degree, white spruce (*Picea glauca*) are commonly found in Montana forests. Spruce trees have stiff, prickly, four-sided needles that are evenly arranged around the entire twigs in a "bottle brush" appearance (**Fig. 1-11**). Needles are attached directly to the stem and grow from woody peg-like bases called **sterigmata (Fig. 1-12)**.

Figure 1-12.

White spruce (*Picea glauca*) **(Fig. 1-13)** primarily grows in northern Montana along rivers. It extends northward into Canada, where it generally replaces Engelmann spruce north of Alberta. Where their ranges overlap, these two species often hybridize. The cones of Engelmann spruce (*Picea engelmannii*) are larger than white spruce (*Picea glauca*). Also, the cone scales of Engelmann spruce are ragged or notched, while those of white spruce are smooth and rounded like a thumbnail **(Fig. 1-14)**.

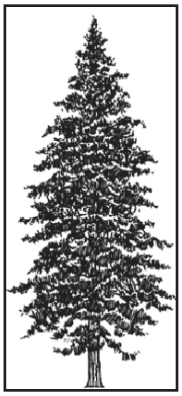


Figure 1-13.

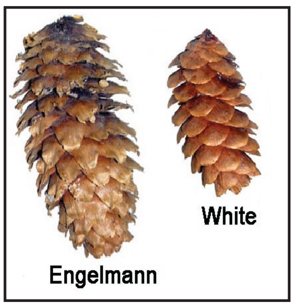


Figure 1-14.

Engelmann spruce (*Picea engelmannii*) **(Fig. 1-15)** is native to higher elevations of the Cascades and Rocky Mountains, including the mountains of western and central Montana and is found in most cool air drainages and at higher altitudes. Needles point towards the branch tip, making the branches softer to the touch. The needles have a distinctive, rank odor when crushed. The wood is lightweight, straight grained, soft, stiff, and can be readily air-dried. It is used for home construction lumber and for prefabricated wood products. Engelmann spruce has a life span of 350 years and can be 8 to 150 feet tall at 200 years of age. Trunk diameter can reach 1 ½ to 2 ½ feet in diameter.

Figure 1-15.

Fir Trees

Firs (Pinaceae: *Abies*) are tall evergreen conifers that have a pyramid-shape and are characterized by short, flat, stemless, flexible needles that grow on the sides and sometimes tops of twigs but rarely on the bottom **(Fig. 1-16)**. Firs can be differentiated from Douglas fir and spruce trees by their upright cylindrical cones that shed their scales rather than dropping off the tree as a whole cone. It should also be noted that the Douglas fir, *Pseudotsuga menziesii*, is not a true fir. Many of the true firs are also incorrectly called balsam. The true balsam fir (*Abies balsamea*) is found east of the Rocky Mountains.

Figure 1-16.

In Montana, there are two species of fir trees that are of economic importance: the grand fir (*Abies grandis)* and the subalpine fir (*Abies lasiocarpa)*.

Grand fir (*Abies grandis*) **(Fig. 1-17)** is a large tree reaching 120 feet in height and 3 feet in diameter. It typically grows in western Montana at lower elevations (up to 4000 feet).

The needles are ½ to 2 inches long with single notched ends and extend straight from opposite sides of the stem. They have a green surface and a silvery white bottom. Grand firs are economically important as lumber, plywood, pulp for paper, framing, sheathing, other structural uses and for Christmas tree markets.

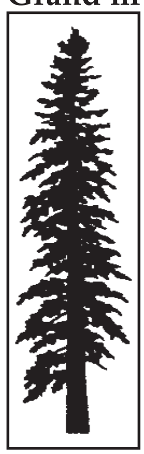


Figure 1-17.

Subalpine fir (*Abies lasiocarpa*) **(Fig. 1-18)** is common at cold, high elevation mountain forests in Montana and can reach a height of 80 feet with a 2 foot diameter. The needles are ½ to 1½ inches long and extend in a spiral from the stem. The wood is used as lumber for home construction, prefabricated wood products and has excellent pulping properties.

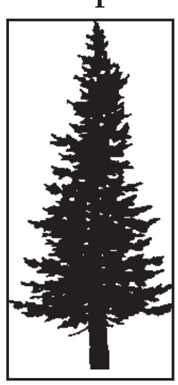


Figure 1-18.

Other Important Trees

Douglas fir (*Pseudotsuga menziesii*) **(Fig. 1-19)**, also known as red fir, is a valuable tree used for Christmas trees, lumber and plywood. The wood is strong and dense and is good for structural support, beams, trusses, docks, bridges and railroad ties. This species can grow on hot and dry sites as the shade tolerant replacement species, or on cool, wet sites as the pioneer species. It is the most versatile and common tree in Montana. It is moderately adapted to survive the effects of fire and coexists with ponderosa pine on dry sites, and with larch, grand fir, and lodgepole pine on cooler and wetter sites. It has the tendency to regenerate in dense thickets under mature ponderosa pines or on cooler north and east slopes, which creates a high wildfire hazard. Douglas fir needles are ¾ to 1¼ inch long and flat, slightly grooved with a sharp tip relative to true firs. Cones are cylindrical and two-to-three inches long with 3-pointed bracts protruding from the scales **(Fig. 1-20)**. The bark is gray-brown, corky looking, and deeply furrowed in mature trees. Inside furrows often rust, turning red in color. Douglas fir trees can have a life span of 300 years and reach heights of 110 to 170 feet tall and three to four feet in diameter.

Figure 1-19.

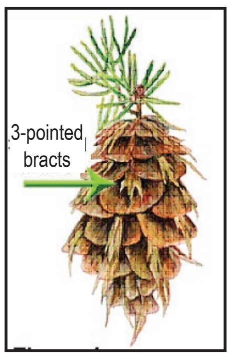


Figure 1-20.

Western hemlock (*Tsuga heterophylla*) **(Fig. 1-21)** is a large tree that can reach a height of 175 feet. It is found in the low-to-mid elevation toe-slope seepages, moist benches, and wet bottoms adjacent to streams of northwestern Montana. These trees dominate where soils are deep, moist, and nutrient poor.

Needles can be ¼-¾ inch long with rounded ends and a grooved center. Cones hang down, are a light brown and reach a length of one inch.

Wood from this tree is used for roof decking, molding, general construction, plywood and newsprint.

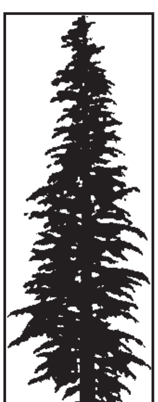


Figure 1-21.

Western larch (*Larix occidentalis*) **(Fig. 1-22)** is a deciduous conifer that can reach a height of 200 feet. It occurs in northwest Montana in open, sunny stands. Needles are 1-1½ inches long, triangular in shape, and soft. Cones can reach 1½ inches in length with a purple/red/brown coloring. The wood is used for construction, railroad ties, pilings, mine timbers, interior and exterior finishing and pulp. It is also one of the most important fuel woods. Western larch is a highly valuable timber species.

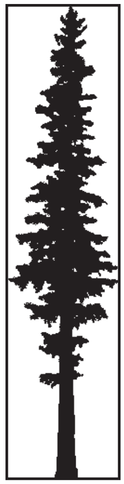


Figure 1-22.

Western redcedar (*Thuja plicata*) **(Fig. 1-23)** is not a true cedar but is a member of the cypress family. It is a large tree that can grow to 150 feet and 6 feet in diameter. These trees prefer moist sites at low elevations in northwest Montana.

The wood is commercially important because it is resistant to decay. Therefore it is used for the construction of exposed building material such as shingles, shakes, and exterior siding. Western redcedar wood is also used for utility poles, fence posts, light construction and pulp.

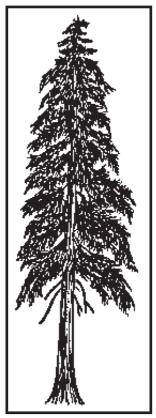


Figure 1-23.

MONTANA'S FOREST INDUSTRY

There are 22.4 million acres of timberland in Montana. Nearly 3.4 million acres of forestlands are permanently reserved as either wilderness areas or National Parks. Eleven million acres of the remaining forestland is administered by the USDA Forest Service, with 5.2 million acres of this public estate designated by current forest plans as suitable for timber production.

Private forestlands occupy some 6 million acres, with 1.6 million owned and managed by timber companies. Montana's timber industry turns trees, a renewable resource, into a wide variety of products, including lumber, plywood, particle board, cardboard boxes, posts and rails, log homes, and wood pellets.

The rest of the Montana's forestlands are comprised of State, Bureau of Land Management (BLM), Tribal, County and other land ownerships.

In Montana, the wood products industry contributes about $970 million, or 6 percent of the states total economy (Montana Wood Products Association).

Quick & Easy ID

	Needle	Cone	Bark
Douglas fir	flat, grooved	2-3 in, three-pointed bracts beyond scales	grooved
Lodgepole pine	bundles of 2	0.75-3 in, spined scales	orange/ brown/gray flaky
Ponderosa pine	bundles of 2-3	3-6 in, spined scales, rounded base	brown/orange/yellow plated
Western white pine	bundles of 5	5-10 in, thin scales	gray, thin, smooth
Grand fir	single, notched end	2-4 in, scales fall to the ground	gray/red/ brown. thin, resin blisters
Subalpine fir	single	2-4 in, scales fall to the ground	gray/red, thin, resin blisters
White spruce	single, sharp rigid tips	1-2.5 in, smooth scales	brown/silvery, thin
Engelmann spruce	single, sharp-pointed tips	1.5-2.5 in, thin soft scales	gray/red/ purple/brown, thin, scaly
Western hemlock	single, flat, rounded end, grooved	0.75-1.5 in	brown, broad flat ridges, thick
Western redcedar	scale-like	0.5 in, 8-10 spined scales	gray/red/ brown, thin, fibrous
Western larch	bundle 14-30, triangular	1-1.5 in, thin scales	red/brown, scaly, thick

SILVICULTURE

Silvics is a specialized branch of forest ecology that deals with the biological characteristics of individual trees and their communities. For example, tree growth, reproduction, and biotic (interactions with other organisms) and abiotic (environmental interactions) influences are studied as well as the influence the tree communities have on the environment they grow in. Overall, this information is then utilized to successfully reproduce and grow forest crops. Silviculture methods attempt to control the establishment, composition, character, and growth of tree stands in order to manage forests for economic and ecological purposes. This knowledge is required for not only maximized long-term economic return but also the maintenance of important ecological forest functions. Important areas of silviculture are:

1) Planting and establishing trees after harvest that are resistant to pests and pathogens that were in the area pre-harvest. Site preparation for specific tree species is necessary.

2) Managing established forests which may require thinning to reduce competition for light, water, and nutrients minimizing the stress experienced by the new forest crop. Slash, windfall and dead trees need to be removed at the appropriate seasonal time to decrease pest source populations.

3) Harvest of tree crop at the appropriate seasonal time.

4) Salvage and storage at the appropriate seasonal time.

PRACTICE QUESTIONS

1. Closely spaced annual rings indicate________________ trees.

A. fast growing
B. slow growing
C. very tall
D. very short

2. The dead, central wood in the trunk and larger branches, usually darker and harder than the sapwood is____________.

A. stomatawood
B. timberwood
C. heartwood
D. bractwood

3. What type of tree typically colonizes after a disturbance?

A. Larch
B. Spruce
C. Pine
D. Fir

4. What type of tree has sterigmata?

A. Larch
B. Spruce
C. Pine
D. Fir

5. An example of a deciduous conifer is the_____.

A. Larch
B. Spruce
C. Pine
D. Fir

6. The younger, living outer layer of wood in the trunk and branches, softer and lighter in color than heartwood is__________.

A. sapwood
B. timberwood
C. heartwood
D. bractwood

7. Waste products of cell processes found in vacuoles and cell walls, giving brown colors is______.

A. carotenoids
B. tannins
C. chlorophyll
D. xylem

8. Green pigment in chloroplast necessary for photosynthesis is_________.

A. carotenoids
B. chlorophyll
C. anthocyanin
D. tannins

9. ___________ is the water-conducting tissue that transports water upward in a tree.

A. xylem
B. phloem
C. outer bark
D. cambium

10. Roots do not perform the function of___ .

A. support
B. manufacturing plant food
C. absorbing moisture
D. absorbing plant nutrients

11. What is the study of tree biology and community ecology?

A. forestry
B. dendrology
C. ecology
D. silvics

12. What part of a tree has greater resistance to insect and fungi attack as well as reduced permeability?

A. stomatawood
B. timberwood
C. heartwood
D. bractwood

II. MONTANA FOREST PESTS

Pests can be defined as any organism that causes economic or aesthetic damage to humans or their property. Examples include exotic weeds that displace native vegetation, deer mice (*Peromyscus maniculatus*) that carry the deadly hantavirus, and gypsy moths (*Lymantria dispar*) that defoliate oaks (*Quercus* spp.). Pests can be classified as key pests, occasional pests or secondary pests **(Table 2-1)**.

Table 2-1.

Key Pests	Occasional Pests	Secondary Pests
Cause major damage on a regular basis. **Example:** An 80 percent infestation of leafy Spurge can reduce livestock carrying capacity by 100 percent. Grasshoppers consume up 25 percent of the available forage in the western United States annually.	*Become intolerable on an irregular basis. Often as a result of changes in climate, environment, or human activity.* **Example:** Dry conditions can cause seed bugs to move from rangeland to areas of higher moisture like lawns, flower beds, swimming pools and houses.	*Occur as a result of actions taken to control a key pest.* **Example:** Cheatgrass establishment in areas that have been sprayed for spotted knapweed. Ticks and fleas plague people after their natural hosts have been eliminated.

Forests have a varied occurrence of pest species. At times the damage caused by these pests may have reached levels that require no action because costs of treating are greater than the profit gained. However, if a pest is detected and accurately identified steps preventing an increase in population and the ensuing damage can be taken.

INSECTS

All living organisms are grouped or classified by common characteristics. The major groups are called kingdoms. Each kingdom is then further divided into increasingly smaller groups based on similarities. The different levels of groups are named by the convention of **taxonomists** (scientists who study classifications). The standard groups in a typical complete classification of species are (the example is for mountain pine beetle *Dendroctonus ponderosae)*:

KINGDOM (Animalia)
PHYLUM (Arthropoda)
CLASS (Insecta)
ORDER (Coleoptera)
FAMILY (Scolytidae)
GENUS (*Dendroctonus*)
SPECIES (*ponderosae*)

Insects belong to the phylum Arthropoda which includes all animals with segmented legs, segmented bodies and exoskeletons (spiders, ticks, mites, centipedes, millipedes, shrimps, lobsters, and many other organisms). Insects can be differentiated from the majority of other arthropods by the following distinctive traits **(Fig. 2-1)**: **(1)** a body divided into three parts: head, thorax and abdomen**, (2)** three pairs of legs, **(3)** usually one pair of antennae and a pair of compound eyes (a few exceptions to these characteristics are found), **(4)** usually two pairs of wings, although insects such as lice, fleas and ants do not have wings and flies have one pair of wings.

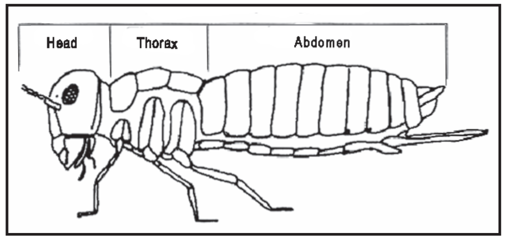
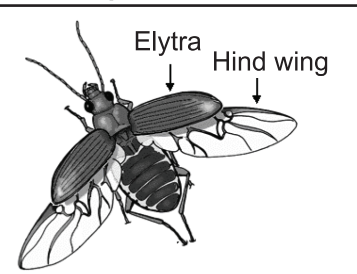
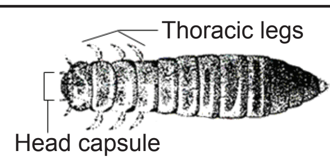


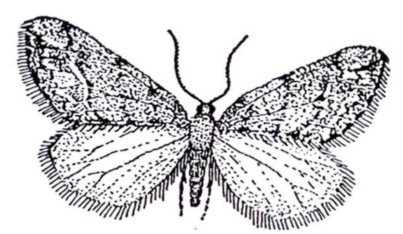
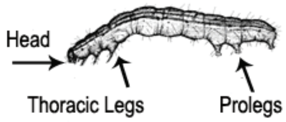
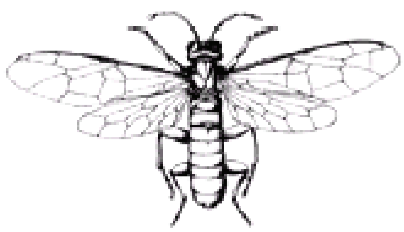
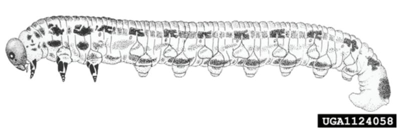
Figure 2-1.

Less than one percent of the estimated one million insect species on the earth are pests. An even smaller percentage are considered forest pests. Yet, insect pests of conifer trees are capable of limiting timber production, creating tree and fire hazards, reducing visual quality, affecting wildlife use, and degrading watershed properties.

Of the 31 insect orders, 3 contain most of the forest insect pest found in Montana: **Coleoptera** (beetles, weevils), **Hymenoptera** (sawflies, wasps, bees), and **Lepidoptera** (moths, butterflies). These insects are organized into their respective orders given specific morphological characteristics **(Table 2-2).**

Table 2-2.

Order Coleoptera	
	Adult beetles have one pair of hardened outer wings (**elytra**) that act as a protective cover for the second pair of membranous wings. Adults have one pair of antennae, a pair of compound eyes, and chewing mouthparts.
	The larvae (grubs) have three pairs of thoracic legs and a well developed head capsule with chewing mouthparts.

Order Lepidoptera	
	Adult moths and butterflies usually have two pairs of large wings covered with scales. Adults have one pair of antennae, a pair of compound eyes, and siphoning mouthparts.
	The larvae (caterpillars) have three pairs of thoracic legs, three to six pairs of prolegs with crochets, and chewing mouthparts
Order Hymenoptera	
	Adult sawflies and bees have two pairs of membranous wings. Adults have one pair of antennae, a pair of compound eyes, and chewing/lapping mouthparts.
	The larvae may or may not have thoracic legs and chewing mouthparts. Sawfly larvae have at least four pairs of prolegs without crochets. The larvae of bees and wasps usually are more grub-like without prolegs.

Bark Beetles (Scolytidae)

Management of bark beetle populations is dependent on preventive measures and the maintenance of healthy trees. General silvicultural practices that improve tree vigor limit the susceptibility of a tree to bark beetle infestation. Infestations have been found to be linked to windthrow, snow breakage, spring/early summer drought, logging, fires, road and housing development and other human activities. Slash from these activities act as reservoirs of beetle population growth and should be removed. Trees that are mature or over mature, and are in dense stands are more likely to be infested. Dense stands will also increase the likelihood of infestation of younger, smaller diameter trees. Stands with high incidence of root disease also have a greater chance of infestation. Thinning and patch cutting of stands into an age and size class mosaic, and selective harvesting of risky trees (in riparian area, along roads or edges) are valuable prevention tools. Predicting outbreaks is another important preventive tool. Precipitation levels between April and July can be used to determine the intensity of infestation later in the season.

Insecticides can be used for direct control of beetles. Unfortunately, control requires the combined efforts of all landowners within the designated management area and, therefore, broadcast applications. Pesticide control of bark beetle control is only valuable in the spring when adult beetles are flying. **Once the adult beetles, eggs, or larvae are in the bark, pesticides are ineffective.** Treatments are only effective before adults lay eggs. Infested trees cannot be saved with insecticide treatments and sanitation harvesting should be practiced. To limit beetle population the infested tree should be removed. Then the tree's bark should be burned, the tree should be limbed and exposed to the sun, submerged in water, or sprayed with insecticide.

Figure 2-2.

Chemical attractants (mountain pine beetle: exo-brevicomin trans-Verbenol Myrcene; Douglas fir beetle: Frotalin MCOL or Seudenol Ethanol) can be used as tree baits to stimulate attacks in selected stands and influence landscape pattern of mortality. They can also be used in conjuction with funnel traps **(Fig. 2-2)** to monitor beetle populations. Anti-attractants can also be used (mountain pine beetle: Verbenon; Douglas fir beetle: methylcyclohexenone or MCH).

Several predators and parasites feed on bark beetle adults and larvae. Natural enemies of mountain pine beetle, Douglas fir beetle, western pine beetle and the fir engraver are predaceous beetles such as the checkered clerid (*Enoclerus lecontei* and *Enoclerus sphegus*), trogossitid beetles (especially *Temnochila chlorodia*), a predaceous dolichopodid fly (*Medetera aldrichii*) and parasitic wasps. Some nematodes (internal parasitic worms) limit or prevent egg production within females whereas other nematodes feed on beetle eggs. Woodpeckers, nut hatches, and a few other bird species are common predators. Aggregations of bark beetles attract natural enemy populations and may eventually limit the infestation.

The bark beetles are the most economically injurious insects to Montana forests. Notable pest species are mountain pine beetles (*Dendroctonus ponderosae*), Douglas fir beetles (*Dendroctonus pseudotsuga*), Western balsam bark beetles (*Dryocoetes confusus*), fir engravers (*Scolytus ventralis*), spruce beetles (*Dendroctonus rufipennis*), pine engravers (*Ips pini*), and Western pine beetles (*Dendroctonus brevicomis*).

The **mountain pine beetle** (*Dendroctonus ponderosae*) is stout, black, and cylindrical (4-7½ millimeters (mm) long) with the head visible when viewed from above **(Fig. 2-3)**. The antennae are elbowed with a flattened club. It is considered one of the most destructive forest pests attacking mature lodgepole forests. In 2005, 820,400 acres of Montana forests were infested. Adult beetles tunnel under bark to construct egg galleries (less than or equal to 90 centimeters (cm) long) in the cambium parallel to the grain of the wood. The adult beetle may also introduce blue-staining fungi into the sapwood, decreasing the translocating abilities of the tree. Larvae feed on the wood, creating galleries at right angles to the initial gallery. The tree can be girdled when larval density is high. Indications of infestation: pitch tubes **(Fig. 2-4)**, red foliage, and circular emergence holes without frass (waste material produced by feeding insects). It takes one year for the beetle to complete its life cycle.

Figure 2-3.


Figure 2-4.

The **Douglas fir beetle** (*Dendroctonus pseudotsuga*) is very similar to the mountain pine beetle in size and shape. It attacks Douglas fir and western larch, preferring slash, windfall and diseased trees, but will attack living trees if populations reach epidemic levels. The adult constructs galleries less than 50 cm, with an average of 25 cm **(Fig. 2-5)**. Indications of infestation: fresh frass found in bark crevices, red foliage, and entrance holes with boring dust visible on bark. Pitch tubes will not be present. It takes approximately one year for this beetle to complete its life cycle.

Fir engravers (*Scolytus ventralis*) attack young and mature true fir stands such as *Abies concolor*, *Abies grandis* and *Abies magnifica* but occasionally attack *Pseudotsuga*, *Tsuga* and *Picea.* It typically breeds in slash and windthrown trees but outbreaks on living trees can occur due to drought, disease and defoliation. The egg galleries formed by the adults are scored transversely across the grain of the wood from each side of the entrance **(Fig. 2-6).**

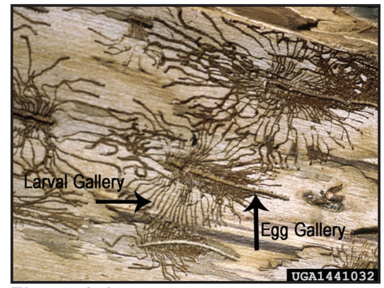


Figure 2-6.

Western balsam bark beetle (*Dryocoetes confusus*) adults (about 4 mm in length) attack subalpine fir, but other occasional hosts are *Abies* species, Engelmann spruce and lodgepole pine **(Fig. 2-7)**. Blue-stain fungus can be introduced during feeding. Females have a dense patch of yellow hair on the head while males have little hair. The adults lightly score the wood, creating galleries that radiate from the central entrance (nuptial chamber) **(Fig. 2-8)**.

Figure 2-7.

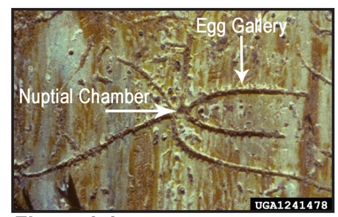


Figure 2-8.

Pine engravers (*Ips pini*) **(Fig. 2-9)** are frequent pests of ponderosa pine and at times are important pests of lodgepole pines. Typically only trees that are stressed by wind, fire, and drought will be attacked. In outbreak years young trees may be killed and mature trees may be top damaged by the beetle infestation. The adults are yellow to brown (3-7 mm long) with a concavity at the rear of the elytra which is marginated on each side with 4 tooth-like spines. The third spine

Figure 2-9.

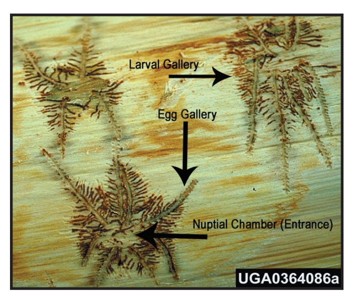


Figure 2-10

is more prominent in males than in females. Galleries radiate from the entrance (nuptial chamber) forming a Y- or H-pattern aligned with the grain of the wood **(Fig. 2-10)**. The boring dust and frass is pushed to the outside of the entrance during construction of the gallery.

Spruce beetle (*Dendroctonus rufipennis*) adults **(Fig. 2-11)** are light brown to reddish-brown (4-7 mm in length). They can be distinguished from the mountain pine beetles by the sclerotized plate on the dorsal side of each of the last two abdominal segments. Engelmann, white and Sitka spruce are attacked as well as other *Picea* species. The spruce beetle will usually breed in slash and windthrown trees. Following blow down events and successive warm summers stands of mature, living spruce will be attacked. The adult will construct an egg gallery about 24 cm in length **(Fig. 2-12)**. Indications of infestation include: the presence of loose frass in bark crevices and red foliage. Pitch tubes will not be present. It takes approximately two years for the beetle to complete its life cycle.

Figure 2-11.

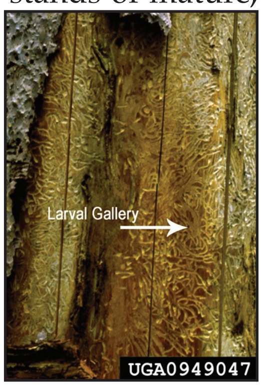


Figure 2-12.

Western pine beetle (*Dendroctonus brevicomis*) **(Fig. 2-13)** is similar to the mountain pine beetle but attacks ponderosa pine and is somewhat smaller (3-5 mm in length). It is a minor pest but the susceptibility of ponderosa is increasing with the continually dry conditions of Montana. Egg galleries are random, branched across the grain **(Fig. 2-14)**. Indications of infestation: inconspicuous pitch tubes and red boring dust.

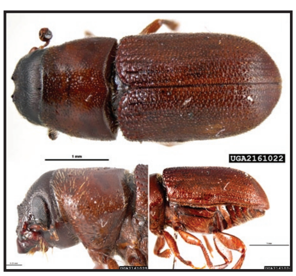


Figure 2-13.

Figure 2-14.

Terminal Feeders (Curculionidae)

Terminal weevil management like bark beetle management requires preventive measures and the maintenance of healthy trees. Several management strategies are useful in controlling terminal weevil damage: **1)** Plant pure stands at high densities (2½ meter (m) spacing or less). Dense growing conditions do not prevent weevil infestation but increase upward growth benefiting the general form of the tree. Spacing (pre-commercial thinning) and brush control should be delayed until the stand reaches 25 years of age or 5 m in height. **2)** Plant host tree species in a mixture with suitable non-host species. **3)** Plant host trees resistant to terminal feeders in a mixture with susceptible host trees. **4)** Clip infested leaders before emergence of the adult. Leave one dominant lateral to maintain proper terminal shoot growth. Repeat the procedure for three consecutive years. Clipped leaders should be disposed of by burning as adult weevils can still emerge. **5)** Applications of appropriate insecticides according to label directions (such as insect growth regulators in late April). However, pesticide application over large areas is not cost effective and can be detrimental to other insects. Birds, other insects, and mammals are predators of terminal feeding insects. However, natural enemies do not significantly control damage.

Important terminal feeders in Montana forests are the white pine weevil (*Pissodes strobi*) and lodgepole pine terminal weevil (*Pissodes terminalis*).

White pine weevils (*Pissodes strobi*) are reddish brown with patches of lighter brown or grey scales **(Fig. 2-15)**. They are about 4-5 mm in length and have long, slender snouts and clubbed antennae. Major hosts are Colorado blue, white, and Engelmann spruce, and Eastern white pine. In early spring, adults chew into the bark of a year-old leader and lay eggs. The larvae **(grubs)** have a smooth-surface, are curved and legless, and are yellowish white with light brown heads. They feed gregariously beneath the

Figure 2-15.

Figure 2-16.

bark working down into the phloem. Indications of infestation: wilting and deformed/bushy/ forked leaders **(Fig. 2-16)**. Damage from attack may result in the loss of 3 or 4 years of height growth, forking and heavy branching.

Lodgepole terminal weevil (*Pissodes terminalis*) **(Fig. 2-17)** is similar to the white pine weevil. The principal host is lodgepole pine. Adults lay eggs in the current leader growth. Individual larvae mine into the phloem-cambial region towards the expanding bud then pupate in the pith. Indications of infestation: death of the current year's leader, forking and heavy branching. Trees most susceptible to initial attack are those in poorly drained sites, edge trees, naturally regenerated stands, following fire, and those that have been spaced to low densities at an early age. **Lodgepole terminal weevil management may increase the chances of Western gall rust and comandra blister rust damage**.

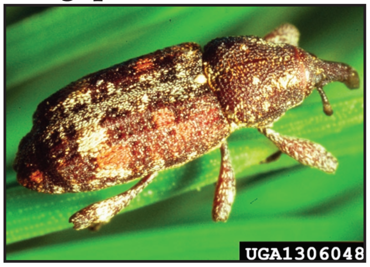


Figure 2-17.

Defoliators

Defoliating insect management requires effective monitoring and evaluation of pest populations in order to maximize suppression of those pests and prevent large outbreaks. Defoliation can easily be detected from the air or ground during outbreak years but early detection is possible by annual monitoring of adult males using sex pheromone sticky traps. Larvae can be monitored by sampling foliage in the lower crown of host trees. Increases in population density can then be detected and populations can be suppressed. When outbreaks are large, chemical control may be required, although it is usually not practical due to the expense and environmental impact. If pesticides are chosen they should be used on young larvae soon after emergence.

Many species of parasitic wasps, insect predators, birds, and small rodents feed on defoliating insects. These natural enemies, as well as disease and poor weather conditions, can keep populations low. However, when climate and forest stand conditions are favorable, outbreaks can occur and natural enemies have little effect on the population. Usually populations are then self-regulated by diminishing food supplies, leading to starvation.

Lepidopteran defoliating pest species in Montana are the Western spruce budworm (*Choristoneura occidentalis*), the Douglas fir tussock moth (*Orgyia pseudotsugata*), the Western false hemlock looper (*Nepytia freemani*) and the larch casebearer (*Coleophora laricella*) The most important defoliating hymenopteran pest is the pine sawfly (*Neodiprion nanulus contortae*).

The **Western spruce budworm** (Tortricidae: *Choristoneura occidentalis*) **(Fig. 2-18)** is one of the most destructive forest defoliators in Montana, defoliating a total of 454,176 acres in Montana during 2005 and 187,000 acres in 2004. The larvae attack Douglas fir, true firs and occasionally western larch and *Picea* species. Adults have mottled orange and brown wings folded flat over their body. The larvae are initially light green with brownish heads and become brownish with ivory-colored spots as they grow. Larvae mine into the needles and later enter the swelling buds. Indications of infestation: malformation, webbed branch tips, foliage discoloration, and foliage shedding **(Fig. 2-19)**. It takes approximately one year for the moth to complete its life cycle. Trees will recover if defoliation does not exceed two continuous years.

Figure 2-18.

Figure 2-19.

Douglas fir tussock moth (Lymantriidae: *Orgyia pseudotsugata*) adult males have brown forewings, grey hind wings, and feathery antennae. Females are wingless and have thread-like antennae **(Fig. 2-20).** Larvae (2 - 2.6 cm long) are colorful with black hairs projecting from the front and back and tussocks of hair on the first and fourth abdominal segments **(Fig. 2-21)**. Indications of infestation: brown and

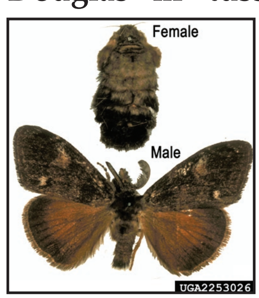


Figure 2-20.

shriveled new and old foliage, loose webbing, and defoliated crowns. Feeding can be economically damaging to Douglas fir and true fir stands during outbreaks. The outbreaks will end after about three years when the natural pathogen, nucleopolyhedrosis virus, acts upon the large moth density.

Figure 2-21.

Western false hemlock looper (Geometridae: *Nepytia freemani*) adults **(Fig. 2-22)** are mottled gray and black with a one-inch wingspan. Eggs overwinter in clusters on needles. Larvae **(Fig. 2-23)** emerge early in the season and feed on the underside of Douglas fir foliage causing the needles to shrivel and die. Not all of the needle is consumed. Regenerated, mature, and semi-mature trees can be completely defoliated during serious outbreaks that can last 1-3 years. They will also feed on western hemlock, Engelmann spruce, subalpine fir and ponderosa pine. The larvae are easy to distinguish with a wide ventral yellow stripe surrounded by several black stripes.

Figure 2-22.

Figure 2-23.

Larch casebearer (Coleophoridae: *Coleophora laricella*) adults (4 mm in length) are silvery-brown moths with narrow fringed wings **(Fig. 2-24)**. The moth is an introduced pest. They lay eggs during late spring and early summer on Western larch needles. The larvae (5-6 mm in length) mine into needles. Larvae create cases by hollowing out a portion of a needle, lining it with silk, and removing it from the rest of the needle **(Fig. 2-25)**. Pupation occurs in the case. Larvae can completely defoliate trees causing growth loss, branch die back, and possible mortality.

Figure 2-24.

Figure 2-25.

Pine sawfly (Diprionidae: *Neodiprion nanulus contartae*) adult females are yellow-brown; males are mostly black. They emerge in early fall, laying eggs in the cuts they make in the needles of lodgepole and ponderosa pines. The yellow-green black headed larvae **(Fig. 2-26)** hatch in late spring and are 10 mm in length when full grown. Larvae feed gregariously until mid-summer on old foliage, generally avoiding new needles. Needles may have chewed sections with missing tips or may be completely consumed. When the larvae are full grown they drop to the ground and pupate in papery, tough cocoons in the duff, or ground debris.

Figure 2-26.

Wood Borers

To avoid or at least minimize wood boring insect damage the timely and appropriate removal and storage of cut timber should be practiced. Methods of management include: **1)** rapid removal of timber from the field, **2)** avoid felling timber during egg-laying season, **3)** avoid storing timber in sort yards for an extended period of time, **4)** store logs in pond/watermist storage decks, **5)** keep storage away from forested areas, **6)** remove breeding and overwintering habitats away from storage area, **7)** pesticide application according to label directions once timber is cut.

Important wood boring beetles in Montana are the roundheaded borers (Cerambycidae), ambrosia beetles (Scolytidae), and the metallic wood borers (Buprestidae). Wood boring hymenopteran pests are the horntails (*Sirex* species).

Longhorned beetles (Cerambycidae: *Acanthocinus, Tetropium, Monochamus, Ergates, Opsimus, Prionus, Rosalia, Xylotrechus, Ortholeptura, Spondylis* species) adults **(Fig. 2-27)** are large beetles (larger than 20 mm in length) with colorful or patterned elytra and antennae as long or longer than the body. The larvae (roundheaded borers) are long and rounded at the front end **(Fig. 2-28)**. They feed on many western conifer species

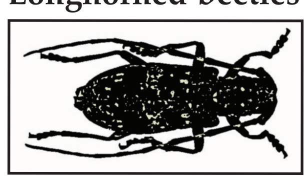


Figure 2-27.

by boring through the cambium into the sapwood. They are not considered major pests because they attack weakened, recently cut, or windthrown trees.


Figure 2-28.

Ambrosia beetle (Scolytidae: *Trypodendron, Gnathotrichus, Xyleborus, Platypus* species) adults **(Fig. 2-29)** are small (5 mm), cylindrical, and reddish brown to black. The larvae are small, white, and legless. They bore straight into the wood, feeding on introduced fungus that can cause staining. Galleries are produced in varying patterns depending on the species. Many western conifers are affected.


Figure 2-29.

Metallic wood boring beetle (Buprestidae: *Melanophila, Buprestis, Trachykele* species) adults **(Fig. 2-30)** are compact, bullet-shaped, often with a metallic sheen. The antennae are shorter than the body unlike the antennae of the longhorned beetles. Larvae (flatheaded borers) lack legs and are long with their front end widened and flat **(Fig. 2-31)**. The larvae attack many western conifers, through the cambium into the sapwood. Galleries are wide and winding with tightly compacted frass. Typically, they infest only weakened, recently cut, or wind thrown trees. A few species can damage small diameter healthy trees.


Figure 2-30.


Figure 2-31.

Horntail or wood wasp (Siricidae: *Sirex* species) adults **(Fig. 2-32)** have long cylindrical bodies, thick waists, horn-like tails, and two pairs of membranous wings that are unequal in size and shape. Females bore holes into old, diseased, or weakened trees with their long ovipositors and lay eggs. Most western conifers (*Abies lasiocarpa, Picea engelmannii, Picea glauca, Pinus ponderosa and Pseudotsuga menziesii*) are attacked. The larvae are cylindrical and yellowish white, with a pointed tail, a semi-spherical head, and small thoracic legs. The larvae mine into the wood creating circular galleries filled with boring dust.

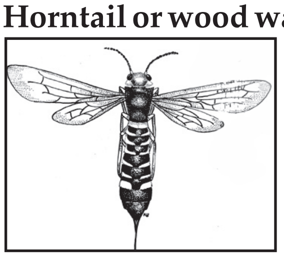


Figure 2-32.

FUNGAL DISEASES

Forest pathology includes the study of forest disease causes **(etiology),** spread **(epidemiology)**, impact and management. Recent studies have estimated that the economic losses from tree diseases may be higher than those of both insects and fire combined indicating that forest health and declines in stand are often most closely associated with forest disease. It has also been shown that diseases often affect the composition, structure and dynamics of plant communities and may play a role in creating suitable habitats and nesting sites for wildlife.

The pathogens causing disease symptoms are usually living organisms. Abiotic and decline diseases are caused by other factors. The biological pathogens that most commonly affect forests are viruses, bacteria, fungi, and nematodes**.** Like insects, pathogens are classified into specific groups with a scientific name for accurate identification. Please note: pathogens and diseases are not the same thing and should not be confused. Interacting pathogens, hosts and environmental factors (**Fig. 2-33)** produce specific diseases and varying disease symptoms.

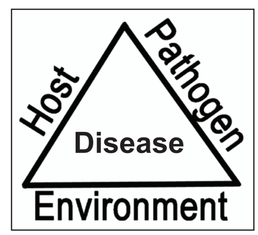


Figure 2-33.

Root Diseases

In Montana, root diseases significantly impact timber stands west of the Continental Divide. Riparian areas east of the divide can be affected–especially subalpine fir and white spruce stands. During 2005, root disease mortality occurred in more than one million of Montana's acres. Root diseases can also severely affect nursery trees. Important root disease pathogens are *Armillaria ostoyae*, *Phellinus weirii*, *Heterobasidion annosum*, *Phaeolus schweinitzii*, *Leptographium wageneri*, *Fusarium* species, and P*ythium* species. Douglas fir, grand fir, and subalpine fir are the most root disease susceptible tree species in Montana. Most pines, Western larch, and Western redcedar are fairly tolerant. Root disease crown symptoms include reduced leader growth, foliage discoloration, and thinning.

Armillaria root disease is one of the most common root diseases and affects the most acres in Montana. It is caused by the fungal pathogen *Armillaria ostoyae* (Marasmiaceae). Trees most susceptible are Douglas fir and firs (grand, white, red and subalpine). Other conifers may become infected during the first 15 years of growth. The root and root collar cambium are infected causing girdling and resulting in tree mortality often as groups or as scattered, individual trees. Symptoms of infection are those typical of most root diseases. Other more diagnostic indications include: resinous bark on the root collar and mycelial fans at the root base under the bark **(Fig. 2-33)**. Bark beetles will often invade secondarily. To manage for *Armillaria ostoyae*: **1)** remove infected stumps at the time of harvest and **2)** plant more resistant or poor-host species.

Figure 2-33.

Laminated root rot, caused by the fungus *Phellinus weirii* (Hymenochaetaceae), has three forms: Asian and North American Douglas fir forms, and a cedar form. The North American strain will infect *Abies*, *Tsuga*, *Picea*, and *Pinus* species but Douglas fir and grand fir are most susceptible, with western hemlock and subalpine fir less susceptible. Most other tree species are tolerant or resistant to the Douglas fir strain. The cedar form usually infects species of cedar. Laminated root rot significantly reduces commercial forest yield through mortality, growth reduction, and butt rot. **Butt rot** is the fungal decay of the root crown heartwood and does not directly kill the tree. Infected trees are more susceptible to windthrow and insect damage. Typical root disease crown symptoms apply. The most diagnostic sign of *Phellinus weirii* infection is the cream/dark yellow mycelium on the outer bark of the roots **(Fig. 2-34)**.

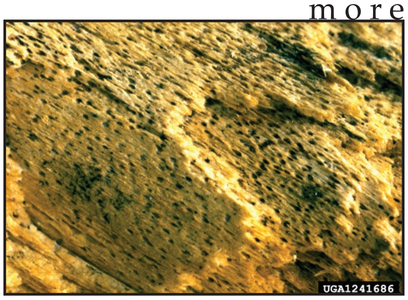


Figure 2-34.

Annosum root disease is caused by the fungus *Heterobasidion annosum* (Bondarzewiaceae). North America has two forms: the p-type infecting pine, incense cedar, hardwood and brush; and the s-type, occurring on other conifer species. All economically important conifer species, alder, and broad leaf maple are susceptible. The incidence of Annosus root disease and the ensuing damage (mortality and butt rot) in managed forests are related to the frequency and intensity of thinning. The roots of freshly cut stumps may be colonized by fungus airborne spores which can spread to adjacent healthy root contacts. Spores can infect stem wounds on thin-barked species such as hemlock and fir (*Abies* species). Typical root disease crown symptoms apply. An indicative sign of Annosus decay is yellow-brown to red-brown staining of root and stump heartwood **(Fig. 2-35)**. Prevention of annosus root disease at sites known to harbor the pathogen is recommended as cultural controls are not effective. Stump infection can be prevented by treating freshly cut stumps with granular Sodium Tetraborate Decahydrate or Disodium Octaborate Tetrahydrtae. There are only two borate products registered for annosus control.

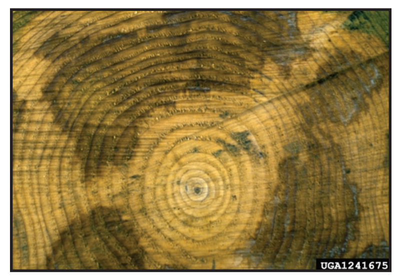


Figure 2-35.

Schweinitzii root and butt rot is caused by the fungal pathogen *Phaeolus schweinitzii.* It can infect all conifer species but Douglas fir is the most susceptible. Symptoms of infection are poor shoot growth and branch die back. Heartwood decay begins as a yellow stain progressing to red/brown cubical cracking that may leave a hollow butt **(Fig. 2-36)**. Trees are then more susceptible to windthrow and breakage.

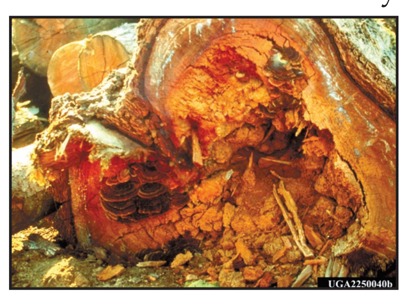


Figure 2-36.

Blackstain root disease is caused by the fungus *Leptographium wageneri.* Two varieties infect North American trees: *ponderosum* occurring on pines and spruce, and *pseudotsugae* on Douglas fir.

The root beetle *Hylastes nigrinus* appears to be the primary vector of the pathogen. Other beetles such as the mountain and western pine beetles are associated with infections. Typical root disease crown symptoms apply. The disease is indicated by dark brown/black stain along the annual rings in the roots and root collar sapwood **(Fig. 2-37)**. Blackstain is a **vascular wilt** disease that kills trees by disrupting xylem sap flow, causing wilting and other drought-like symptoms.

Figure 2-37.

Fusarium root rot is caused by several *Fusarium* species. The pathogen is a problem for both container and bareroot nurseries. It is spread by seeds, water, contaminated growing media, and used styroblocks. Heavier soils can also increase the incidence of infection. Douglas fir, lodgepole pine, and Engelmann and white spruce are most susceptible. White pine, western hemlock, and larch may also become infected. Needle symptoms include chlorosis, flaccidity and purple coloration, and browning **(Fig. 2-38)**.

Figure 2-38.

Pythium root rot is caused by fungal pathogens in the genus *Pythium* (Pythiaceae). Many plant species can become infected although mature tissue is seldom attacked. Bareroot and container seedlings are susceptible if the **1)** soil or growing medium drainage is poor, **2)** temperature is unfavorable for root development, or **3)** the same seedling species is grown in a field over several years. Symptoms include: poorly developed root systems, shoot stunting, and chlorosis **(Fig. 2-39)**. Soil fumigation or fungicide drenches in bareroot nurseries can be utilized. Fungicidal drenches can be used in containers. Root pieces left in bareroot nurseries and unsanitized growing containers can increase intensity of the infection over time.

Figure 2-39.

Foliage Diseases

Foliage diseases typically infect needles and leaves but will invade buds and young twigs. Young/small trees are more susceptible than large/mature trees. Trees are often infected when they are out of their native range, are in pure stands or dense stands, and are under 30 years old. Therefore, nurseries are typically infected. Most pathogens infect either foliage of the current season or older foliage, not both, so mortality is rare. Overall, needle diseases affected approximately 17,000 acres of Montana forest land in 2005. Important pathogens inducing foliage diseases are: *Lophodermella concolor, Elytroderma deformans, Botrytis cinerea Sirococcus conigenus* and *Meria laricis.*

Pine needle cast is caused by the fungal pathogen *Lophodermella concolor* (Rhytismataceae) and is restricted to two-needle pine species–primarily lodgepole pine. Indications of infection include: reddish foliage in May and June, turning straw-colored by July, old needles shed and new growth remains giving branches a "lion's tail" appearance, and **fruiting bodies** (shallow oval depressions on the needle surface) are formed on dead and dying needles **(Fig. 2-40)**. Defoliation usually occurs in years following moist summer weather. Young trees are most susceptible to repeated infections.

Figure 2-40.

Elytroderma needle blight, caused by the pathogen *Elytroderma deformans* (Rhytismataceae), is restricted to two- and three-needle pines, primarily lodgepole and ponderosa pine. It may also be found on other North American pines. Moist environments (e.g. near lakes and streams) have greater occur-

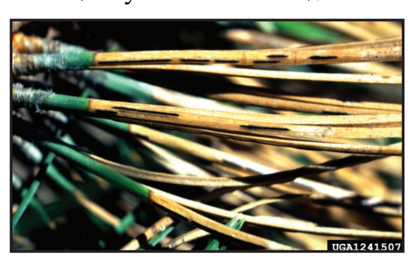


Figure 2-41.

rences of the diseases. Indications of infection appear in early spring following inoculation during the previous fall and include: flagging, tufted witches brooms, and small dark streaks (fruiting bodies) on the dead foliage **(Fig. 2-41)**. Growth reduction can result from defoliation. Branches and stems may become deformed. Young trees are the most susceptible but infected mature trees are more susceptible to root disease and/or bark beetle infestations.

Gray mold *(Botrytis cinerea)* occurs in container nurseries, rarely occurring in bareroot seedling production. This fungus has a wide host range and can be damaging to western hemlock, spruce, Douglas fir, and western redcedar seedlings. Nursery pines seem to be less affected than other species because they are smaller and have a more upright growth habit, limiting the within-canopy conditions that favor the disease. Infection can cause watery-moulding, killing of lower needles, leader, branches, and stems. Tan/brown watery lesions may also appear. The symptoms move upward and may eventually kill the entire shoot. **Gray mold** (mycelium and spores of the pathogen) is present on the dead tissue **(Fig. 2-42)**.


Figure 2-42.

Sirococcus shoot blight caused by the fungus *Sirococcus conigenus* affects Sitka, white and Engelmann spruce, lodgepole and ponderosa pine, Douglas fir, and, very rarely, western hemlock seedlings. The needles of infected seedlings may be green near the tip and dead needles are light to reddish brown. Fruiting bodies will form at the base of the diseased needles **(Fig. 2-43)**. The pathogen is seedborne but secondary transfer to uninfected seedlings can occur. To prevent spread of the disease, seedlots with the disease should apply a fungicide as soon as symptoms appear. Development of fungicide-resistant strains of pathogenic fungi such as *Botrytis* can occur, therefore prudent use of fungicides is encouraged. To decrease the chances of spread **1)** reduce humidity in greenhouses, **2)** increase temperatures, **3)** increase illumination (light-stressed seedlings are most susceptible) and if practical, **4)** diseased seedlings should be uprooted and burned.


Figure 2-43.

Larch needle cast is caused by the pathogen *Meria laricis* and affects many *Larix* species as well as seed-orchard Douglas fir. It is one of the most serious diseases of the container grown western larch. During early spring needles become infected, infection can continue to develop throughout the summer until late December if moisture levels are high. Symptoms begin on the lower part of the tree advancing upward as the disease progresses. Needles will become yellow and wilt becoming reddish brown over time, droop and fall off **(Fig. 2-44)**. Lesions on the needles can also be found. Sources of the disease are diseased needles from previous years and airborne spores from surrounding larch (or possibly Douglas fir) populations. To manage the disease **1)** trees should be removed (if feasible), **2)** container nurseries, greenhouses and other growing areas should be thoroughly sanitized, **3)** bareroot nurseries can be plowed or cultivated, and **4)** reduce watering as much as possible if the disease is present.


Figure 2-44.

Cankers & Stem Damage

Pine shoot blight is caused by the pathogen *Sphaeropsis sapinea.* Ponderosa pine is the primary host in west central Montana but other two- and three-needle pines can be infected. Mortality is rare because only the current-season needles, shoots, and seed cones are infected. However, seedlings of pine and white spruce may be killed. Symptoms of infection are stunted new shoots


Figure 2-45.

and flagged branches in the crown. Resinous stem cankers **(Fig. 2-45)** will form on infected stems at the youngest branch whorls and often on stems at the base of blighted needles. Fruiting bodies are found at the base of needles and cone scales. Infection increases the chance of attack by the pine engraver beetle.

Western gall rust is induced by the fungal pathogen *Peridermium harknessii* (Cronartiaceae) and infects two-needle pines (lodgepole, ponderosa, and jack pine) as well as many introduced pines. **Galls** (woody globose or asymmetrical swellings) will form on the branches and stems of one-year-old growth **(Fig. 2-46).** The bark of the galls will slough off in late spring, revealing orange-colored spores. Most infections of mature trees occur on the branches, therefore damage and growth loss is minimal. Gall formation on young trees is often on the main stems producing malformations, increasing the chance of breakage in high winds or under heavy snow loads.

Figure 2-46.

White pine blister rust is caused by the introduced (non-native) pathogen *Cronartium ribicola* (Cronartiaceae). It affects native five-needle or soft pines (whitebark, sugar, western and eastern white, limber, and Swiss stone pine). Exotic and ornamental soft pines may be infected. Alternate hosts include currants and gooseberries (*Ribes* species) as well as louswart (*Pedicularis* species). Young trees are most susceptible and are killed within the first few years of infection. Cankers are diamond-shaped, orange-colored and occur 2½ m off the ground. Older tree cankers are rough with resin. Top killing will usually occur. Another symptom of infection is indicated by the presence of dead branches (red flagging) in the lower portion of the crown **(Fig. 2-47)**.

Figure 2-47.

VEGETATION

Any vegetation that interferes with a forest program must be managed. Those plants that require management include any that are directly affecting and/or are in competition with the forest crop. Other reasons for managing vegetation in the forest environment are habitat restoration, prevention or management of noxious weeds, and the protection of endangered species.

Parasitic Plants

The roots of parasitic plants such as true (*Phoradendron*) and dwarf (*Arceuthobium*) mistletoes have roots that grow within a host plant where they access nutrients and water. True mistletoes photosynthesize sunlight, producing sugars but dwarf mistletoes do not. *Phoradendron* and *Arceuthobium* produce flowers that are pollinated by insects initiating seed set. There are several species of *Phoradendron* that are common to the Western U.S. but are of little importance in Montana. The seeds of *Phoradendron* are distributed by birds.

Dwarf mistletoes (Viscaceae: *Arceuthobium* species) **(Fig. 2-48)** grow on stems and branches of living conifers. The seeds produced by these plants are spread by hydraulic pressure within the plant's fruit structure. The seeds are shot from the fruit as far as 30 to 40 feet from the parent plant. The sticky coating on the seed helps it adhere to the host plant. Four species occur in Montana (*Arceuthobium americanum, Arceuthobium cyanocarpms, Arceuthobium douglasii, Arceuthobium laricis*) parasitizing specific conifers (lodgepole pine, limber pine, Douglas fir, whitebark pine, subalpine fir, and Western larch). Plants develop 3 years after the initial infestation, therefore surveys for mistletoe must consider latent infection. Symptoms of infection include: conspicuous brooms and swollen branches and stems at site of infection. Reduction of wood quality and growth (diameter and height) and mortality of the tree can occur. Dead tissue from infection can act as entrance points for stain and decay-producing fungi. Management of mistletoe is not possible with chemical and biological controls. Silvicultural controls such as clearcutting the usable tree crop and removing all other infected trees is an effective management strategy. If clearcutting is not possible, shelterwood or seed tree harvests are other possibilities. Thinning may be useful in lightly infested areas.

Figure 2-48.

Undesirable Vegetation

Vegetation that is undesirable are plants that may:

- Impede workers.
- Interfere with the survival and development of a desired tree species.
- Serve as fuel for wild fires.
- Inhibit prescribed burning.

A forester might undertake an undesired vegetation management program with one or more of the following objectives in mind:

- Removing unwanted vegetation from planting sites to favor the planted trees.
- Releasing more desirable species from less desirable overtopping species.
- Increasing survival, nutrition, and growth of newly planted trees by eliminating competition.
- Reducing rodent habitat and preventing rodent damage.
- Thinning excess plants from a stand.
- Preventing disease movement through root and foliage.
- Preventing invasion of herbaceous and/or woody vegetation into recreational areas and wildlife openings.
- Controlling vegetation along forest roads and around buildings and facilities.
- Eliminating poisonous plants from recreational areas.
- Controlling production-limiting plants in a seed orchard or tree nursery.

For example, if the objective for a site is to plant and grow conifer trees, then native shrub species that shade the trees may be considered undesirable until trees become taller than the shrub species. The shrubs are considered undesirable and require integrated pest management techniques such as herbicides, grazing, or fire to control the undesired plants and/or provide site preparation for conifer planting. Examples of undesired vegetation include:

Trees: undesirable hardwoods and conifers, including deformed and defective or undersized individuals of both commercial and non-commercial species. Large trees can occupy significant growing space within a stand. Trees reduce the economic value of otherwise healthy, desirable trees. They affect both small and commercial size trees within a stand.

Brush: including shrubs, small trees and woody perennials that prevent light from reaching tree seedlings and deprive taller commercial species of water and nutrients. It interferes with natural regeneration or planting and can create a habitat for rabbits and rodents that may damage newly planted stands. Over time, a build-up of brush in the understory can pose a fire hazard to the tree stand.

Vines: plants with climbing or creeping stems may drag down tree branches and crowns, and compete with desirable trees for light and nutrients. Vines have vigorous sprouting habits and are some of the most difficult weeds to control.

Herbaceous plants that retard the growth of conifer seedlings or other desired species. Tree seedlings competing with herbaceous plants may develop poorly or die, especially in time of drought. Herbaceous plants also create favorable cover for tree damaging animals such as mice, gophers and cotton rats. They pose the potential for loss of a new plantation by wildfire.

Weeds

Quantifying the damage caused by weeds to the environment can be difficult because many environmental resources are not measured in terms of dollars (clean water, native species, wildlife habitat). We can express damage as the cost to manage weeds but this does not address the actual environmental impacts. The infestations of spotted knapweed alone in Montana are estimated to cost $42 million annually. Costs include loss of forage for livestock, cost of management, and decreased land value. Plants commonly referred to as weeds have characteristics that give them the ability to spread and compete well with many cultivated and native plants. Most weeds have one or more of the following characteristics:

- Continuous seed production for as long as growing conditions permit;
- Unique ways of dispersing and spreading, including vegetative propagation and seed production;
- Ability of seeds to remain dormant in soil for long periods of time;

- Ability to grow under adverse conditions;
- Adaptation to a wide variety of soil and climatic conditions;
- Compete well for soil moisture, nutrients and sunlight; and
- Genetic adaptability, with a wide gene base for competition with beneficial plants.

Weed spread sources include humans, wind, water, and wild or domestic animals. Humans are the most effective agent in the dissemination of weeds. Most exotic weeds found in the United States are here due to the movement of humans and their products. Weed seeds are moved in hay and seed products; by machinery and vehicles; and in common carriers, railroads and trucks hauling cargoes of grain, hay, livestock, and other farm commodities. Movement along travel corridors scatters seeds along rights-of-way and highways, which become sources of infestation to adjoining fields. Humans may also plant weeds inadvertently if weed seeds contaminate seed used in revegetation efforts.

Wind spreads seeds over great distances. Many weed seeds have structural features which aid their distribution by wind. Some seeds have wings, like those of maple trees, or they may have long, silky hairs or parachutes attached to them such as milkweed (**Fig. 2-49a**) or Canada thistle. Tumbleweeds (e.g. Russian thistle) are especially adapted for seed dispersal when blown along the ground.

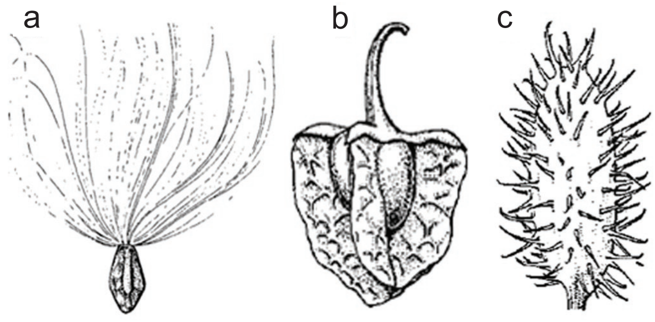


Figure 2-49.

Water also effectively spreads seeds. Most weed seeds will float if they fall on the surface of streams, lakes or irrigation canals. For example, curly dock seed has bladder-like floats to aid in dispersal (**Fig. 2-49b**). Flood waters, running streams, and irrigation water all contribute to spreading weed seeds. Irrigation canals, when first filled, often carry heavy loads of weed seeds downstream where they may be washed ashore or deposited in silt along the way.

Wild and domestic animals also aid in the dispersal of seed. The viability of most weed seeds is unaffected by passage through the digestive tracts of animals. Many weeds, such as cocklebur (**Fig. 2-49c**), sandbur, and beggar-ticks, have awns or hooks on the seeds that attach to the hair of animals.

When managing weeds, managers should be aware of the specific characteristics or traits of the weed or weed population that can affect management efforts. Weeds can have various **root structures and life cycles**. The success of an integrated forest pest management will require an identifying root structure or understanding the life cycle of the invasive plant in order to use the appropriate tools and timing to manage the weeds. The following are some of the common types of root systems and life cycles of weeds.

Weeds can have deep rhizomes (horizontal stems growing beneath the ground; (**Fig. 2-50a**) which can develop new roots or shoots, shallow fibrous roots (**Fig. 2-50b**), or tap roots **(Fig. 2-50c**).

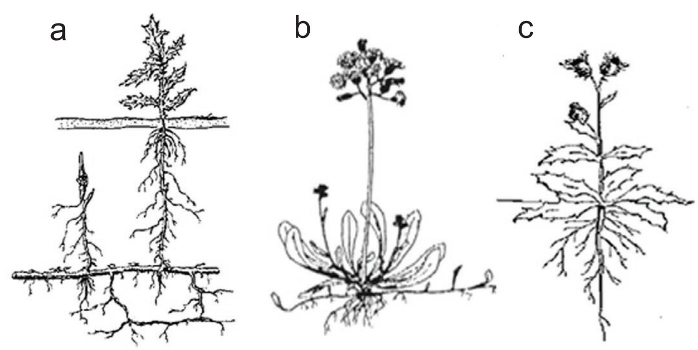


Figure 2-50.

The life cycle (or growth habit) of each weed species describes how long each plant lives and timing of development. **Annuals** complete their life cycle from seed to mature plant in less than one year. Summer annual plants germinate in the spring, flower and produce seed in mid-to-late summer, and die in the fall (**Fig. 2-51**) . Winter annuals germinate from late summer to early spring, flower and produce seed in mid-to-late spring and die in the summer **(Fig. 2-51**). Plant growth as a winter or summer annual often depends on geography and climate.

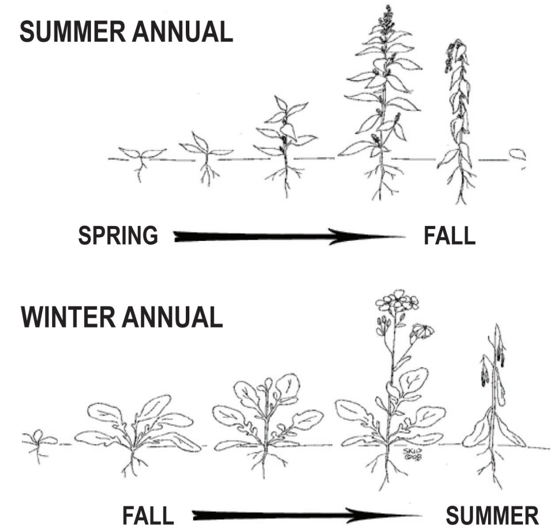


Figure 2-51.

Control methods should be taken to prevent seed production. Annual weeds are most susceptible to control in the seedling stage, prior to bolting. Kochia, lambsquarters, redroot and prostrate pigweed, Russian thistle, green and yellow foxtail, and crabgrass are all examples of summer annuals. Winter annuals include common chickweed, downy brome, field pennycrass and many other mustards.

Biennials live for two growing seasons. Seeds germinate in the spring, summer, or fall of the first year and plants overwinter as a basal rosette of leaves with a thick storage root. Plants flower and produce seed the summer of the second year and die in the fall (**Fig. 2-52**). Common biennials include common mullein, burdock, houndstongue, bull thistle, and musk thistle. Effective control of biennial plants is very similar to control for annuals. Early spring or fall spraying of the rosette is an effective time for control.

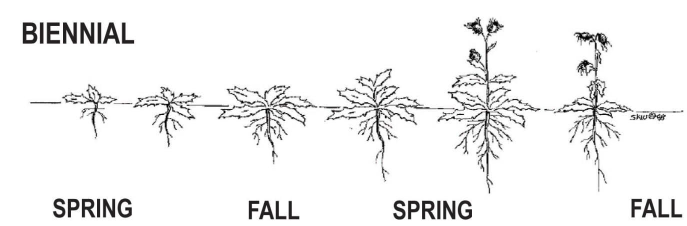


Figure 2-52.

Perennials produce vegetative structures, allowing them to live for more than two years. They reproduce by seed in addition to spreading vegetatively. Simple perennials overwinter by means of a vegetative structure, such as a perennial root with a "crown," but they reproduce almost entirely by seed (**Fig. 2-53**). Dandelion and spotted knapweed are common examples of simple perennials.

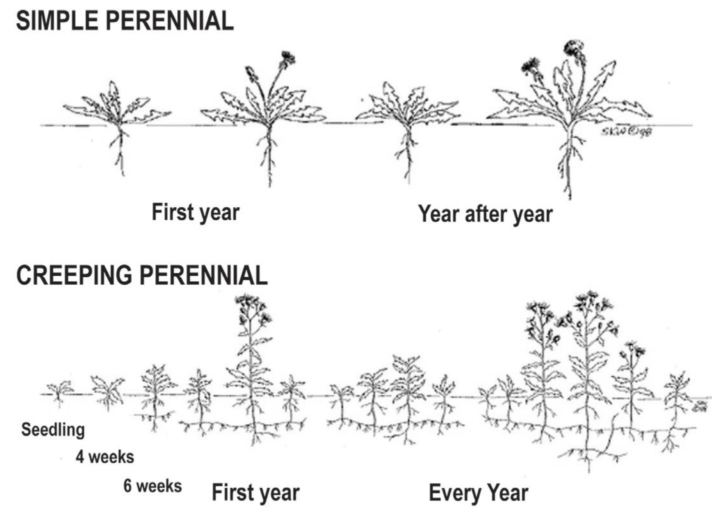


Figure 2-53.

Creeping perennials overwinter and produce new, independent plants from vegetative reproductive structures. These structures include rhizomes, tubers, bulbs, stolons and creeping roots. Most creeping perennials can also reproduce and spread from seeds (**Fig. 2-53**). Quackgrass, Canada thistle, leafy spurge and field bindweed are creeping perennials.

Management of annual and biennial weeds must be accomplished before the plant produces seed. Control is most effective when the plant is in the seedling stage actively growing, but prior to flowering. During the vegetative stage control is possible but more difficult since the plant is putting energy into the production of seeds. Chemical control of annuals during the flowering stage is not feasible because most of the plant's energy is going into seed production. Often flowering annual plants will set viable seed even after control methods are applied if they are applied at a later stage of development. Maturity and seed set completes the annual plant life cycle. Control is not effective at this stage.

Perennial weed control should be aimed at either the seedling or the regrowth stages of development. Chemical control during the vegetative growth stage is less effective. However, control is more effective at the bud stage than the flowering stage. Chemical control at maturity is not feasible since the above ground portions of the plant die back at this time. Fall treatment of regrowth is very effective because the plant is translocating nutrients to the root system and will also translocate herbicide to control the roots. To achieve effective control of perennials, underground plant parts must be controlled. Long-term management is essential for effective control. For more information on weed management, read the Forest Pest Management section, starting on p. 30.

Noxious weeds are invasive plants that cause economic and/or environmental impacts. They are a landowners' legal responsibility to control per the Montana County Noxious Weed Control Act. Noxious weeds are further defined by this act as being any exotic plant species which may render land unfit for agriculture, forestry, livestock, wildlife or other beneficial uses or that may harm native plant communities. Plants can be designated statewide noxious weeds by rule of the Department of Agriculture or county-wide noxious weeds by district weed boards following public notice of intent and a public hearing. Currently, Montana has 27 state-listed noxious weeds (Appendix B).

One common objective for forestlands is to manage for wildlife species and their habitat, including ungulates and bird life. The presence of noxious weeds can interfere with this objective by displacing native plants that provide wildlife shelter and food. For example, leafy spurge is known to reduce habitat usage by deer and elk, and spotted knapweed can decrease forage for grazing animals and influence foraging behavior and ungulate population distribution. Similarly, noxious weeds can impact bird habitat and small mammals. For example, weeds such as Russian knapweed can reduce small mammal populations by altering the native plant communities that the small mammals need.

To manage forest lands efficiently, it is necessary to reduce the impacts of noxious weeds. Noxious weeds dominate millions of acres in Montana, causing environmental and economic damages that can interfere with forest management. For example spotted knapweed can degrade soil and water resources by increasing sedimentation, reducing wildlife habitat and forage, and decreasing the density, biomass, and basal area of desired native plants. Noxious weeds can also serve as a source or alternate host of plant diseases and insect pests.

Noxious weeds that could invade forest lands include *Cirsium arvense*, *Acroptilon repens*, *Centaurea maculosa, Centaurea diffusa, Potentilla recta, Euphorbia esula, Linaria dalmatica, Linaria vulgaris, Tanacetum vulgare, Chrysanthemum leucanthemum, Cynoglossum officinale, Hieracium aurantiacum, Hieracium pratense*, *Hieracium floribundum*, *Hieracium piloselloide.* For a complete list of Montana's noxious weeds, see Appendix B. In addition, *Echium vulgare* (blueweed) is a new invader and currently being considered as an addition to Montana's noxious weed list.

Canada thistle (Asteraceae: *Cirsium arvense*) (**Fig. 2-54**) is a colony forming perennial with an extensive horizontal and vertical root system. It can reproduce either vegetatively through rhizomatous roots or from seed. It commonly invades pastures, meadows, and waste places with rich, heavy soils and is present in every county in Montana. The rosettes have spin-tipped, wavy leaves. As the plant develops, the leaves become more lobed and the spines become more prominent. The stem leaves are alternate, lance-shaped, lobed, spine-tipped and lack stalks. The stems are erect, ridged, one to four feet tall, often branched, slightly hairy, and lack spines. Flowers are usually purple (sometimes white) in heads ½ to ¾ inch in diameter and form clusters at the end of branches. Canada thistle flower heads often appear much smaller than most other thistles. Many bracts are present beneath the petals but spines are absent or consist of weak prickles. The long, flattened seeds have tufts of white hairs at the top for dispersal.

Figure 2-54.

Russian knapweed (Asteraceae: *Acroptilon repens*) (**Fig. 2-55**) is a rhizomatous perennial forb found throughout Montana. It commonly invades disturbed sites including roadsides, riverbanks, clear cuts, and croplands and is not often found in healthy natural habitats. Once established, Russian

Figure 2-55.

knapweed forms dense colonies due to the creeping adventitious shoots branching off the black, bark-like roots. The basal leaves are toothed and covered with fine hairs making them appear grayish-green in color. One to many stems grow from the basal rosette and can grow to 3 feet tall. The leaves on the lower stem are deeply lobed and two to four inches long. The leaves on the upper stem are narrow, toothed, and up to 2 ½ inches long. A solitary, purple flower head can develop at the tip of each leafy branch with individual plants producing as many as 200 flower heads. The bracts of Russian knapweed have no black spot, spines, or sharp tips. The distinctive characteristic of the bracts are their rounded papery tips. The flowers generally bloom from June to August.

Spotted knapweed (Asteraceae: *Centaurea maculosa*) (**Fig. 2-56**) is found in every county in Montana with the heaviest infestations in the western part of the state. It is often found in disturbed grasslands, shrublands and open forestlands and along roadsides. The basal rosettes of spotted knapweed have deeply-lobed, grayish-green leaves up to 6 inches long which radiate from a common center point. The stem leaves are finely divided into linear segments. One to many highly branched stems grow out of the rosette with heights ranging from one to four feet. One pinkish-purple flower head develops on the end of each branch of the stem, allowing individual, highly-branched plants to produce as many as 300 flower heads. The bracts, under the petals, have dark, fringed tips which appear as multiple spots and give this noxious weed its characteristic name. Unlike diffuse knapweed, spines are not well developed on the bracts. The flowers produce black seeds about 1/8 inch long. Spotted knapweed has a deep taproot which is relatively easy to distinguish from the rhizomatous roots of Russian knapweed.


Figure 2-56.

Diffuse knapweed (Asteraceae: *Centaurea diffusa*) (**Fig. 2-57**) is a highly competitive annual, biennial, or short-lived perennial which invades disturbed or overgrazed lands, however it can also be found in undisturbed grasslands, shrublands, open forests, and riparian communities. The seedlings of diffuse knapweed have finely divided leaves with small hairs. Mature leaves are divided into linear segments, broadly lance-shaped in outline, grayish-green in color, and covered with a thin layer of wooly hairs. The leaves radiate from a common center point in the young plant. One to many sparsely hairy stems grow out of the basal rosette and are rough textured. The bracts, located under the flower petals, form stiff, cream-to-brown colored spines divided into spreading comb-like teeth. Also, the absence of a black spot on the bract distinguishes diffuse knapweed from spotted knapweed. The white, or occasionally pink, flower head, and the characteristic bracts, distinguish diffuse knapweed from other knapweed species. The fruits are brown or grayish and the plant is tap-rooted.

Figure 2-57.

Sulfur cinquefoil (Rosaceae: *Potentilla recta*) (**Fig. 2-58**) is a rapidly spreading perennial forb that is adapted to a wide range of environmental conditions. It invades grassland and open-forest communities where it displaces native vegetation including native cinquefoils. Sulfur cinquefoil has a single taproot. It may have several spreading roots but no rhizomes. The leaves are palmately compound with five to seven toothed leaflets which radiate from a center point. Relatively few leaves are attached at the base of the plant. Most of the leaves grow along the length of upright stems. Leaves are attached to the stem by a stalk, with the leaf-stalk length and leaf size decreasing upward on the stem. Conspicuous, pointed hairs protrude outward at right angles from the stem and leafstalks. A single to several erect stems may reach one to two feet tall, possible branching, with a terminal, multi-flower inflorescence. Flowers have five light yellow petals with deeply notched tips and a yellow flower center. Three obvious characteristics distinguish sulfur cinquefoil from other cinquefoils. Leaves of sulfur

Figure 2-58.

cinquefoil appear green on the underside rather than silvery, sulfur cinquefoil's seeds are ridged while other cinquefoil's seeds usually are not, and sulfur cinquefoil has comparatively more stem leaves and fewer basal leaves than other *Potentilla* species.

Leafy spurge (Euphorbiaceae: *Euphorbia esula*) (**Fig. 2-59**) is a long-lived and aggressive perennial forb. It is suited to a wide variety of habitats and grows primarily in untilled soils including pastures, rangelands and woodlands. It is present in every county in Montana. It reproduces both vegetatively and by seed. Rootstalks can reach depths of more than 14 feet and have pink buds, which develop into new shoots. Stems of leafy spurge are one to more than 3 feet tall and have alternate, narrow, one to four inch long simple leaves. Both the stems and the leaves contain a white, milky sap. The flowers are yellowish-green, small, and arranged in many small clusters containing seven to 10 flowers. Although the flower is relatively inconspicuous, it is subtended by showy, heart-shaped yellow bracts which are often mistaken as the flower. Seeds are oblong, grayish to purple, and borne in a three celled fruit. Capsules containing the seeds burst open with force when ripe, propelling the seed and aiding in dispersal.


Figure 2-59.

Dalmatian toadflax (Scrophulariaceae: *Linaria dalmatica*) (**Fig. 2-60**) is an herbaceous perennial forb that was introduced as an ornamental and has escaped cultivation and is now most commonly found along roadsides, fences, range lands, croplands, open forests, clear cuts, and pastures. Dalmatian toadflax is an aggressive invader of disturbed soils and forms colonies capable of displacing native vegetation. Dalmatian toadflax reproduces by seed and a rhizomatous root system. Leaves and stems are waxy and a whitish to bluish shade of green. Heart-shaped leaves are alternately arranged on the stem, have smooth edges, and clasp around the stem. The robust stems grow to three feet tall with flowers developing at the base of the upper leaves. The snapdragon-like flowers are bright yellow, have an orange throat and a long spur. Irregular angled seeds are produced in the 2-celled capsule.


Figure 2-60.

Yellow toadflax (Scrophulariaceae: *Linaria vulgaris*) (**Fig. 2-61**), also called butter-and-eggs, is similar to Dalmatian toadflax. It is an aggressive competitor commonly found along roadsides, fences, range lands, croplands, clear cuts, open forest lands, and pastures and is capable of stressing native plant communities. It can adapt to a wide range of environmental conditions. Yellow toadflax reproduces by seed and rhizomes allowing it to quickly colonize a site. Stems are 8-24 inches tall and are usually not branched. Leaves are numerous, pale-green to gray-green in color, and are individually connected to the stem. Long (2½ or more inches), narrow leaves are pointed at both ends, have smooth edges, and are alternately arranged on the stem. Although leaves resemble those of leafy spurge, yellow toadflax does not produce milky sap. The snapdragon-like flowers grow on short stalks (¼ inch long) in dense clusters at the top of stems. Flowers (1 to 1¼ inches long) are yellow with an orange throat and a downward pointing yellow spur (1 inch long), and bloom from June-July.

Figure 2-61.

Common tansy (Asteraceae: *Tanacetum vulgare*) (**Fig. 2-62**) is an aromatic perennial forb which reproduces by seed or rootstalks. It invades disturbed sites and is commonly found along roadsides, trails, fence rows, pastures, stream banks and waste areas. Common tansy grows one to six feet tall and the stems are often purplish-red. On the stem, leaves are alternate and hardly vary in size, they are deeply divided into leaflets with toothed margins. Yellow-orange, button-like flower heads which lack long petals are numerous (20 to 100) in flat-topped, dense clusters on the terminal stem. The yellowish-brown seeds

Figure 2-62.

have five-toothed ridges. Common tansy, originally from Europe, was introduced to the United States for its ornamental and medicinal qualities and has escaped cultivation.

Tansy ragwort (Asteraceae: *Senecio jacobaea*) is a tap-rooted biennial or short-lived perennial currently found in northwestern Montana (**Fig. 2-63**). It can be found in disturbed areas including creek bottom lands, pastures, forest clearcuts and openings, overgrazed pasture, and along roadsides. The rosettes of tansy ragwort consist of 10 to 20 leaves, with web-like hairs, which are directly attached to the main stem. Basal leaves are two to 10 inches long, irregularly lobed into leaflets with the leaflets lobed again. The terminal leaf lobe is the largest and longest. On the stem, leaves are alternately arranged, evenly distributed, and decrease in size up the stem. When leaves are crushed they give off an unpleasant odor. Tansy ragwort is generally one to three feet tall but may reach six feet. Stems and leaf stalks are often purplish and have cobwebby hairs. The stems may be several or solitary and may branch near the terminal inflorescence. The daisy-like flower heads have yellow petals and a yellow center, are less than an inch in diameter, and are clustered on the terminal stem.

Figure 2-63.

Oxeye daisy (Asteraceae: *Chrysanthemum leucanthemum*) (**Fig. 2-64**) is a showy perennial forb which was introduced from Eurasia as an ornamental. Since introduction, it has escaped cultivation partly due to its success at spreading by rhizomes and seed. It is an aggressive invader of pastures, meadows and roadsides and can be found in high elevation meadows. The basal and lower stem leaves are on long narrow stalks. These leaves have rounded teeth, are two to five inches long and are widest at the tip. Upper stem leaves become progressively smaller, have no stalk, and are toothed. The mature plant is typically one to two feet tall with single flower heads on each simple or once-branched stem. Stems are smooth to sparsely hairy. Flower heads, one to two inches in diameter, consist of white ray flowers (long petals) and yellow disk flowers (center of flower head). The flowers have no odor and produce ribbed seeds.

Figure 2-64.

Houndstongue (Boraginaceae: *Cynoglossum officinale*) (**Fig. 2-65**) is a shade tolerant, biennial forb that can be found growing in disturbed pastures, meadows, waste places, roadsides, trails, riparian areas and forested land. It can rapidly colonize disturbed sites when its bur-like seeds spread via hair, wool or clothing. Houndstongue forms a rosette in the first year of growth and produces a flowering stem the second year. The rosette is comprised of large (up to 12 inches long), velvety leaves which lack teeth or lobes and are rough to the touch (resembling a hound's tongue). The flowering stem grows one to four feet in height, has alternate leaves which get smaller higher on the stem, and branches near the apex. The terminal branches are where the flowers develop. As the plant matures, the terminal, scorpion-tail-shaped portion of the branch unrolls and displays the flowers. The five petals of the flowers are reddish-purple and unite at the base. The seeds of each flower consist of four bur-like, adhesive nutlets, commonly about $^{1}/_{3}$ inch long.

Figure 2-65.

Orange hawkweed (Asteraceae: *Hieracium aurantiacum*) (**Fig. 2-66**) is a competitive perennial weed species that can quickly form dense monocultures. It is found primarily on native meadows, forest openings, permanent pastures, hayfields, roadsides and right-of-ways. Orange hawkweed spreads by seed and by a shallow, fibrous

Figure 2-66.

root system. In the vegetative stage, the basal rosette consists of narrow, spatula-shaped, hairy leaves four to six inches long with darker green on the upper surface. The largely leafless flowering stems range from one to three feet in height with occasionally one to three small leaves present. Bristly hairs are present on the leaves and stems and the entire plant contains a milky juice. Five to 30 flower heads form a compact, umbelliform inflorescence on the terminal stems. Flower heads have red-orange petals with notched tips.

Meadow hawkweed complex (Asteraceae: *Hieracium pratense*, *Hieracium floribundum*, *Hieracium piloselloide*) (**Fig. 2-67**) are a large problem in Montana. These three -petaled yellow species have been highly successful at spreading because of their ability to reproduce by seeds, rhizomes, stolons, and adventitious root buds. The species of the meadow hawkweed complex are similar in appearance to orange hawkweed. The roots are shallow, fibrous and creeping. Basal rosettes have hairy, narrow, spatula-shaped leaves which are dark green on top and light green below. A rosette can produce 10 to 25 flowering stems which can grow up to three feet tall. The stems are covered with short, stiff hairs and few, if any, leaves. The entire plant contains a milky juice. Five to 30 bright yellow, dandelion-like flowers make up the inflorescence. The three species of the meadow hawkweed complex are difficult to distinguish because they interbreed. However, introduced hawkweed species can usually be distinguished.

Figure 2-67.

Blueweed (Boraginaceae: *Echium vulgare*), also known as common viper's bugloss is a new invasive weed in Montana (**Fig. 2-68**). It is currently present in eight counties in Montana, most of which are in the western part of the state. Blueweed is a biennial introduced as a garden plant and grows well in overgrazed pastures and open forests where it replaces more desirable species. Blueweed has a taproot which can produce several stems. First-year plants produce a basal rosette of long, narrow, bristly leaves. The leaves are alternate, narrow to lance-shaped and covered with long, stiff hairs with an enlarged red or black base. Stem leaves get smaller in size up the stem. Stems are reddish, up to 90 cm tall and covered with bristly hairs with swollen red or black bases. The flowering stem is bristly haired throughout. The flowers are blue, funnel-shaped, about two cm wide, and appear on one side of the stem. Flowers are reddish purple in bud, are composed of five sepals, petals, long stamens, and one hairy pistil. The flower stalks are shorter than the sepals. Each flower produces four seeds. The seeds, often referred to as nutlets, are angular, grayish brown and about three mm long.

Figure 2-68.

PRACTICE QUESTIONS

1. What differentiates beetle and lepidoptera larvae:

A. Prolegs
B. Crochets
C. 3 pairs of thoracic legs
D. Both A & B

2. In general, defoliation by insects occurs during the ____ stage.

A. Adult
B. Larval
C. Egg laying
D. Both B & C

3. The development of flagging, tufted witches brooms, and small dark streaks on the dead foliage are signs of:

A. Dothistroma Needle Blight
B. Elytroderma needle blight
C. Canker
D. Tip Moth

4. Disease and insect control problems are more severe in ____.

A. Single species, same age forests
B. Mixed species forests
C. Central USA
D. High elevations

5. Weed trees can include _____.

A. The non-commercial species
B. Those outside their native area
C. Defective or deformed
D. All of the above

6. Defoliator insects have natural controls. These include:

A. Wasps
B. Decreased food supplies
C. Rodents
D. All of the above

7. Bark beetles feed on ___ in their ____ stage.

A. The bark - Adult
B. The bark - Larvae
C. Foliage - Larvae
D. Cambium layer - Larvae

8. Disease control in forests (not nurseries) on a practical, effective and pesticide availability basis is limited to _____.

A. Fumigants
B. Fungicides
C. Pruning
D. None of the above

9. The best protection from bark beetles in forest stands is _____.

A. Silviculture methods that increase tree vigor
B. Pesticide applications
C. Prevention
D. Both A & C

10. Signs giving evidence that a tree is being attacked by the Armillaria shoestring root rot fungus include:

A. Conks on the side of the tree
B. Ooze coming out of tree cracks
C. Honey-colored mushrooms, rhizomorphs ("shoestrings"), and mycelial fans
D. Many lichens on the tree trunks

11. What do most fungi require to attack a tree successfully:

A. Weakened tree
B. Insect vector
C. Wounds
D. Drought conditions

12. Root and butt rot causes wood to ________________.

A. Break into small squares
B. Disintegrate into powder
C. Calcify
D. Splinter easily

13. An occasional pest is one is which

A. Causes major damage regularly
B. Occurs when controlling another pest
C. Causes damage irregularly
D. Always causes problems

14. Fir engraver beetles infest:

A. *Abies* species
B. Occasionally *Tsuga* species and *Picea* species
C. *Pinus* species
D. Both A & B

15. One management method for terminal weevils includes:

A. Planting pure dense stands
B. Sanitation clipping
C. Plant a mix of host and non-host trees
D. Of the above

16. This insect mines into the expanding bud and pupates in the pith:

A. white pine weevil
B. Lodgepole pine weevil
C. western pine beetle
D. western spruce budworm

17. What is the study of forest disease causes?

A. epidemiology
B. silvics
C. etiology
D. ecology

18. Laminated root rot is a disease caused by the pathogen:

A. *Phellinus weirii*
B. *Armillaria ostoyae*
C. *Phaeolus schweinitzii*
D. *Fusarium* species

19. Signs and symptoms of an infection are caused by an interaction between:

A. Pathogen and host
B. host, pathogen, environment
C. Environment and pathogen
D. Disease, pathogen, environment

20. Nucleopolyhedrosis virus acts upon large densities of the:

A. Douglas fir moth
B. Western spruce bud
C. Western false hemlock
D. Larch casebearer

21. Noxious weeds are:

A. Invasive plants that cause economic and/or environmental impacts.
B. A landowners' legal responsibility to control.
C. An exotic plant species which may render land unfit for agriculture or forestry.
D. Plants that have the ability to dominate an area.
E. All of the above.

22. Plants commonly referred to as weeds have characteristics that give them the ability to spread and compete well with many cultivated and native plants. Most weeds have at least one the following characteristics:

A Seed production for as long as growing conditions permit.
B. Seeds are short-lived in the soil.
C. Plants adapted to specific soil and climatic conditions.
D. Poor competitors for soil moisture, nutrients and sunlight.

23. The success of an integrated forest pest management will require identifying root structure or understanding the life cycle of the invasive plant in order to use the appropriate tools and timing to manage the weeds.

A. True
B. False

24. Control of annual and biennial weeds is most effective when the plant is in the seedling stage actively growing, but prior to flowering.

A. True
B. False

25. For optimal perennial weed control, weed treatments should be applied at either the vegetative growth or plant maturity stages.

A. True
B. False

26. **S**potted, Russian, and diffuse knapweed can all be distinguished from each other based on the characteristics of their _____________.

A. Roots
B. Bracts
C. Leaves
D. Insect pollinators

27. You think there is an infestation of either leafy spurge or yellow toadflax in your forest management unit but there are no flowers for identification. What key characteristic distinguishes these two noxious weeds in the vegetative stage?

A. Leafy spurge has linear leaves and yellow toadflax has heart-shaped leaves.
B. Leafy spurge leaves contain a white, milky sap.
C. Yellow toadflax leaves contain a white, milky sap.
D. They cannot be differentiated in the vegetative stage.

28. Which species does NOT reproduce by rhizomes, lateral roots or rootstalks?

A. Dalmatian toadflax
B. Oxeye daisy
C. Common tansy
D. None of the above

III. FOREST PEST MANAGEMENT

Forest pest management requires accurate pest identification and knowledge of pest biology and life history combined with long-term silvicultural practices. Once pests are identified and monitored regularly, control methods can be reviewed and evaluated to determine their economic and environmental benefits and costs. The effects on threatened or endangered species as well as other non-target organisms must be taken into consideration. The control practice can then be carried out following local, state and federal regulations while keeping accurate records of all methods employed.

An important principle of pest management is to use a control method only when necessary to prevent unacceptable levels of damage. Even though a pest is present, it may not be necessary to control it. Costs of control may be greater than damage or losses.

Pest management practices are often described according to the approaches used to manage a pest problem. These approaches include:

- Prevention
- Suppression
- Eradication

Prevention is action that is taken to thwart the occurrence of a significant pest problem. Prevention is the most effective and economical approach to pest management. This approach may include either chemical or non-chemical methods. Prevention involves **a)** encouraging natural enemies of the pest, **b)** monitoring pest populations and other relevant factors, and **c)** using resistant stands before pest numbers increase and cause economic damage.

Five general goals of prevention are:

1) minimizing pest spread by quarantining imported plants and animals to prevent the introduction of foreign diseases and insects; using certified weed free hay, seed and mulch on forest lands, and washing vehicles to prevent the spread of noxious weeds.

2) containing existing pest infestations by restricting the encroachment of the pest onto adjacent pest-free lands. To contain the spread of pests, avoid, remove or manage pests to prevent reproduction in travel corridors where humans may inadvertently transport the pest, and manage infestation borders to concentrate efforts on the advancing edge of the infestation.

3) minimizing disturbance of the area under management. Many invasive weed species such as Russian knapweed and Dalmatian toadflax readily invade disturbed soils; bark beetle infestations have been linked to unkept slash, roads, and housing developments.

4) maintaining a healthy balanced ecosystem is also important; healthy trees are less susceptible to insects and disease, and competitive desirable vegetation inhibits weed invasion.

5) education of land users and owners on the impacts and prevention of pests such as invasive plants and western spruce budworm can help prevent the spread of forest pests and overuse of pesticides. Education programs can also help provide additional manpower in detection and reporting of new pests.

Suppression of pest populations through management efforts reduces pest numbers below an economic injury threshold but does not eliminate them. Suppression sometimes lowers pest numbers so that natural enemies are able to maintain control. Suppression is the goal of most pesticide applications used to manage weeds, insects and diseases. Post emergence application of herbicides to reduce emerging weed populations is regarded as suppression. Spraying mature spotted knapweed plants with 2,4-D may not kill the mature plants, but it will limit seed production and possibly kill younger, more susceptible plants. For more information on suppression techniques, see the following section on Iintegrated Pest Management.

Eradication completely eliminates a pest from a designated area. For vegetation, this includes depletion of the pests' propagules from the soil. A key element in an eradication plan is early detection and rapid response methods. If a pest is detected and a management plan is rapidly employed, then the pest may be eliminated. For example, if a new pest such as the Mediterranean fruit fly is detected in a fruit growing area, regulatory agencies may implement widespread actions to totally eliminate the pest before it becomes established to a point that it can no longer be eradicated. Eradication programs are most effective on small infestation because it is still feasible to treat them with highly efficacious methods with limited expense. Over larger areas, eradication is a radical approach to a pest problem and can be very expensive and often has limited success. In general, eradication does not work towards the elimination of an established pest population that is spread over a large area.

The pest control strategy chosen depends on the nature of the pest, the environment of the pest, and economic considerations. Combining prevention and suppression techniques usually enhances a pest management program. However, objectives might differ for the same pest in different situations. Eradication of spotted knapweed in most of western Montana is not feasible, where eradication in parts of eastern Montana is justifiable where the weed is not prevalent.

As with any pest management activity, a cohesive, carefully designed eradication plan will increase the chances of achieving management goals. An eradication effort should include early detection ability, careful site monitoring (survey/inventory), highly effective control methods, public education, adequate funding, and clear lines of communication to all invested individuals. Early detection and rapid response prevents reproduction that can lead to further spread. Continued monitoring of sites to treat pests that were missed, or germinated from the seedbank, is also critical for eradication.

INTEGRATED PEST MANAGEMENT (IPM)

A variety of pest management techniques – herbicide, biological control, mechanical and cultural – can be implemented to negatively impact forest pests. Integrating two or more management techniques holds the most promise for long-term success. Integrated pest management (IPM) is a pest control strategy that deliberately uses a combination of management techniques to reduce pest populations to economically acceptable levels. IPM focuses on the long-term prevention, eradication, or suppression of pest problems. IPM uses cultural, biological, physical, and mechanical methods in site-specific combinations. With IPM, pesticides are used only when careful field monitoring, based on economic threshold levels, indicates they are needed. Pesticides are then selected on the basis of their effectiveness and toxicity. The main aim of IPM is to control only the harmful pests without affecting beneficial and non-target organisms, human health and the environment. Integrated pest management offers the possibility of improving the efficacy of pest control programs while reducing some of the negative effects. Many successful IPM programs have reduced energy and pesticide usage.

There are many ways to manage pests. Whenever possible, it is best to combine several methods into an integrated pest management program. Pest management techniques include:

- Biological Control
- Chemical
- Cultural & Mechanical
- Regulatory

Biological control generally includes the manipulation of one biological organism to control a pest organism. Most insect pests are attacked by other arthropods (insects, spiders, mites), and bacterial, fungal or viral pathogens. Specific weeds may be controlled by insects with specialized feeding habits.

When a non-native pest is found in a given area, it may be assumed that the biological organisms that regulated its population in its native environment are lacking. In such a situation, the classical approach of biological control is employed to **1)** determine the pest's native home, **2)** locate beneficial organisms that naturally control the pest organism in its native area, and **3)** if feasible, import, multiply, release and establish the beneficial organisms in the problem area to facilitate biological regulation of the pest problem. If successful, the importation and establishment of the beneficial organisms will result in a long-term reduction of the pest problem and repeated releases of the beneficial organisms will not be required.

When existing or already-introduced beneficial biological organisms are mass-reared and released periodically to supplement the naturally occurring or classically-introduced biological agents, the approach is called augmentation. The mass-rearing of yellow-winged knapweed rootmoth (*Agapeta zoegana*) and the knapweed root weevil (*Cyphocleonus achates*) in cages prior to release is an example of augmentative biological weed control.

Pest populations can also be maintained by a number of native, naturally-occurring predators, parasites and diseases. If such forces were not in effect, we would be overrun by pests. The balance of pest populations and their natural enemies can be significantly influenced by cultural practices and the use of chemicals. Populations of natural enemies can be enhanced by selective use of cultural practices or decimated by the indiscriminate use of pesticides. In some cases, pesticides have been developed that effectively control a pest population without having a significant effect on beneficial species.

Chemical controls are the most readily recognized method of pest management. The range of risks and benefits attributed to pesticides will remain a key issue of society. The use of pesticides will remain as a dominant method to be incorporated in future pest management programs. Pesticides are tested and labeled for specific pests, crops and for land-use situations. Use of insecticides, fungicides and herbicides is common in managed seed orchards, forest nurseries, intensive short-rotation plantations, and in Christmas tree production. In general, the most commonly used forest pesticides are herbicides used for site preparation, herbaceous weed control, and in pine release treatments. Insecticides are seldom used in general forest management because of high treatment costs and because some pest insects are highly mobile. Currently, the only disease control treatment common in general forestry field applications is for annosus root rot. Vertebrate animals are sometimes controlled through trapping or hunting, but chemical repellents and poison baits may be employed.

Herbicides, the most common forest pesticides used, are effective tools for controlling weeds and other undesired vegetation when used properly. Because of the many factors and principles involved in research on herbicides, information about chemical weed control is rapidly increasing. New recommendations are continually replacing old ones. Be sure to read and follow all label directions from a current product label. Herbicides are registered for the specific forest uses and application methods for which they have been tested. Uses other than those indicated on the label are unlawful and may not provide the needed control. Off-label use can cause adverse effects to non-targeted species on- and off-site by drift or movement in soil and water. Furthermore, unauthorized use may pose a hazard to human health.

When using chemical controls in forest best management, it is important to understand the **basics of herbicide selectivity**. For example: how herbicides control plants, why an herbicide is phytotoxic to one species and not another, and how herbicides can be used to best accomplish the results desired. Combinations of the factors below can be used to improve herbicide selectivity:

- Structural differences in plants
- Differences in absorption
- Differences in translocation
- Physiological differences
- Herbicide concentrations

Structural differences among plants permit selective applications. The narrow, upright leaves of a grass may lack the exposed leaf surfaces of a broad leaf plant. Water droplets can stick only to a small portion of an upright leaf surface. On the other hand, a broad leaf plant has a wide leaf surface, which extends parallel to the ground and will hold more spray, causing the plant to be more affected by the herbicide. Another important structural difference is the location of the growing point of the plant. The growing point of many grasses is protected because it is located at the base of the plant. Contact sprays may injure the leaves of the grass plant, but not contact the growing point. Broad leaf plants have exposed growing points at the tips of the shoots and in the leaf axis. The growing point is, therefore, more accessible to the herbicide. Additionally, the waxiness (cuticle) or hairiness (pubescence) of a plant may prevent spray droplets from adhering to the leaf. If the chemical droplet adheres to the leaf hairs without contacting the leaf surface, it will not be absorbed. On the other hand, hairs may collect and hold greater amounts of droplets, preventing the spray from running off the leaf surface. Waxy leaves may require use of an additive with the herbicide to dissolve the waxy layer and allow contact with the leaf surface.

Absorption is the movement of a material into the plant from an external source. Some plant surfaces absorb herbicides quickly; other surfaces may absorb the chemical slowly, if at all. Parts of the plant leaf surface, the cuticle and the stomate, account for differences in absorption. The cuticle is a waxy layer or thin film on the leaf surface, which retards the movement of water and gases (oxygen and carbon dioxide) into and out of the leaf. The cuticle varies in thickness in different plants and can vary within the same plant exposed to different environmental conditions. Shaded plants often have thinner cuticles than plants grown in the sun; and young leaves usually have thinner cuticles than older leaves. An herbicide must penetrate the cuticle layer and cell wall. High temperature and low humidity usually result in poor cuticle penetration.

A plant leaf is perforated by small openings or pores called stomates; these open into the intercellular spaces within the leaf. The number and distribution of the stomates vary from plant to plant. The stomatal opening can be an effective port of entry for the herbicide if they are open at the time of application. This is why some foliar applied sprays are more effective when applied in the early morning or late evening when there is less sunlight and the stomates are more likely to be open. Stomatal penetration cannot occur unless the surface tension of the spray solution is significantly reduced by the use of wetting agents.

After the herbicide is absorbed, it must be *translocated* within the plant to the site of action. There are two tissue systems in which an herbicide may move within the plant: the phloem, which conducts food from the plant leaf to the stem and roots; and the xylem, which conducts water and nutrients from the roots to the stem and leaves. Herbicides move through these conducting tissues to other parts of the plant. Phloem tissues are composed of living cells. It is important, therefore, not to kill the stem and leaf tissues too quickly. Rapid foliage kill will result in poor transport and poor root control. Movement in phloem will be toward the roots during maturation of the plant and near budding. This indicates the importance of proper timing of an herbicide application, especially for the control of perennial weeds. It is necessary to apply a translocated herbicide when a perennial is storing up root reserves. Most growth regulators including 2,4-D, as well as dicamba and glyphosate, move readily in phloem tissue. Xylem tissue of a plant is made up of non-living cells. It is the water conducting, transpiration system in the plant and movement is only from the roots upward to leaf and shoot tips. Translocation of chemicals applied to either the roots or foliage will only move toward the leaf tip. Atrazine, metribuzin, and diuron are examples of xylem conducted herbicides.

The *physiological differences* between plants also affect herbicidal toxicity. Differences in enzyme systems, responses to pH changes, cell metabolism, cell permeability, variations in chemical constituents, and polarities may all influence the selectivity of an herbicide to plants. Any herbicide that stimulates or blocks certain biochemical processes in a plant can affect the plant's growth. Enzyme reactions may be blocked in one plant species, but not in another, by the same chemical. The following are examples of enzyme reactions: 2,4-DB converted to 2,4- D by certain plants has enzymes that can degrade triazine herbicides into harmless compounds.

The rate of application or *concentration* may determine whether an herbicide inhibits or stimulates plant growth. Low concentrations of 2,4-D can act as a growth hormone and increase the rate of respiration and cell division, resulting in stimulated plant growth. At higher rates, growth is excessive and results in death of the plant.

Chemicals which can be used to remove certain plant species with little or no effect on other species are referred to as **selective herbicides**. Selectivity depends on the amount of chemical used, the application method, the degree of foliage wetting, soil moisture and texture, temperature, humidity, and application timing. Since selectivity can be influenced by all of these factors, the same chemical may be either selective or non-selective, depending on the amount used. For example, selectivity can depend on physiological differences of plants and the properties of the herbicide. Translocated herbicides move within the plant through the vascular system (phloem and/or xylem) after the material is absorbed into the tissue. *Translocated herbicides* may be effective in controlling roots as well as top growth of plants. A commonly used selective, translocated herbicide in

Montana is 2,4-D. Alternatively, *contact herbicides* do not translocate within the plant. This group of herbicides controls only the plant or portion of the plant actually contacted by the chemical. In order to obtain effective control with contact herbicides, adequate coverage of the foliage is essential. This may be accomplished by using a high volume of carrier or diluent to apply the herbicide.

Environmental conditions and application methods affect the selectivity of *soil application* treatments of herbicide. To be effective, the chemical must be carried into the soil by moisture or mechanical incorporation. Selectivity depends on the plant tolerance, soil texture, location of the herbicide in the soil, and difference in growth habit of the desired plants and weeds. These herbicides are generally translocated in the xylem. Herbicide selectivity can also be determined by timing of applications. Pre-plant treatments are made to the soil before desired species are planted. Typical pre-plant treatments are applied after seed bed preparation but directly before planting. Pre-emergence treatments are made to the soil after the desired species planted, but before emergence of any plants (weeds or desired). Post-emergence herbicides are applied to the soil after the desired plants or weeds have germinated and started to grow.

Herbicides which are toxic to all plants, called **non-selective herbicides**, may be used to control a wide variety of vegetation in an area. These chemicals can be used to control vegetation along fence rows, for planting preparation, around electrical power lines and substations, rights-of-way, storage areas, around informational or road signs, and more. Non-selective herbicides require foliar applications to the leaves of growing plants. Non-selective translocated herbicides move from the foliage to the roots, resulting in control of a wide variety of plant species. There are few herbicides that can be classified as translocated, nonselective and glyphosate is one good example. Contact non-selective herbicides control vegetation at the point of contact, and therefore one treatment is usually sufficient to control annual weeds but not perennial plants. Because roots and even larger woody parts are not killed, resprouting may occur, and control is often short-lived. Due to poor control, the currently labeled contact herbicides are rarely used in forestry. However, treatments to kill and dry vegetation to increase fuel loading for site preparation burning can be used.

Non-selective herbicides soil applications include a wide variety of soil fumigants and soil sterilants that are applied directly to the soil. Non-selective soil fumigants are most often used to control all plant growth, as well as other soil organisms, before planting a desirable species. They function as a vapor or gas, which diffuses through the soil and has a short life in the soil. The treated area may be replanted, usually within a month or less. Non-selective soil sterilants are chemicals that control all green plants for a period of up to two or more years. They are classified as:

1) temporary sterilants, which control plant life for four months or less;

2) semi-permanent sterilants, which control all plant life for four months to two years; or

3) permanent sterilants, which persist in the soil for longer than two years

For both selective and non-selective herbicides, the length of time the herbicide residue remains depends on the herbicide used, the rate of application, and the soil moisture and texture.

Cultural & Mechanical practices have often been overlooked because of the development of pesticides. As public interest in environmental issues expands, the impact of cultural and mechanical pest management practices is receiving greater attention. Some examples of these methods that influence the incidence of pest problems include:

- Grazing
- Pulling, tilling, cutting, mowing
- Fire
- Traps and Barriers
- Revegetation
- Other environmental modifications

However, each of these methods can have a positive or negative impact depending on the pest in question.

Grazing management is traditionally used to alter plant succession. Overgrazing is often responsible for altering natural plant succession and leading to non-native plant invasion. However, grazing is also a method commonly used in IPM to remove invasive weeds or other undesired plants. Cattle, goats, and sheep can be used to control weeds and other undesired vegetation. The use of sheep to control leafy spurge and goats to control woody vegetation has been very successful. By itself, grazing will not eradicate undesired plants. When combined with other management techniques such as herbicides or biological control, grazing can successfully reduce large infestations and control the spread and density of unwanted vegetation. Grazing may be particularly useful in environmentally sensitive areas (e.g. riparian areas), in areas where other treatments (e.g. herbicides) are prohibitively expensive, and in steep and rocky terrain. In addition, animals can also be used as part of restoration efforts by loosening and texturing the soil surface and incorporating seed of desirable plants.

Pulling, tilling, cutting, or mowing methods are used to uproot, bury or impede plant growth and development. Pulling plants can be effective against some shrubs, tree saplings, and herbaceous, particularly annuals and tap-rooted plants. For hand-pulling to be effective, as much of the root as possible must be removed because remaining root fragments have the potential to re-sprout. Tillage brings seeds to the soil surface where germination is stimulated and then the seedlings can be controlled with a second tillage or other management technique. Tillage is most effective on annual weeds but can also be used for perennial species if repeated tillage is used. Some plants can be killed by cutting the root below the root crown (where the stem becomes the root), thus preventing the plant access to the carbohydrates stored in the roots. Woody vines, shrubs and trees can also be cut and then treated with pesticides to prevent regrowth. Mowing vegetation can prevent or reduce seed production, deplete root reserves, prepare a site for revegetation, and favor growth of more desired species. Mowing should be timed to stress the plant at its most vulnerable time of its life cycle. Since most plants regenerate, multiple mowing treatments may be necessary. If used alone, these mechanical techniques may not be effective against species with deep tap roots or spreading rhizomes and in some cases may encourage the growth of plants that prefer disturbed habitats. For example, some perennial, rhizomatous weeds can increase with tillage, especially if repeated treatments are not applied.

Trap and Barrier methods can be used for several forest pest insects. Traps include: trap trees, multiple funnel traps (see page 10), drainpipe traps, and slot traps. Traps with aggregation pheromones are often used to trap small, isolated beetle populations. Anti-aggregation pheromones can also be used to divert beetles from uninfested trees. In an infested stand, aggregation pheromone lures can be attached to infested trees and anti-aggregation lure to those uninfested. Spruce beetles can be trapped in limbed, cool, shaded, green trees (dbh greater than 12 inches) that are felled before beetle flight. The trap trees will be infested with approximately 10 times more beetles than a standing tree. The mountain pine beetle is often controlled by trapping the beetles in naturally windblown trees. These trees are then removed in spring after beetle attack and before adult emergence. Trap trees can also be baited with aggregation pheromones. The populations of defoliating lepidopteran such as the Western spruce budworm can be sampled for monitoring programs using traps baited with pheromone.

Fire is an important part of a healthy forest ecosystem. Prescribed burning can be used to manage undesired vegetation and some weed species if the fire is if timed to impact the most vulnerable stage of the plant. For example, prescribed fire used to prevent seed set of annual weeds for several years in a row can deplete the seed bank and impact the population. However, for many perennial weeds, burning will stimulate growth and increase the weed biomass, cover and/or seed production. Burning can also be used to remove dead plant debris which is beneficial for reducing wildfire risk, clearing a site for reforestation / revegetation work, and increasing herbicide contact on weedy plants. Prescribed fire can also reduce needle blight on pine seedlings and root disease as well as other undesirable forest conditions. When properly timed and executed, prescribed fire has little adverse effect on the environment. However, prescribed burning can present risks and have undesirable effects. Prepare a written, prescribed burning plan before each burn to identify measurable objectives for burning and specific conditions under which the burn will be conducted. Be sure to make a smoke management screening evaluation and conduct a follow-up evaluation of the effectiveness of your prescribed burn. In most states, you must contact the local Forestry Commission/ Department office for a burning permit before you start the burn.

Revegetation is an important part of an IPM plan and restoring a plant community after removing unwanted vegetation or restoring a site to it desired state (e.g. road removal). By introducing competitive desired plant species, it will prevent re-colonization of noxious weeds or other undesired vegetation, reduce erosion, and improve species diversity and overall ecosystem health. When developing a revegetation plan, several things must be taken into consideration including the site characteristics, the cause of the degradation, the objectives of the project, and costs. Common methods of revegetation include drill seeding, broadcast seeding, and hydroseeding. Bare root seedlings, container plants and woody sprigs are also used. Revegetation is also important for planting desired tree species after pathogens have killed entire stands. For example, pathogen-resistant whitebark pine trees are being identified and seeds are harvested to grow and then plant whitebark pine seedlings where white pine blister rust has killed large stands of the tree.

Regulatory actions are often employed to prevent immigration of foreign pests or to prevent the dispersal of already established pests. In Montana there are several laws in place to protect its natural and economic resources, including the Montana Nursery Law, which allows for inspection, certification, and embargo of all nursery stock for listed pests. A plant pest is any insect, fungus, virus, bacteria, noxious and exotic weed, or other organism that can damage a plant. Imported plants and animals are often held in quarantine for a period of time to allow inspection for pests and diseases. There is also a quarantine program in place to prevent the movement of Japanese beetles into uninfested areas. It is prohibited to move regulated items that can be hosts and be possible carriers of the beetle into uninfested areas from infested areas without proper certification.

There are several laws in place to help inhibit the introduction and spread of noxious weeds in the state. The Montana County Noxious Weed Control Law is a state mandated law controlled at the county level. It declares that it is unlawful to allow any noxious weed to propagate or produce seeds unless the landowner is in compliance with the weed management plan of their county or one established for their property. Under the weed control law there are three categories of noxious weeds in Montana based on how abundant the species is in the state. The control criterion ranges from suppression and prevention of new infestations for category one weeds to early detection and eradication for category three. Other regulatory measures to control the spread of noxious weeds include the Montana Noxious Weed Seed Free Forage program, which provides certified weed free forage status to hay, grain and straw. When using forage on public lands, most agencies require the forage to be certified weed free. In addition, some governmental entities require fill material come from weed free gravel pits.

FOREST PEST MANAGEMENT (FPM)

FPM protects forest resources using an IPM approach by **1)** detecting and monitoring forest pest conditions, **2)** assessing potential pest impacts, **3)** evaluating available management or treatment options, **4)** managing stands for pests, and **5)** assessing management results.

1) Detection and monitoring by scouting for pests, and conducting surveys or inventories are key components of any IPM program including forest pest management. Initial detection requires accurate pest identification. It is important to know:

- Biology and life cycles
- Susceptible life stage
- Growth requirements
- Mode of spread
- Interaction with environmental conditions
- Symptoms of infestation/infection
- Natural enemies

Misidentification of pests leads to mismanagement. In order to develop a forest pest management plan, forest managers need to know which pests are present, where these occur (and equally important, where they do not occur) and their approximate infestation size and abundance. Effective monitoring of pest populations and their damage over time determines change in damage levels and geographic distribution and can lead to predictions of damage for the following year. Monitoring can determine the pest density:

Weeds - number per given area and pattern in that area.

Insects - stage or size, indications of infestation, and level of damage.

Disease - severity, symptoms of infection, and level of damage.

Pest inventories and surveys are observations made at a single point in time to detect the occurrence of one or more pest species within a management area. An *inventory* is defined as a cataloguing of the entire management area, whereas a *survey* is a sampling of a representative portion of a management area. Without knowing the extent of pest distribution, management can be random and the full management potential may not be fully realized. For example, the information gained from the inventory may help determine if a prevention, eradication, or suppression approach to pest management is taken.

2) Assessing potential pest impacts using sampling information collected from surveys or inventories, and the historical relationships between various pest stages and damage can identify areas where pest impacts will be greatest. For example, inventories help answer questions of where the pest occurs and what habitats the pest is likely to occur in, and provide insight into where to look for additional populations of the same species. Patterns may emerge over time that reveal certain associations between a pest species and the environment such as preference for a particular soil type, moisture level, or shade tolerance. Inventories and surveys may also help predict likely dispersal routes for pest.

Control action guidelines help decide whether management actions are needed to avoid losses from pest damage. **Injury levels** (sometimes called economic or aesthetic injury levels) establish the amount of pest damage occurring from given pest densities. It is the lowest pest population that will cause economic damage. An example equation:

$$\textbf{Injury Level} = \frac{C}{VIDK}$$

C = the cost of management per unit area
V = market value per unit area
I = injury amount caused per pest
D = the damage per injury amount
K = the reduction in pest attack by control

Critical density is the pest density at which control measures should be employed to prevent the populations from reaching the injury level. This measure is usually estimated from judgement and experience.

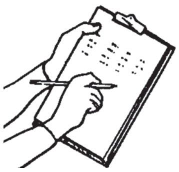
Guidelines for insect pests are generally numerical thresholds based on specific sampling techniques and are intended to reflect the population level that will cause economic damage if no action is taken. Guidelines for other pests, including weeds and pathogens, are usually based on the vegetative history of the area, weather conditions, and other observation and can be more difficult to estimate. In forest stands, the economic threshold can be computed if you know:

- Pesticide and application costs
- Labor and machinery costs
- Future commodity prices of the stand
- Expected pest free yield
- Expected level of pest control
- Expected yield losses

Programs may need to be developed to gather the data necessary to compute economic thresholds. Decision support models (e.g. spruce budworm decision support system) have recently been developed to better quantify and understand injury levels at both the stand and forest level.

3) Evaluating available management options is necessary when it is determined that a control is needed to avoid further losses from pest damage. The goal of controls is to keep pest populations below specified injury levels. The before mentioned approaches (prevention, suppression, or eradication) of pest management are chosen and implemented using a combination of cultural/mechanical (e.g. direct removal of a pest), biological (e.g. parasitoids, viruses, bacteria, fungi) or chemical (e.g. registered chemicals and microbial) controls. Different levels of government, researchers, universities, industry and special interest groups help identify the best available control options and ensure that they are biologically, economically and environmentally beneficial, as well as socially acceptable. The control options utilized should not only control pest populations and reduce levels of expected damage but also encourage natural enemies and if feasible, reduce the use of chemical controls.

4) Management plans are formulated and implemented. The plan will identify areas at greatest risk and determine the resources necessary to conduct the operation. Some resources may need to be acquired from in-house sources, support from co-operators, independent contractors or a combination. During implementation the response to the control/treatment of not only the pest, but also the forest stand, must continue to be monitored (by scouting, or conducting surveys/inventories) regularly. A **record keeping system** is a must in IPM programs. Successful implementation requires keeping records on the following:



- Pest control methods
- Environmental conditions
- Past, present, and future re-vegetation
- Pesticide use history
- Results of the pest management practices
- Relative yield results

5) Assessment of treatment results will help determine the success of pest management strategies. A critical evaluation will tell you what worked and what didn't. In addition, pest populations can also change which then calls for different strategies. It is important to note that a good evaluation is tied to a good **record keeping system** that helps you modify and continually fine-tune the IPM program. When evaluating an IPM program you must ask yourself:

- Did IPM work?
- What went wrong and what went right?
- Was the pest properly identified?
- Was the field sampling unbiased?
- What was the pest activity before and after implementation of IPM strategies?
- What changes to the system would make it better?
- Was the choice of control based on sound judgement or outside pressure?

Consider all components of the IPM system including monitoring, action thresholds, and treatment options for overall effectiveness.

Ground and aerial surveys are required to assess the effectiveness of various controls/treatments. Ground surveys typically include monitoring pre- and post-spray populations and subsequent damage levels in both treated and untreated areas. Statistical analyses are conducted to measure treatment effects (i.e. insect mortality, foliage protection) and measure differences between treatments. By doing so, the most effective protection tools can be identified and recommendations made to improve future operations. Aerial surveys are conducted to provide an overall view of the distribution and severity of defoliation within treated areas in comparison to levels that were forecast. They can also be used to compare treated areas in untreated areas having similar populations. This can provide a measure of the overall proportion of the treated area that received acceptable protection.

PRACTICE QUESTIONS

1. What is the first thing you should do when you detect the presence of a pest?

A. Select a control tactic.
B. Identify the organism.
C. Determine the threshold level for control.
D. Notify the Department of Agriculture.

2. What IPM practice depends on natural enemies of pests?

A. Biological management
B. Mechanical management
C. Pesticide use
D. Cultural management

3. The effectiveness of a pesticide application is related to:

A. Choosing the right pesticide
B. Proper timing
C. Good coverage
D. All of the above

4. A good assessment of forest pest management strategy requires:

A. Biocontrol
B. Site-specific
C. Diagnosis
D. Record keeping

5. After pest management tactics are applied:
A. Don't return to the site until pests are a problem again
B. Don't return to the site until the biocontrol organisms are active
C. Return to the site and harvest the crop
D. Return to the site and evaluate the degree of pest control

6. Biological control organisms are not affected by pesticides.
A. True
B. False

7. Sound IPM practices have both economic and environmental benefits.
A. True
B. False

8. What IPM practice manipulates the environment to make it more favorable for plants and less favorable for pests?
A. Biological management
B. Mechanical management
C. Pesticide use
D. Cultural management

9. Once a pest in a forest stand is brought under control, what should the manager do periodically to determine the status of the pest population within the stand?
A. Monitor the stand
B. Regularly release natural enemies
C. Regularly spray a biological pesticide
D. Immediately thin the stand

10. Reducing pest populations below an economic threshold is which pest management practice?
A. Prevention
B. Suppression
C. Eradication
D. Biological control

11. Prevention is the most effective and economical approach to pest management.
A. True
B. False

12. Examples of pest management techniques include:
A. Biological Control
B. Foliar chemical treatments
C. Revegetation
D. Traps
E. All of the above

13. The most important factors that affect herbicide selectivity are:
A. Plant structural differences
B. Difference in absorption and translocation
C. Physiological differences
D. Herbicide concentrations
E. Answers B, C and D
F. All of the above

14. The first step in a forest pest management plan is to:
A. Assess the impacts of the pest on the forest ecosystem
B. Apply management techniques to control the pest
C. Identify which pests are present through detection techniques
D. Evaluate which treatment options are available for management.

15. The Montana County Noxious Weed Control Law requires all landowners to prevent noxious weeds on their properties from going to seed or reproducing.
A. True
B. False

16. Pest management practices are often described according to the approaches used to manage a pest problem. These approaches include: Prevention, Eradication, and Suppression
A. True
B. False

IV. PESTICIDES

Pesticides are any chemicals that are used to control pests such as insects, plant diseases, fungi, weeds, nematodes, snails, slugs, etc. Therefore, insecticides, fungicides, herbicides and many other "cides" are all types of pesticides.

Pesticides are classified as **general or restricted-use**. **General-use** pesticides are those pesticides less likely to harm the user or the environment when used according to the label. **Restricted-use** pesticides (RUP) are those pesticides that have a greater potential to harm the environment or the applicator when not used as directed. However, not all highly toxic pesticides are classified as RUPs. Certification is required for an applicator to purchase, apply or supervise the application of a "restricted use" pesticide (RUP).

Many pesticides are **contact** pesticides. To be effective these need to be absorbed through the external body surface or the exposed plant tissue. Contact pesticides have to reach their target directly to be effective. Other pesticides are **systemic** in action. Systemic pesticides can be moved (translocated) from the site of application to another site within the plant or animal where they become effective; for example, insecticides that are absorbed by foliage and translocated throughout the plant can kill chewing or sucking insects.

PESTICIDE LABELS

Every pesticide applicator has the responsibility to read, understand and follow the label information so no harm will result from misuse or mishandling of the pesticide. Handling pesticides in a manner not consistent with label instructions is not only illegal, but it can also endanger the health of the applicator, other people, animals, plants, or the environment.

Classification. Pesticides are classified as either "general-use" or "restricted-use." If a pesticide is restricted use, a restricted-use box will be at the top of the label and will explain why the pesticide is classified as restricted-use (RUP). RUPs have a greater potential to harm the user or environment if used improperly than do general use pesticides.

Pesticide names. The name under which the pesticide is marketed is known as the brand or product name. Because active ingredients have complex chemical names, many are given a shorter common name. Only common names that are officially accepted by the Environmental Protection Agency may be used in the ingredient statement on the pesticide label. The manufacturer's name may also be noted here.

Type of pesticide. The label must indicate what type of pesticide the product is or what types of pests it will control. Example: Insecticide, Herbicide or Fungicide.

Ingredient statement. Each pesticide label must include the active and inert ingredients in the product. The active ingredient is the chemical part of a pesticide formulation that actually kills the pest. Inert ingredients are added to formulations as filler and to aid in storage. Inert ingredients do not contribute directly to pest control. Both active and inert ingredients are expressed as a percentage. Always check the active ingredients when comparing pesticides. Two pesticide products with the same active ingredient, but with differing concentrations, may show some difference in the amount of control that is achieved when used at the same rate.

The EPA registration number indicates that the pesticide has been registered by the EPA and legally may be sold or applied according to label directions. Also on the label is the EPA establishment number that identifies the facility where the pesticide was manufactured.

Signal Words. The signal word indicates the relative acute toxicity of the pesticide's active ingredient. Acute toxicity is measured by testing five methods of exposure: oral, dermal, inhalation, eye irritation, and skin irritation. These tests establish the toxicity of a product which determines the signal word that appears on the label. "KEEP OUT OF REACH OF CHILDREN" is required wording on all pesticide containers.

Precautionary statements. Precautionary statements identify the potential hazards to humans, animals and the environment. This section also lists ways that the risks can be minimized or avoided such as the type of Personal Protective Equipment, or PPE, required to handle or apply the pesticide. You must wear the personal protective equipment (PPE) that is listed on the label. There are also warnings as to the pesticide risks to wildlife, birds, fish, bees or to the environment, and any special fire, explosion, or chemical hazards the product may pose. User safety recommendations are also noted in this section of the label.

Statement of practical treatment (First Aid). The statement of practical treatment lists the first aid treatment that should be administered to someone accidentally exposed to the pesticide. There may also be a 'Note to Physicians' to provide emergency medical personnel with poison treatment information, antidotes, and often provides an emergency phone number to contact for further information. Very often there will be a toll-free number or Internet Web address listed so that you can directly contact the manufacturer for more information regarding the pesticide. In the event of a pesticide accident where someone needs to be transported to a medical facility, make sure that the pesticide labels accompanies the victim.

Environmental statements. These statements identify the potential environmental hazards posed by the pesticide. This section also lists ways that the risks can be minimized or avoided.

Directions for use. Remember, it is a violation of federal law to use any pesticide in a manner inconsistent with its labeling. A pesticide may be used only on those sites named in this section of the label. You may not use higher dosages or more frequent applications than is allowed. You must follow all directions for use, safety, mixing, diluting, storage and disposal. The use directions and instructions are not recommendations, they are **requirements**.

Agricultural Use Requirements. The Worker Protection Standard (WPS) was passed into law to protect employees on farms and in forests, nurseries and greenhouses from exposure to both general and restricted-use agricultural pesticides. The WPS covers workers who are exposed to pesticides in the production of agricultural products. If you are using a pesticide with labeling that refers to the WPS, and you are producing an agricultural crop, then you must comply with the standard as noted on the label. Contact your local Montana Department of Agriculture representative to determine if you need to comply with the Worker Protection Standard. Some pesticide uses are not covered by the WPS, even when the Agricultural Use Requirements section is on the labeling. For example, pesticide use on pastures, in rangelands, for the control of vertebrate pests (rodents), and on rights-of-way are not covered by the Worker Protection Standard. This section will also state the amount of time that must pass before any workers are allowed to re-enter treated areas. This is known as the Restricted Entry Interval or REI. Also noted may be other intervals between pesticide application and harvest of food crops.

A Non-agricultural Use Statement may also appear with instructions for those applicators exempt from the Worker Protection Standard.

Storage and Disposal. All pesticide labels contain general instructions for the appropriate storage and disposal of the pesticide and its container. Nevertheless, always store pesticides in their original containers and never store pesticides in containers that can be mistaken as food or feed containers.

General Use Instructions. This section is generally the largest section of the label and states: **1)** the pests that the manufacturer claims the product will control, **2)** the crop, animal, or site the product is intended to protect, **3)** when, where, how, and in what form the product should be applied, **4)** the proper equipment to be used, **5)** the correct rate or dosage, **6)** mixing directions, **7)** compatibility with other often-used products, and **8)** the minimum time between the applications. Mixing instructions may also be noted here.

PESTICIDE SAFETY

Safety First

Pesticides are designed to harm or kill pests. Since human beings are living organisms, pesticides may also harm or kill people. With some pesticides it only takes a few drops in the mouth or on the skin to cause damage. Others are less toxic, but prolonged, unprotected exposure can also cause harm. Toxicity refers to a pesticides ability to cause death or serious bodily damage. Acute toxicity is the ability of a pesticide to cause harmful effects soon after a single exposure or dose. The symptoms associated with an acute toxic exposure may occur within minutes or up to 12 to 24 hours after the exposure. Acute toxic effects are nearly always the result of an accident or careless handling.

Exposure

Pesticides can enter the body by four main routes:

1) Dermal, or skin exposure, occurs when pesticides get on your skin and are absorbed by your body. Dermal absorption accounts for about 90 percent of the exposure pesticide users receive from pesticides. In general, oil-based pesticides, such as emulsifiable concentrates (EC), are absorbed most readily. Water-based formulations are obviously absorbed more readily than dry materials unless the dry materials are mixed with water. Also, pesticides enter the body more readily through scrapes and cuts than through unbroken skin. Hot, sweaty skin also absorbs pesticides faster than cool, dry skin.

If a pesticide gets on your skin:

- **a)** Immediately remove your clothing
- **b)** Wash the exposed area with water and soap; brush residues from under your fingernails
- **c)** Shampoo hair well
- **d)** Put on fresh, clean clothes
- **e)** See a physician if you feel ill

The skin on various body parts does absorb pesticides at various rates **(Fig. 4-1)**. Dermal absorption rates are based on a numerical scale in which the value of one for the forearm represents the lowest skin absorption rate. That value forms the basis for assignment of values to the other body parts. While the forearms and hands absorb the least amount of pesticides, the majority of skin exposures are to the hands and forearms which can have cumulative effects.

The skin is extremely sensitive to the toxic effects of pesticides. The majority of all accidents using chemicals are exposures to the skin, and most exposures result in a rash-type outbreak, ranging

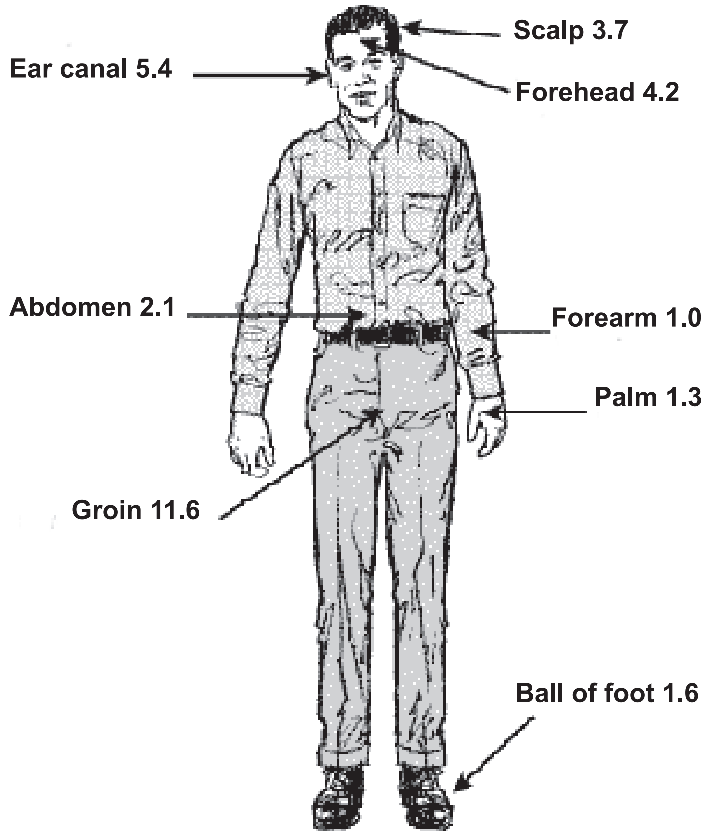


Figure 4-1.

from a minor irritation to painful burning. Skin exposures may also lead to more serious poisonings. Over time, enough low toxicity pesticides can be absorbed by the skin to cause damage to the nervous and respiratory systems. This type of poisoning often goes undetected until another exposure, even a relatively small one, brings on serious complications such as lung failure. For these reasons, take particular care to protect your skin from contact with all pesticides, regardless of the toxicity rating. **Read the pesticide label and wear the PPE that is required.**

ALWAYS READ THE LABEL

2) Oral exposure occurs when a pesticide is accidentally ingested or swallowed. The most common form of oral exposure occurs when a pesticide is illegally stored in unlabeled bottles or food containers and then accidentally ingested or fed to animals. Oral exposure may also occur because of an accident, or as the result of carelessness, such as blowing through a plugged nozzle with your mouth, or smoking and eating without washing your hands after using a pesticide. Also, oral exposure may occur when many airborne spray particles are inhaled and trapped in the secretions of the upper respiratory tract. They can then be swallowed.

When a large amount of pesticide is swallowed, the decision you must make is whether or not to induce vomiting or to dilute the pesticide. Read the Statement of Practical Treatment (First Aid) section of the label and get immediate medical attention. Never induce vomiting if the victim is unconscious. The victim could choke.

3) Inhalation exposure is when you breathe in pesticide vapors or dusts. Inhalation exposure can occur from the applicator smoking when handling pesticides, breathing smoke from burning containers (not legal in Montana), breathing fumes from pesticides while applying them without protective equipment, or inhaling fumes while mixing and pouring pesticides. Many types of solvents used in the pesticide formulation process are very dangerous to breathe. They can cause a "high," dizziness, or even unconsciousness. They may cause permanent damage to the kidney, liver, and nervous system of workers exposed to the vapors for a prolonged time. **Read the label to determine if respiratory protection is required for the pesticides you are using.**

ALWAYS READ THE LABEL

4) Eyes are particularly absorbent to pesticides and some pesticides can cause irreversible damage to your eyes. If you splash any chemical into your eyes, wash out your eyes with plenty of cool, clean water for at least 15 minutes. Seek medical attention immediately.

WARNING: Never wear contacts, especially soft contact lenses, anytime you work with pesticides.

Toxicity

In order to determine the toxicity category of a pesticide for labeling purposes, acute toxicity testing is often conducted on laboratory animals. There is one of four words that are required on a pesticide label to indicate the acute toxicity of the pesticide. These are called signal words and are assigned on the basis of the highest measured toxicity, be it oral, dermal, or inhalation. Since the toxicity category and signal words are based on the total formulation, certain products may have the same active ingredient but may bear different signal words in different formulations **(Table 4-1)**.

Table 4-1.

SIGNAL	TOXICITY RATING	LETHAL DOSE 160 lb. human[2]
Danger[1]	Highly toxic OR Highly corrosive	Few drops to 1 Teaspoon.
Warning	Moderately toxic	1 Teaspoon to 1 Tablespoon.
Caution	Least toxic	1 Tablespoon to a pint or greater.

[1] Sometimes the word 'Danger' appears with the word 'Poison' and the skull and crossbones symbol for extremely toxic pesticides. Danger by itself usually relates to the pesticide's capacity to cause serious skin or eye damage.

[2] Remember that a 40 lb. child could be poisoned by one-fourth the amount required for an adult. Always store pesticides in their original containers and keep away from children, livestock, pets and anyone not trained in pesticide use.

Chronic toxic effects are pesticide illnesses or injuries that do not appear immediately (within 12 to 24 hours) after you are first exposed to a pesticide. Chronic toxic effects may cause long-term or delayed adverse health effects, including cancer, tumors, mutations to inherited genetic material, birth defects and harm to developing fetuses. Chronic toxic effects occur when a person is routinely exposed to small amounts of pesticides while mixing, loading, applying a pesticide or by working in fields after pesticides have been applied. Always wear safety equipment when handling, mixing, applying and when disposing of pesticides.

Systemic effects are delayed illness or injury to the circulatory system, nervous system, kidneys or liver. Some systemic effects may result from acute exposure but most are commonly associated with the chronic effects of pesticides. Examples of systemic effects include: blood disorders (anemia or an inability to clot), nerve or brain disorders (paralysis, excitation, trembling, blindness, or brain damage), skin disorders (rash, irritation, and ulceration), lung and respiratory disorders (such as emphysema and asthma), and liver and kidney disorders (jaundice and kidney failure).

Allergic effects are harmful effects that some people develop when they are exposed to a pesticide. It usually takes more than one exposure for a person's body to develop a response that results in an allergic reaction. This process is known as sensitization. Once a person's body is sensitized to a substance, an allergic reaction may occur and could include: systemic effects (asthma or even shock), skin irritation (rash blisters, or open sores), eye, nose, and throat irritation (itchy, watery eyes, sneezing and tightness in the throat), and photosensitivity (reactions to sunlight form rash-like areas).

There is no way to predict who will be allergic to any given pesticide. Unlike acute and chronic effects, allergic effects are not so much properties of the pesticide but of the people who use them. In other words, a pesticide's toxicity does not affect the likelihood of an allergic response. People who are allergic to many things in their environment may be more likely to be allergic to some pesticide products.

Personal Protective Equipment (PPE)

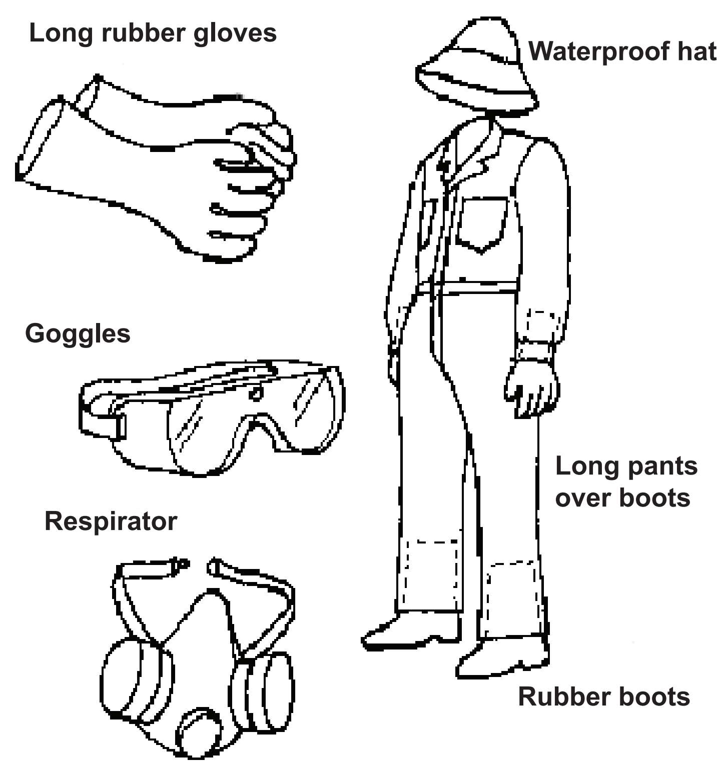


Figure 4-2.

Gloves. At least 98 percent of all accidental skin exposures can be avoided by wearing extra-long, unlined gloves designed specifically for pesticide use.

WARNING: cotton, canvas, or leather gloves can never be cleaned or decontaminate and dishwashing gloves do not withstand chemical penetration. Every time you put on the glove, you are exposing your skin to pesticides.

Use chemically resistant gloves made of materials such as nitrile or neoprene. Read the pesticide label!

ALWAYS READ THE LABEL

Some labels are very specific on the type of gloves you are required to use. Make sure the gloves reach almost to the elbow and make sure your gloves fit properly. Destroy and discard leaky gloves immediately. If shirtsleeves become saturated with a pesticide, remove the clothing and wash the skin with lots of soap and water.

Coveralls. When working with pesticides, it is best to wear more layers of clothing to cover as much of your skin as possible. As a minimum, always wear clean, long pants and long-sleeved shirts that are made of extensive-wear fabric and are free of holes and tears. Cotton woven materials, such as heavy denim, offer adequate protection from dry formulations in limited exposure situations and from low toxicity pesticides as long as the fabric does not become saturated. Starched clothing and layering adds more protection from pesticides. Another route to increasing protection offered by clothing is to add a water/soil repellent finish. Aerosol products such as Scotchgard® Fabric Protector are available in stores (grocery, department or hardware stores) for home application. Research shows that a moderately heavy application of these finishes offers the same level of protection to splashes or spills as does the olefin (Tyvek®) coverall, but the soil repellent finish needs to be reapplied after each laundering.

Coveralls can be added over regular work clothes for added protection from pesticides with the signal words 'DANGER-POISON', 'DANGER' and 'WARNING.' Coveralls used for pesticide applications are commonly made of uncoated Tyvek, a lightweight non-woven fabric made of olefin fibers. Tyvek is not liquid proof and is not suited for moderately to highly toxic products. Polylaminated Tyvek, PVC-coated fabrics and coveralls made of nitrile are best suited for more toxic products. Again, let the pesticide label be your guide. For maximum protection, hooded coveralls provide added safety for the head, neck, and ears. Elasticized sleeves, wrists, and ankles and bound or sealed seams also increase protection. Again, let the label be your guide when selecting coveralls.

Whenever clothing becomes saturated with a pesticide, you should remove the saturated clothing, wash the area with soap and water and put on clean clothing. The saturated clothing should be properly discarded.

Aprons. Chemical-resistant aprons offer protection from spills and splashes of concentrates during mixing and loading and should always be worn over regular work clothes or coveralls. Bibbed aprons are designed to cover the area from the knees to the chest. Some styles come with attached sleeves or separate sleeves for arm protection. Other aprons split below the waist to tie around the legs. Disposable apron materials are similar to coverall materials.

Footwear. Unlined, chemical-resistant footwear is essential for moderately and highly toxic pesticides and is really a sensible practice for all pesticide use. Common boot materials are PVC, natural rubber, neoprene, butyl, and nitrile. Never use latex when handling pesticides containing solvents (emulsifiable concentrates). Regardless of what a label may or may not state, it is never a good idea to wear leather or canvas footwear when applying any pesticides.

Head. Wear a chemical-resistant hat or hooded coveralls where there might be the possibility of contamination to your head, face or neck. Your protective hat should be wide-brimmed to prevent any high splashes from landing on your face or neck. The headband should be plastic and not leather or any other fabric that can absorb pesticides.

Eyes. The eyes are an extremely sensitive and fragile area of the human body. If you do not wash out your eyes immediately after an accidental chemical exposure, eyesight can be permanently lost within two minutes. Obviously, a little prevention can go a long way. A pair of indirectly vented goggles will provide protection for your eyes. If foggy lenses are a concern, a full-face shield will protect the eyes just as well as goggles and will cover exposed areas of the face. Keep an eye-washing station set up or keep a personal eyewash bottle handy to flush out your eyes in case there is some chemical splashed into your eye.

Always wear eye protection when the pesticide label requires it and always wear eye protection when mixing. During mixing, pesticides are being poured directly from their containers, and are more concentrated and more likely to splash.

Lungs. Your lungs are much more absorbent than is your skin. Whenever there is a risk of inhaling vapors, fumes, or dust, wear a respirator with a particle cartridge or canister designated for pesticides. Most pesticide labels will list the kind of respirator that is required for that pesticide.

Cleaning PPE

Wear chemical resistant gloves when handling soiled Personal Protective Equipment (PPE). All PPE should be thoroughly cleaned with warm water and detergent after each use. Wash gloves and boots before you take them off to help prevent contamination while you remove them.

Read and follow instructions from the PPE manufacturer unless the pesticide label requires other cleaning requirements. If no specific instructions are given, wash items thoroughly in detergent and hot water; air dry and place in a well-ventilated place. Some plastic or rubber items that are not made flat, such as gloves, footwear, and coveralls, must be washed twice: once to clean the outside surfaces; and secondly, after turning the item inside out. Rigid items (hats or helmets) should be washed by hand; use hot water and heavy duty detergent.

Hang items to dry if possible. Hang for 24 hours in a well-ventilated area, preferably outside. Remember, sunlight helps to degrade pesticide molecules. Store cleaned items separately from other clothing or unused PPE and away from areas where pesticides are handled.

Pesticide manufacturers are required by federal law to specify the clothing and equipment that a user needs to apply a pesticide safely. Failure to wear specified protective clothing is a violation of federal law.

ALWAYS READ THE LABEL

Pesticide Poisoning

You should learn to recognize the symptoms of pesticide poisoning. Quick action may prevent additional exposure and minimize injury. The pesticide label may also note specific signs and symptoms for that particular pesticide.

The **signs and symptoms** of pesticide poisoning will vary with the pesticide, the exposure and the individual. Also, the symptoms of pesticide poisoning may be confused with the symptoms of heat stroke, heat exhaustion, food poisoning, asthma, flu and other illnesses. So, be aware that your symptoms may or may not be the result of exposure to a pesticide. If you think you have been exposed to a pesticide, alert your physician. **Pesticide poisoning symptoms are often similar to the flu.**

Mild Symptoms: Headache, fatigue, loss of appetite, dizziness, weakness, nervousness, nausea, perspiration, diarrhea, loss of weight, thirst, moodiness, and irritation of skin, eye, nose and throat.

Moderate Symptoms: Nausea, trembling, muscular in-coordination, excessive salivation, blurred vision, constricted throat or chest, labored breathing, flushed or yellow skin, abdominal cramps, vomiting, diarrhea, mental confusion, perspiration, rapid pulse and cough.

Severe Symptoms: Vomiting, loss of reflexes, inability to breathe, muscle twitching, constricted pupils, convulsions, unconsciousness, thirst, fever and rapid breathing.

First Aid

Prevention is always the best first aid. Always read the labels of the pesticides you are using and have a plan-of-action ahead of time in case of an accident. Read labels first to find out if any special first aid equipment is required for that pesticide. In general, medical attention should be obtained if any feeling of discomfort, illness or unusual appearance occurs. Remain alert to symptoms of pesticide poisoning because the symptoms may be delayed up to 12 to 24 hours after exposure. Also, remember to provide a pesticide label to medical staff. The label contains specific instructions for doctors to use in treating pesticide-poisoning emergencies. The label is probably the most important piece of information a physician can have. All pesticides have the potential to cause bodily harm. Always read the label before using a pesticide and become familiar with basic first aid procedures for that product.

PESTICIDE FORMULATIONS

The manner in which a pesticide is marketed is known as its formulation. A single pesticide may be sold in more than one kind of product formulation (e.g., liquid, granular, dust) and in various concentrations. For example, the insecticide malathion is available as an emulsifiable concentrate, a wettable powder, or as a dustable powder.

A pesticide formulation consists of one or more chemicals: **active** ingredients (a.i.) are part of the pesticide formulation that kills the pest and **inert** ingredients (carriers) are added to the active ingredient of a pesticide product to make it suitable for storage, handling or application. Examples of inert ingredients are talc in a dust formulation or a petroleum distillate in an emulsifiable concentrate (EC) formulation. Pesticide formulations can be divided into dry, liquid, and fumigant **(Table 4-2)**.

Selecting a Formulation

✔ What is the target pest or pests? How will the formulation affect non-target plant and animal species? Because of solvents and emulsifiers, EC formulations may injure non-target species or crops.

✔ How will the formulation influence the compatibility of other pesticides? Because of the solvents and emulsifiers, EC's may combine better with other pesticides.

ALWAYS READ THE LABEL

✔ What application equipment is best for certain formulations? EC's may cause hoses and pump parts to deteriorate. Dry Flowables (DF) may cause pumps to wear or may need mechanical agitation in the tank to keep the products suspended. Wettable Powder (WP) and DF formulations may not stay suspended in backpack sprayers.

✔ What concerns are there for the safety of the applicator and other people? Is the active ingredient I need to use available in a different formulation? Dry formulations are more easily inhaled. Liquid formulations are more easily absorbed into the skin. Perhaps a highly toxic pesticide is available in water-soluble packets (WSP) that would limit handling exposure.

NOTE: aluminum phosphide is a fumigant that is formulated mainly as a pellet or tablet. Phosphine gas is produced when aluminum phosphide reacts with ambient humidity. It is a restricted-use pesticide and highly toxic!

Table 4-2.

DRY	CARRIER	ADVANTAGE	DISADVANTAGE
Wettable powders (WP)	Combined with a finely ground dry carrier such as talc. WP's are then mixed with water for application as a spray.	Easy to store and transport Lower toxicity to plants than liquid formulations	Inhalation hazard when pouring and mixing. Needs good and constant agitation in the spray tank. Abrasive to many pumps and nozzles.
Water soluble packets/bags (WSP, WSB)	Pre-weighted amounts of dry active ingredient are packaged in water-soluble plastic bags that dissolve in water.	Reduce handling hazards associated with highly toxic pesticides.	Packets dissolve when exposed to water. Bags or packets are usually premixed at a specific rate.
Flowables (F or FL)	The finely ground active ingredient is suspended in a liquid and then mixed with water for application.	Easy to handle and apply Seldom clogs nozzles.	Requires agitation. May leave visible residue.
Dry flowables or water dispersable granules (DF or WDG).	Like WPs but active ingredient is formulated on a granule instead of powder.	Easier to mix than WPs. Less exposure to fine dusts.	Difficult to keep suspended in backpacks.
Granules or pellets (G, P or XP for eXtruded Pellet)	Most often used for soil applications. The active ingredient is coated onto or absorbed into large, coarse particles such as clay pellets or granules.	Ready to Use (RTU); no mixing Drift hazard is low as particles settle quickly.	Dust from application equipment might present hazard to applicator. May need to be incorporated into soil. May need moisture to activate the active ingredient (ai).
LIQUID	**CARRIER**	**ADVANTAGE**	**DISADVANTAGE**
Emulsifiable concentrate (E or EC)	Liquid formulation containing: the active ingredient, one or more solvents and an emulsifier to aid in mixing with water.	Easy to handle, store and transport. Little agitation required. Will not usually settle.	More of a hazard to non-target plants and animals. Easily absorbed through skin of plants and animals.
Soluble liquid (S)	A liquid formulation in which the active ingredient readily dissolves in water. Consists of the active ingredient and additives.	Will not separate or settle out when mixed with water.	Few in number.
OTHER	**CARRIER**	**ADVANTAGE**	**DISADVANTAGE**
Microencapsulation (ME or M)	Pesticide particles are surrounded by a plastic-like polymer coating. Applied as a spray, the capsule slowly releases the pesticides, prolonging the active life of the pesticide.	Increased safety to applicator. Easy to mix, handle and apply.	Some bees may pick up the capsules and carry them back to the hive thereby poisoning the entire hive.

Mixing Pesticide Formulations

Some labels prohibit the use of a liquid fertilizer and some labels require a specific mixing order. In the absence of such guidelines, a way to remember the sequence for mixing solid and liquid formulations is **D-A-L-E-S**.

Fill the spray tank ¼ full of water and begin agitation. Add any compatibility adjuvant or other additives used to counteract hard water conditions (water conditioners, ammonium sulfate, etc.)

Begin the **D-A-L-E-S** sequence:

Pre-mix **D**ry formulations in a small bucket before adding to the spray tank.

Agitate until the dry formulations are uniformly dispersed. Add water as needed.

Add **L**iquids.

Emulsifiable concentrates and **S**urfactants go in last.

Top off the tank and continue agitation until the pesticides are properly mixed.

It is better to mix liquids with liquids or dry formulations with dry formulations. Small quantities of dry formulations often mix easier if pre-mixed with water in a small bucket first (called **slurry**). When mixing into cold water, slurry dry herbicides first. Mixing of a dry product directly into contact with an oil-based adjuvant or oil-based EC formulation may cause encapsulation of the dry formulation and cause uneven suspension of the tank mixture.

Pesticide Compatibility

Often, two or more pesticides are mixed together to control more than one pest during the same application. However, some pesticides may be chemically incompatible and a chemical reaction may result in loss of pesticide activity, increased toxicity to the applicator, or injury to the treated surface. The label often lists compatibilities of the pesticide involved.

ALWAYS READ THE LABEL

Testing for compatibility may be needed if the label does not list restrictions.

WARNING: Always wear the labeled personal protective equipment (PPE) when mixing or pouring pesticides.

Perform compatibility test in a safe area away from food and sources of ignition. Use a clean, clear quart-size jar. Fill the jar to about ¼ full with water. Add pesticide(s) to the jars in the proper order (**D-A-L-E-S**). One teaspoon of a liquid formulation in one quart of water is roughly equivalent to one quart of pesticide in 50 gallons of water per acre.

Use 1½ teaspoons of a Wettable Powder for each pound recommended per acre. Add the remaining water.

Tighten the lid, shake the jar vigorously and feel the sides of the jar to determine if the mixture is giving off heat. If so, the mixture may be undergoing a chemical reaction and the pesticides should not be combined. If the mixture clumps, or if any solids settle to the bottom (except for wettable powders), the mixture probably is not compatible. Finally, if no signs of incompatibility appear, test the mixture on a small area.

Immediately after use, clean both inside and outside of the mixing materials (utensils or jars). Wear personal protective equipment (PPE), including rubber boots, a rubber apron, goggles, and possibly a respirator. Dispose of the rinse water (called **rinsate**) onto a site listed on the pesticide label. Do not use the materials for any other purpose after they have contacted pesticides. Mark these containers clearly! Pesticides used in this test should be disposed of onto a site listed on the pesticide label.

Water Quality & Pesticide Performance

Minerals and certain pH levels in spray water (called diluent – used to dilute the pesticide concentrate) can diminish the effectiveness of many pesticides. Mineral ions such as calcium and magnesium, commonly found in hard water, can tie up the active ingredients of some pesticides, especially the salt-based herbicides like glyphosate, sethoxydim, imazethapyr, and glufosinate. This results in poor weed control. The use of water-conditioning additives and some ammonium sulfate-based adjuvants can be used to offset hard water problems.

Extreme pH levels in the spray mixture can also cause some pesticides to break down prematurely. The organophosphate insecticides can breakdown in a matter of hours or minutes in alkaline situations (pH above seven). The insecticide dimethoate loses 50 percent of its strength in just 48 minutes when mixed in water of pH nine. By contrast, the sulfonyl urea (SU) herbicides tend to break down more rapidly where the pH is below seven (acidic). At high pH, 2,4-D tends to become more negatively charged which can slow its absorption into plants. **Know your water pH and check product labels for such limitations.**

ALWAYS READ THE LABEL

As a general rule-of-thumb, the optimum pH for spraying most herbicides is slightly acidic (pH 5 to 7). The exception is sulfonyl urea (SU) herbicides which will break down in acidic environments. Use buffering or acidifying adjuvants to stabilize the spray tank pH. **Read the pesticide label to determine any hard water or pH effects on pesticide application**

ALWAYS READ THE LABEL

Adjuvants. An adjuvant is an additive added to a spray solution to improve the performance of a spray mixture. There are two main types of adjuvants **(1)** surfactants and the **(2)** special purpose or utility adjuvants.

Surfactants (Surface-Acting-Agents) are added to a spray mixture to increase a mixture's absorbing, spreading, and penetrating properties **(Fig. 4-3)**. Non-ionic surfactants (NIS) are composed of alcohols and fatty acids that have neutral electrical charges while in solution and are compatible with most pesticides. Non-ionic surfactants are all-purpose and the most widely recommended. Silicone-based surfactants are increasing in popularity due to their superior spreading ability. Some of these surfactants are a blend of non-ionic surfactants (NIS).

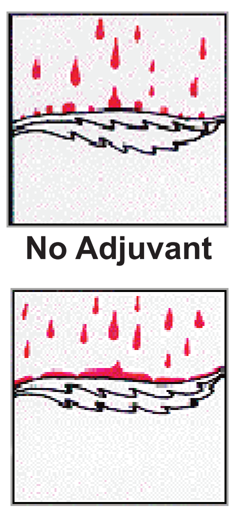


Figure 4-3.

The use of oil-based surfactants in spray solutions is a common practice for certain types of pesticides, mainly the grass herbicides. Oil-based surfactants promote the penetration of a pesticide spray either through a waxy plant cuticle (skin) or through the tough shell of insects. Crop oil concentrates are a blend of petroleum-based paraffinic oil and non-ionic surfactants (NIS). The purpose of the NIS in this mixture is to emulsify oil in the spray solution and lower the surface tension of the overall spray solution. These surfactants exhibit good spreading and penetrating properties but may damage non-target crops because of its petroleum-based ingredients. Methylated and esterified seed oils (MSO and ESO) are derivatives of certain vegetable seed oils (sunflower, soybean, corn, canola) and are combined with a surfactant/emulsifier. These spray solution additives have good spreading and pest-penetrating properties and convey good crop tolerance due to their natural ingredients.

Fertilizer-based Surfactants. Research has shown that the addition of ammonium sulfate to spray mixtures enhances herbicidal activity on a number of hard-to-kill broadleaf weeds. Surfactants containing ammonium nitrogen may also increase the effectiveness of certain polar, weak acid herbicides such as dicamba, glyphosate, sethoxydim, imazethapyr, and 2,4-D amine. It is thought that the ions in the fertilizer tie up hard water ions and also alter leaf pH thereby enhancing herbicidal action. Fertilizers applied with herbicides may cause crop injury. Fertilizers should only be used with herbicides as noted on the pesticide label or where experience has proven acceptability.

ALWAYS READ THE LABEL

Special Purpose or Utility Adjuvants are used to offset or correct certain conditions associated with mixing and application such as hard water, detrimental pH levels, drift, and compatibility problems between pesticides and liquid fertilizers. These adjuvants include acidifiers, buffering agents, water conditioners, anti-foaming agents, compatibility agents, dispersants and drift control agents.

APPLICATION METHODS

The method you choose to apply a pesticide will depend on the nature and habits of the target pest, the site, the pest management objective, the pesticide, the skills of the applicator, available application equipment, and the cost and efficiency of alternative methods. When choosing an application method select techniques that **1)** minimize risks of contact to the applicator and others that may be in the area during and after pesticide application and **2)** minimize release of pesticide to the environment, particularly if the pesticide could contact non-target species.

Pesticides can be applied in a variety of ways. Methods of application can be broadly classified as follows:

- Foliar application (spot application, wick application, broadcast application)
- Basal bark
- Frill, or hack and squirt
- Injection
- Cut-stump
- Soil application
- Pre-emergent soil application before the target species seeds germinate and emerge.

Foliar Application

This method applies pesticides directly to the leaves and stems of a plant. An adjuvant or surfactant is often needed to enable the pesticide to penetrate the plant cuticle, a thick, waxy layer present on leaves and stems of most plants. Foliage stem sprays can be applied from the time the leaves are fully expanded until they begin to turn color in the fall. Some herbicides, however, should be applied only in spring or early fall. Do not treat plants that are under moisture or heat stress and always follow label instructions. There are several types of foliar application tools available.

Figure 4-4.

Spot applications of pesticides are applied to small, discrete areas. For example, spray herbicide directly onto target plants and avoid spraying other desirable plants **(Fig. 4-4)**. These applicators range from motorized rigs with spray hoses to backpack sprayers, to hand-pumped spray or squirt bottles, which can target very small plants or parts of plants.

Wick applications use a sponge or wick to wipe pesticides onto foliage and stems. This methods eliminates the possibility of spray drift or droplets falling on non-target plants. However, pesticides can drip or dribble from some wicks.

Broadcast application is the uniform application of a pesticide to an entire area **(Fig. 4-5)**. A boom, a long horizontal tube with multiple spray heads, is mounted or attached to a tractor, ATV, four-wheel drive vehicle, helicopter, or small plane. The boom is then carried above the pests of interest (diseased trees, weeds, etc.) while spraying pesticide, allowing large areas to be treated rapidly with each sweep of the boom. Offsite movement due to vaporization or drift and possible treatment of non-target areas / plants can be of concern when using this method.

Figure 4-5.

Basal Bark

This method applies a 6-inch band of herbicide around the circumference of the trunk of the target plant, approximately 12 to 18 inches above ground **(Fig. 4-6)**. The width of the sprayed band depends on the size of the plant and the species' susceptibility to the herbicide. Thoroughly wet the basal area until runoff at the ground line is noticeable. The herbicide can be applied with a backpack sprayer, hand-held bottle, or a wick. Applications to control brush can be made anytime, including the winter months, except when snow or water prevents spraying to the ground line. Ester formulations are usually best for basal bark treatments, as esters can pass most readily through the bark (as compared to salts). Esters can be highly volatile; however, so basal bark treatments should be performed only on calm, cool days. During summer,

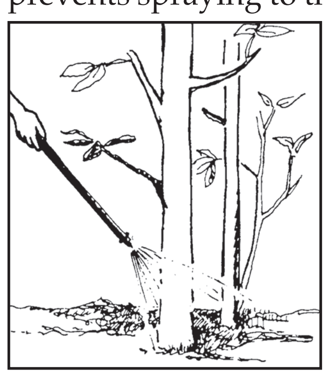


Figure 4-6.

treatment is best carried out in the mornings, which tend to be cooler. Basal treatments can be more labor intensive than foliar sprays but are useful in selectively removing undesirable species from stands of desirable trees. The basal bark treatment works best on young trees with smooth bark. It is usually not effective against older plants with thick corky bark.

Frill, or hack and squirt

This method is often used to treat woody species with large, thick trunks. The tree is cut using a sharp knife, saw, or ax, or drilled with a power drill or other device. Pesticides are then immediately applied to the cut with a backpack sprayer, squirt bottle, syringe, or similar equipment **(Fig. 4-7)**. Because the pesticide is placed directly onto the thin layer of growing tissue in the trunk (the cambium), an ester formulation is not required. This is a very effective method on nearly all brush and tree species. However, flashback can be a problem with some herbicides applied directly into the tree—the injected herbicide moves through root grafts to other untreated adjacent trees and kills them. Read the pesticide label carefully before injecting or frilling trees. Treatment can be made at any time of the year. Deep snow may impede operations, however, and applications made during periods of heavy sap flow in the spring may not be effective. Thickets of brush or species with many stems cannot be easily controlled with these methods.

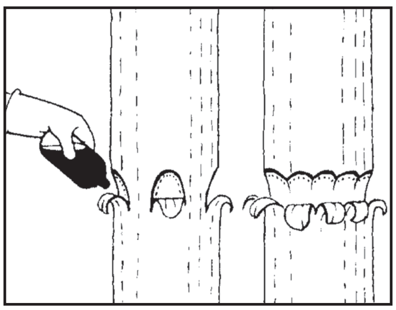


Figure 4-7.

Injection Application

Injection methods use a needle, syringe or specialized tools to inject pesticides directly into herbaceous stems or woody trucks **(Fig. 4-8)**. Pesticide pellets can be injected into the trunk of a tree using a specialized tool – a five foot long, metal tube with "teeth" on one end that grips the trunk of the tree. A sharp push on the tube sends a brass capsule of pesticide into the tree trunk. It is a convenient way of applying pesticides, requires minimal preparation or clean up, and is an easy and safe way to apply pesticides with minimal exposure.

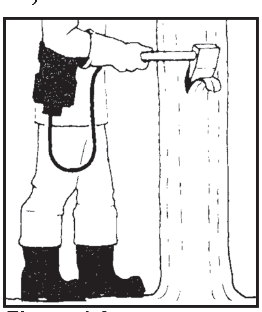


Figure 4-8.

Cut-stump

Cut-stump method is often used to remove woody species that normally re-sprout after being cut or to stop fungal pathogens from spreading to uninfected trees. Use cut-stump herbicide application when the trees are greater than 4 inches in diameter. If smaller, use the basal bark approach. Cut down the tree or shrub, and immediately spray, squirt, or paint herbicide on the exposed cambium (living inner bark) of the stump **(Fig. 4-9)**. The herbicide must be applied to the entire inner bark (cambium) within minutes after the trunk is cut because drying of the cut surface reduces control. The outer bark and heartwood do not need to be treated since these tissues are not alive, although they support and protect the tree's living tissues. Avoid applying too much herbicide that could run-off the stump and onto the ground. If you are applying a chemical for fungus, cut down the infected tree and immediately sprinkle on the chemical. Another method to keep fungus from spreading is to use the beneficial fungus *Phanerochaete gigantea* with chainsaw-blade lubricating oil before cutting down the tree.


Figure 4-9.

Soil applications

These applications are designed for soil-active pesticides applied to the soil as liquid or granular formulations. Granular pesticides, available in various styles and sizes, are applied directly on or in the soil rather than on a growing plant **(Fig. 4-10)**. The pesticide may be incorporated into the soil using tillage equipment to mix the pesticide with the soil. Soil applications can also occur when pesticides are injected beneath the soil surface. Control will not occur until there is adequate rain-


Figure 4-10.

fall or sufficient soil moisture. After rainfall dissolves and moves the pesticide into the soil, where it is taken up by the roots of established plants.

Pre-emergent applications

Pesticides are applied to the soil before the target species germinate and emerge. This method kills vegetation as seeds germinate or new plants grow through the treated ground. Season of the year, soil moisture, texture and pH, as well as organic matter and rainfall affect the soil-active materials.

APPLICATION EQUIPMENT

The six basic classes of ground application equipment include:

- Hydraulic sprayers
- Air sprayers
- Foggers and aerosol generators
- Power dusters
- Hand held equipment
- Granular applicators

Hydraulic Sprayers

Pesticides are delivered under pressure by a pump to one or more nozzles. The primary function of any sprayer is to deliver the proper rate of chemical uniformly over the target area. Water is most often used as the means of carrying pesticide to the target area with hydraulic spraying equipment. The pesticide is mixed with enough water to obtain the desired application rate at a specific pressure and travel speed. The spray mixture flows through the spraying system under pressure and is released through a nozzle onto the target area.

These sprayers come in four basic types: multi-purpose, small general use sprayers, low-pressure/low volume sprayers, and high pressure/ high volume sprayers.

Multi-purpose sprayers are versatile and allow the spray pressure to be adjusted from 40 psi to 400 psi. These sprayers are skid or wheel mounted, powered by auxiliary engines or a tractor PTO (power take off), and the spray is dispensed through a hand gun or field boom.

Small general use sprayers are useful for small spray jobs that are too large for hand equipment. Tank capacities can range up to 25 gallons and the power from a ½ to 2 horsepower engine provides a range of pressures from 50 to 500 psi. Small general use sprayers dispense pesticides through a hand gun or short boom and are usually mounted on a hand-operated cart, tractor or ATV.

Low-pressure/low volume sprayers are normally designed to deliver low to moderate volumes at low pressure—15 to 100 psi. The spray mixture is applied through a boom equipped with nozzles. The boom usually is mounted on a tractor, truck, or trailer, or the nozzle(s) can be attached to a hand-held boom. Roller-type pumps are often used on small tank sprayers (50 to 200 gallons), but sprayers with large tanks (200 to 1,000 gallons) usually have centrifugal pumps. Low-pressure sprayers do not deliver sufficient volume to penetrate dense foliage because of low operating pressure. They are most useful in distributing dilute pesticide over large areas.

High pressure/high volume sprayers are designed to deliver large volumes at high pressure. They are similar to low-pressure sprayers except that they have piston pumps that deliver up to 50 gallons of spray per minute at pressures up to 800 psi. A boom or handgun delivers 200 to 600 gallons per acre. High-pressure sprayers provide thorough coverage and can penetrate dense foliage; however, these sprayers produce large numbers of small spray droplets which can drift. These sprayers can provide low-pressure flow when the proper pressure regulators are used.

Air Sprayers

These sprayers, also known as **ultra-low volume, concentrated blower**, **air-blast**, and **air-mist sprayers**, are used for spraying trees. The pesticides are applied in concentrated form using relatively small volumes of water in contrast to hydraulic sprayers. This method can be more labor intensive for loading equipment but can save resources and prevent damage by reducing pesticide runoff. A low-volume pump delivers the liquid spray under pressure to the fan where it is discharged into an air spread in small droplets by a group of nozzles or shear plates. Pump pressures range from 50 to 400 psi and fans deliver from 5000 to 25,000 cfm. or air velocities of 100 to 150 mph.

Foggers and Aerosol Generators

These sprayers are designed primarily for control of insects. These machines dispense fine particles of pesticides into air as fog or mists where they remain for a considerable time period. Fogs and aerosols are produced by either thermal or mechanical methods of a combination of both. Aerosol equipment can create drift problems. Air currents can assist in moving the pesticide to the target area, taking advantage of the principle of air inversions. Applications are usually made at night when wind, temperatures and humidity conditions are more likely to be optimal.

Power Dusters

These are powered by engine or tractor PTOs. Dusters utilize air stream from a centrifugal fan to carry the pesticide to the target area. They may have single or multiple outlets. Dusters may be impractical for application of some pesticides, especially herbicides, because of the drift hazard.

Hand-Held Equipment

This type of equipment is designed primarily for application of pesticides in small areas and includes hand-pump atomizers, aerosol dispensers, compressed air sprayers, backpack sprayers, dusters, tree injectors, and spot guns.

Hand-pump atomizers use a hand operated pump to force an air stream over the tip of a siphon tube. Pesticide is sucked from the tube and atomized in the air stream. The intermittent type of sprayer produces a spray only on the forward motion of the pump. The continuous sprayer delivers a continuous spray because pressure is produced in the tank. These sprayers are commonly used to control flying insects.

Aerosol dispensers force the pesticide and a propellant through an atomizing nozzle under pressure to create a mist or fog used for controlling insects.

Compressed air sprayers are designed to hold 1 to 3 gallons in the tank. A hand pump is used to pressurize the tank and deliver the pesticide under pressure to the nozzle. Spray patterns and droplet size can be regulated by nozzle type. Solutions, emulsions, or suspension of pesticides can be utilized at pressures which may range from 30 to 50 psi. The use of CO^2 cylinders in place of the hand pump may be utilized to achieve correct pressure.

Backpack sprayers are carried on the back and usually have a 5 gallon capacity. A hand operated piston or diaphragm pump provides the pressure (30 to 100 psi) to expel the pesticide. Backpack sprayers are useful in situations where small areas or widely dispersed individuals require treatment. They are well suited for treating individual brush plants and for basal and cut-surface applications. The sprayers can be fitted with a single nozzle or with a boom with up to three nozzles.

Dusters, or hand sprayers range from small self-contained units to those mounted in wheelbarrows. Air velocity for dispensing the dust is created by a plunger, hand crank, or belt attached to a fan or blower.

Tree injectors offer a precise way of introducing a pesticide (most often an herbicide) into the trunks of well developed brush or trees. The number of cuts and the amount of chemical solution delivered in each blow will depend on the species, trunk diameter, and product being used. Cuts are made at a 60 degree angle with the ground around the circumference of the tree. The cuts must penetrate the bark and reach the sapwood or inconsistent control will result. Tree injectors are feasible in areas where fewer than 500 trees per acre need to be removed or treated.

Adjustable, industry-quality spot guns are recommended to apply several forestry herbicides to the soil at the base of undesired brush and small trees. Their capacity is adjustable from 2 to 20 milliliters per squeeze of the trigger. Frequently, undiluted pesticide is applied, so special care must be taken to assure operator safety.

Granular Applicators

This application is designed primarily for soil applications. Drop-through spreaders, hand-cranked spreaders, air-blown backpack spreaders, hand-broadcast and rotary spreaders are common methods. Shaker cans and hand distribution of pellet or grid-ball formulations may also be used on occasion. Hand-cranked broadcast spreaders can distribute granular or pelletized pesticides on small areas with steep slopes or rough terrain or where machine spreaders are not suitable. Advantages of hand-operated spreaders are that they are small, simple, inexpensive and generally reliable hand tools. Unfortunately, uniform application is often difficult to obtain, and treatment is slow and laborious.

Sprayer Components

When applying pesticides, it is critical to be thoroughly familiar with a sprayer's components to properly select, maintain, and operate the sprayer. The major components of a sprayer are the tank, pump, pressure regulators, and nozzles, and other important components are strainers, pressure gauges, and hoses.

Suitable materials for spray tanks include **stainless steel**, **polyethylene plastic**, and **fiberglass**. Some pesticides corrode aluminum, galvanized, and steel tanks. The cover should form a watertight seal when closed to minimize spills. All tanks should have a drain plug at their lowest point and shut-off valves so that any liquid in the tank can be held without leaking if the pump, strainers, or other parts of the system need to be serviced. Tank capacity markings must be accurate so that you can add the correct amount of water. Agitation is required to combine the components of the spray mixture uniformly and, for some formulations, to keep the material in suspension. If agitation is inadequate, the application rate of the pesticide may vary as the tank is emptied. The two common types of agitation are hydraulic and mechanical.

The heart of the spraying system is the pump, which delivers the necessary flow to all nozzles at the desired pressure to ensure uniform distribution. Pump flow capacity should be 20 percent greater than the largest flow required by the nozzles and hydraulic agitation to compensate for pump wear. When selecting a pump, consider resistance to corrosive damage from pesticides, ease of priming, and power source available. Pesticide sprayers commonly use roller, piston, diaphragm, and centrifugal pumps. Each pump has unique characteristics that make it well adapted for particular situations and should be chosen to best fit the pesticide application program.

A pressure regulator controls the pressure and therefore the quantity of spray material delivered by the nozzles. It protects pump seals, hoses, and other sprayer parts from damage due to excessive pressure, and it bypasses the excess spray material back to the tank. There are two types of pressure regulators—simple relief valves and pressure unloaders. The relief valves are simple bypass valves that require the pump and engine to keep working just as though one were spraying. The unloaders maintain working pressure on the discharge end of the system but move the overflow back into the tank at lower pressure, thus reducing strain on the engine and the pump. Be certain that the flow capacity of the pressure regulator matches that of the pump being used.

Nozzles are important in controlling the volume of pesticide applied, the uniformity of application, the completeness of coverage, and the degree of drift. Many types of nozzles are available, each one designed for specific applications. Regular flat-fan, flood, and whirl chamber nozzles are preferred for weed control. For minimum drift, flood, whirl chamber, and raindrop nozzles are preferable because they produce large droplets.

Proper straining of the spray mixture not only protects the working parts of the spraying system but also avoids misapplication due to nozzle tip clogging. Three types of strainers commonly used on sprayers are tank filler strainers, line strainers, and nozzle strainers. As the mixture moves through the system, strainer openings should be progressively smaller. Strainer mesh is described by the number of openings per linear inch; a high number indicates small openings. Strainers need to be checked for clogs and rinsed frequently.

A pressure gauge must be a part of every sprayer system to correctly indicate the pressure at the nozzle. Pressure directly affects the application rate and spray distribution. Pressure gauges often wear out because they become clogged with solid particles of spray material. A glycerine-loaded diaphragm gauge is more expensive but will last indefinitely.

Use synthetic rubber or plastic hoses that have burst strength greater than peak operating pressures, resist oil and solvents present in pesticides, and are weather-resistant. Sprayer lines must be properly sized for the system. The suction line, often the cause of pressure problems, must be airtight, non-collapsible, as short as possible, and have an inside diameter as large as the pump intake.

Cleaning Application Equipment

Immediately after use, clean both inside and outside of the **mixing**, **loading**, and **application equipment**. Wear personal protective equipment (PPE), including rubber boots, a rubber apron, goggles, and possibly a respirator. The cleanup process is important because many chemicals will rapidly corrode some metals. They may also react with pesticides that will be used later causing a loss of effectiveness and/or crop damage.

To clean equipment:

1) Mix approximately 2 pounds of detergent per 40 gallons of water in the tank. If herbicides such as 2,4-D were used, rinse with an ammonia or charcoal solution. To make an ammonia rinse, fill the tank 1/3 to ½ full. Then add 2 quarts of household ammonia for every 25 gallons of water.

2) Circulate the mixture throughout the bypass or agitator nozzles for 30 minutes. If it is an ammonia rinse circulate the solution and allow a small amount to flow through the nozzles. Allow the remaining ammonia solution to stand overnight to neutralize any herbicide remaining in the equipment.

3) Spray the detergent or ammonia solution through the nozzles onto a site listed on the pesticide label. You can legally spray the rinsate as long as it is to a site listed on the pesticide label. Make sure that the rinsate does not puddle.

4) Flush thoroughly with clean water at several times. You can legally spray the rinsate as long as it is to a site listed on the pesticide label. Make sure that it does not puddle.

5) When the sprayer is to be stored for a long time, add one to five gallons of lightweight oil (about one gallon of oil per 40 gallons of water) before the final flushing. As the water is pumped from the sprayer, the oil will leave a protective coating on the inside of the tank, pump and plumbing.

6) To prevent corrosion, remove nozzle tips and screens and store them in a can of light oil, such as diesel fuel or kerosene. Close the nozzle openings to keep dirt or insects from entering the equipment. Be sure the pump is drained thoroughly to prevent freezing.

7) Add a small amount of oil and rotate the pump four or five revolutions by hand to completely coat the interior surfaces.

8) Before storing equipment, all lines, hoses, valves and the pump should be inspected for damaged parts or leaks. Damaged parts should be replaced before the sprayer is stored.

CALIBRATION

One of the most important aspects of using pesticides is the mixing together of the correct proportions of a pesticide concentrate and its diluent (dill – u – ent). A diluent is anything used to dilute a pesticide concentration before application and is usually water, unless a label specifies otherwise.

Before you can determine the correct proportions to mix, you must first determine a sprayer's application rate through a process called calibration. Calibration is a series of steps to determine how much liquid a sprayer will apply per acre with selected nozzles, pressure, sprayer design, and sprayer speed. The best way to figure the **application rate** is to conduct a calibration test - a trial run over a small known area to later determine the actual application rate in gallons applied per acre **(GPA)**.

Once the actual application rate is known, the acres that a full tank or part of a tank will cover can be determined. Based on pesticide label instructions, we then can determine the proper amount of pesticide to add to the tank. **Using more than the desired amount of pesticide is wasteful, environmentally unsound, AND may violate designated label rates!** Too low an application rate may not be effective, and money will have been wasted for the material and its application.

Prior to calibrating a sprayer, make sure nozzles are all made of the same material. Some materials, like brass, wear faster than stainless steel. Thoroughly clean all nozzles, screens and filters to ensure uniform application. Make sure that all nozzle tips produce uniform spray pattern and deliver roughly the same volume of liquid. Finally, select an operating or field speed appropriate for the conditions of your equipment. When spraying, be sure to maintain the same field speed and pressure you used when you calibrated your equipment.

The Calibration Test Strip Method

The calibration test strip **(Fig. 4-11)** method presented here is the fundamental concept behind calibrating almost any piece of pesticide application equipment.

It is a process-oriented procedure and requires that the applicator have a calculator, a knowledge of grade school math, and remember only two

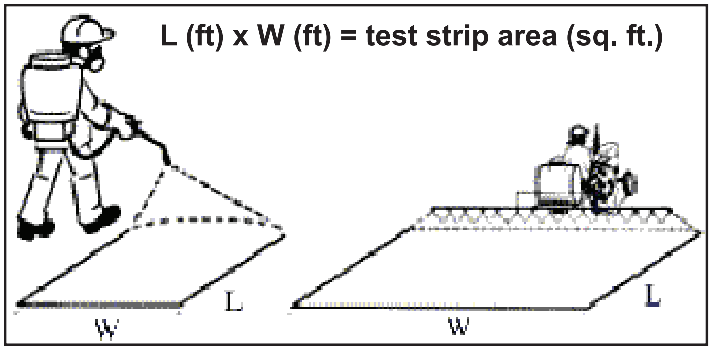


Figure 4-11.

basic pieces of information: there are 43,560 ft² in one acre and how to work a simple ratio problem using simple multiplication and division.

Step 1: Establish a test strip. A test strip is a given area that can be any size, but usually is established according to equipment setup. For boom, broadjet and granular application equipment, the test strip area is the effective swath width (W) in feet, times a known distance (L) in feet (area = length x width). Then divide by 43,560 ft² to determine test area acres. For hand sprayers, the test area is established based on the capability of the equipment to spray a test area without stopping to pump the sprayer.

Example: A liquid sprayer's swath width is 40 feet. The test strip distance is 200 feet long. The area of the test strip in feet is 8,000 ft² (40 x 200). Test area is 0.184 acres. (8,000 ft² ÷ 43,560 ft²). Remember there are 43,560 ft² in one acre.

Example: A 2 gallon hand sprayer needs to be calibrated. A test strip of 15 feet by 15 feet is established. The test strip area is 225 ft² (15 x 15). Test area is 0.0052 acres. (225 ft² ÷ 43,560 ft²).

Step 2: Measure the amount of liquid applied to the test strip. Collect liquid from the sprayer for the same amount of time it takes to spray the test strip at field speed. Or, you can refill the tank back to a set mark to determine how much liquid is applied to the test strip. Remember, in most cases, water is used for calibration of liquid sprayers.

Example: A broadjet sprayer has an effective swath width of 35 feet. The test strip distance is set at 100 feet. It takes 14 seconds to drive the test strip at field speed. The sprayer is stopped and for 14 seconds, three gallons of liquid is collected from the broadjet nozzle at the prescribed sprayer pressure.

Step 3: Set up a simple ratio. The concept behind the calibration strip method is to spray a small area, measure the gallons it takes and then relate it to a per acre basis. We can do this by using a simple ratio: Test strip gallons is to test strip acres; as gallons is to one acre.

$$\frac{\text{Gallons applied to test strip}}{\text{Test strip acres}} = \text{Gallons per Acre}$$

Example: A 66 foot by 66 foot calibration strip is sprayed with water for a total of 2 minutes. Water was then sprayed into a 10 gallon container for 2 minutes at the same pressure.

A total of 7 gallons was collected. The test strip is 0.10 acres (66 ft. x 66 ft.) ÷ 43,560 ft².

$$\frac{\text{Test strip gallons} \quad 7}{\text{Test strip acres} \quad 0.1} = 70 \text{ GPA}$$

Backpack & hand held sprayer calibration is the same as noted above; however, the accurate calibration of this type of equipment is more difficult because operator speed and sprayer pressure are difficult to keep constant. Always strive to keep both pressure and spraying technique consistent between calibration and actual application.

Broadjet sprayers enable a wide swath to be sprayed without using a series of nozzles across a boom. Calibration of these sprayers is easy, as there are generally only one or two nozzles.

Boom sprayer (multiple nozzles) calibration is complicated by the fact that if any one nozzle is providing more or less liquid, then the pattern of the pesticide application may be affected.

Example: A Boom Buster® Model 437 spray nozzle covers 30 feet of swath. The test strip distance is 200 feet long. The area of the test strip in feet is 6,000 ft² (30 x 200). It takes 34 seconds to drive the test strip at field speed. A total of 10.4 gallons was collected from the nozzle for 34 seconds per nozzle.

$$\frac{\text{Test strip gallons} \quad 10.4}{\text{Test strip acres} \quad 0.138} = 75.5 \text{ GPA}$$

Checking nozzle output

Verify that all nozzles are spraying the same volume of liquid, collect from under each nozzle for a standard amount of time. Then take the average flow of all the nozzles. **If the flow of any nozzle varies by more than five percent on either side of the average, then those nozzles should be cleaned or replaced.** It is easy to find five percent. First, find a 10 percent error by simply taking the average and move the decimal place one space to the left. Now divide that number in half to find a five percent error.

Example: Suppose there are six nozzles on a boom and you collected from under each nozzle for 35 seconds.

Nozzle	1	2	3	4	5	6		
ounces	40	40	41	39	38	42	=	40 oz. average

10 percent	=	4 ounces	or	40 ± 4 (36-44) oz.
5 percent	=	2 ounces	or	40 ± 2 (38-42) oz.

All nozzles fall within the acceptable 5 percent error range. None of the nozzles are spraying less than 38 or more than 42 ounces every 35 seconds.

Dry pesticide application (pellets and granular formulations) calibration is similar in many ways to liquid spray calibration. The difference being that granular application equipment must be calibrated with the actual pesticide formulation so always wear the label-prescribed Personal Protective Equipment (PPE) when calibrating dry pesticide application equipment.

Example: A granular spreader makes a 10 foot wide swath. A 20 foot long plastic sheet is placed on the ground. At the desired field speed the equipment is operated across the plastic. Granules are swept up from the plastic and weighed. At total of 0.25 pounds is collected.

$$\frac{\text{Test strip pounds} \quad 0.25}{\text{Test strip acres} \quad 0.0046} = \begin{array}{c}\text{54.3 pounds}\\ \text{per acre}\end{array}$$

Adjusting Output

Consistency is needed between calibration and the actual application. If you calibrate your sprayer at a certain speed or pressure, then make sure you use the same speed and pressure when you apply the pesticide. Pesticide labels can be very specific as to what is required to improve pesticide performance, pesticide uptake and for drift prevention. You may have calibrated your sprayer only to find that its GPA is either too high or too low.

Speed (Fig. 4-12) - As you slow down, you apply more. As you speed up, you apply less. The decision to use speed and the adjustments that need to be made should be done before you mix and before you begin spraying. If you adjust "on the fly" you may apply the pesticide in excess of the labeled rate or at too low a rate to get good pest control.

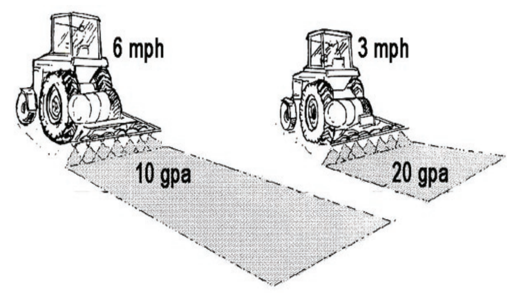


Figure 4-12.

Nozzles - Larger nozzle tips (larger nozzle tip openings or orifices) increase volume, while smaller ones reduce the output and volume. The changing of nozzle tips usually alters the pressure of the system requiring an adjustment of the pressure regulator. Be aware that changes in nozzle tip size will also affect droplet size and spray pattern. Low-volume nozzle tips will generally increase the number of small droplets, thereby increasing the chance of drift. Whenever you change nozzle tips, recalibrate the sprayer and refigure the new output.

Pressure - In order to double output using pressure, you will need to increase pressure fourfold. Increasing pressure can lead to drift problems, the increased incidences of equipment failure, improper coverage or improper placement of the pesticides. It is best to use pressure to fine tune a sprayers output and use speed or different nozzles for major adjustments.

Calculations For Mixing Pesticides

When preparing to apply pesticides, it is most important to mix the correct amount of a concentrated pesticide with a diluent, usually water. But first, you should also have a working knowledge of basic weights and measures **(Table 4-3)**.

The accurate mixing of pesticides is dependent upon two major factors: **1)** the area covered, usually acres, and **2)** the proper product or labeled rate as determined from the pesticide label - 1 pint/acre, 1 quart/acre, etc.

Table 4-3.

8 Pints	=	1 gallon
4 Quarts	=	1 gallon
128 Fluid ounces	=	1 fluid gallon
32 Fluid ounces	=	1 quart
16 Fluid ounces	=	1 pint
1 Tablespoon	=	0.5 fluid oz.
3 Teaspoon	=	1 tablespoon
60 Drops	=	1 teaspoon
43,560 Square Feet	=	1 acre
16 Dry ounces	=	1 dry pound

Step 1: Determine how much area can be sprayed with a given volume in the spray tank. The area is usually expressed in acres. You must first know your sprayer's application rate in GPA.

$$\frac{\text{Spray tank volume}}{\text{GPA}} = \text{Acres treated}$$

Example: Your sprayer is calibrated to 25 GPA and you are going to use a full 500 gallon tank.

$$\frac{\text{Spray tank gallons} \quad 500}{\text{GPA} \quad 25} = 20 \text{ acres}$$

Example: Your sprayer is calibrated to 25 GPA and you are going to use a full 250 gallon tank.

$$\frac{\text{Spray tank gallons} \quad 250}{\text{GPA} \quad 25} = 20 \text{ acres}$$

Example: Your sprayer is calibrated to 35 GPA and you are going to use 2 gallons of a 500 gallon tank.

$$\frac{\text{Spray tank gallons} \quad 2}{\text{GPA} \quad 35} = 0.057 \text{ acres}$$

This formula can also be used to fill out your restricted-use application records. One requirement is that you fill out the area sprayed, usually in acres. For example, suppose your sprayer is calibrated at 25 GPA and you just sprayed 500 gallons of a pesticide and water solution. By using the formula, you can determine you have sprayed 20 acres.

Or suppose you know you have a 20 acre pasture and your sprayer is calibrated at 25 GPA. If you back-multiply, you will find that you need 500 gallons of solution to cover that 20 acre pasture. (20 acres x 25 GPA)

Step 2: Once you determine how many acres you can spray with a given volume, you then can determine how much pesticide you need to add to the spray tank.

$$\text{Acres X Labeled rate} = \text{How much pesticide you need to add to a given volume in the tank}$$

Example: A pesticide label calls for a rate of 1 pint/acre to be applied for the control of perennial noxious weeds. The sprayer to be used is calibrated to apply 25 Gallons per Acre (25 GPA). A 20 acre field is to be broadcast sprayed with 500 gallons of a pesticide and water mix (500 gallons ÷ 25 GPA = 20 acres).

$$\frac{\text{Spray tank gallons} \quad 500}{\text{GPA} \quad 25} \text{ X } \frac{\text{1 pint}}{\text{per acre}} = 20 \text{ pints}$$

You will then be adding 20 pints in a 500-gallon mixture. There are 8 pints in a gallon so you will need to add 2½ gallons of pesticide to the tank. Fill the tank half-full with water, add the pesticide, surfactants, then top off the tank with water to the 500-gallon mark.

Example: Suppose you have a backpack that can treat 0.057 acres with 2 gallons of water (2 gallons ÷ 35 GPA = 0.057 acres). The label recommends a 1 pint per acre rate to control a particular pest. One pint equals 16 ounces, so:

$$\frac{\text{Spray tank gallons} \quad 2}{\text{GPA} \quad 35} \text{ X } 16 \text{ oz.} = 0.912 \text{ oz.}$$

This formula will also help you fill out your restricted-use application records. Another requirement is that you document how much undiluted restricted-use pesticide used. If you just sprayed 20 acres and you accurately mixed at the labeled rate of 1 pint per acre, then you most likely sprayed out 20 pints of the undiluted pesticide.

PESTICIDE STORAGE & DISPOSAL

The proper storage and disposal of pesticides is an essential operation for all applicators. Improper storage and disposal may create serious health hazards or cause environmental contamination. All pesticide labels contain instructions for the appropriate storage and disposal of the pesticide and its container.

ALWAYS READ THE LABEL

Storage

Pesticides should never be stored in an environment where people live, work or play, nor should they be stored near other living organisms. They should be stored in a separate building, room, or enclosure that is locked with a weatherproof sign on the door stating: 'Danger – Pesticides, Keep Out' along with the skull and crossbones symbol. Along with this sign, post a list of chemicals being stored. The storage area should have adequate ventilation to reduce concentrations of toxic fumes and provide stable temperatures. Also, do not store pesticides near steam lines or heating devices. The storage area needs to be cool and dry, out of direct sunlight, where flooding damage will be unlikely. Storage areas should not have floor drains.

Do not store pesticides near food for human consumption, animal feed, fertilizer, seed, veterinary supplies, or other stored products. Do not store pesticides in anything used as a food, feed or drink container, even for a short time. **Make sure the pesticides stay in the original container with the label plainly visible.** Store sacks, cartons, and fiberboard boxes containing pesticides where they will not encounter moisture. Always keep the lids and bungs tightened on containers. Store different pesticides in separate locations within the storage area; insecticides with insecticides, herbicides with herbicides, etc. Stored containers should be periodically checked for corrosion, leaks, breaks and tears. Faulty containers constitute a hazard and must be disposed of immediately. If a pesticide container becomes damaged, transfer its contents to a container that held the same product, or better yet, contact the manufacturer and ask for an empty container. Label the new container immediately. If you cannot salvage the old label, contact the manufacturer, obtain another label from the Internet or write the exact contents directly on the container or on a tag attached to the container. Unlabeled pesticides are worthless and dangerous.

Keep an adequate supply of clean water and soap close to, but not in, the storage area as well as a shovel, dustpan, broom, and proper type of fire extinguisher. If you are storing large quantities of pesticide product, install a sprinkler system. Fire fighting equipment should be checked periodically and ready for use at all times. Inform the fire department and your physician, in writing, of the nature, quantities and hazards of these compounds. Ask your local fire chief to inspect your facility at least once a year. Request your physician or local hospital to have the antidotes required in case of poisoning.

Each pesticide formulation has a storage life. For example, chlorinated hydrocarbons are very stable and can be stored for a number of years with little or no chemical change, while organophosphorus pesticides have a relatively short storage life. Certain conditions can bring about the degradation of these materials. Labels will warn of such limitations and specific steps for prevention of pesticide deterioration. For example, liquid concentrations stored at low temperature for prolonged periods of time may crystallize, separate of break down. Similarly, heat may cause vaporization of certain volatile compounds. The resultant materials may be more or less toxic than the original, or may not perform as originally intended. Some labels provide information on storage standards for the particular pesticide product. If storage information is not available locally, contact the company representative for recommendations

ALWAYS READ THE LABEL

Disposal

Before selecting a pesticide, know your target pest and make sure that the site you are going to spray is listed on the pesticide label. Determine the size of the application area and mix only enough pesticide for the particular job. Preventing a pesticide surplus is the best way to prevent a disposal problem. Use your calibration and mixing formulas to help you.

> ***Example:*** If your sprayer's application rate is 30 gallons per acre (GPA) and you have a 20-acre field to spray, you would then need a total solution of 600 gallons (pesticide and water). If the label rate is 1 pint per acre, you will be adding 20 pints of pesticide to water to make a 600-gallon solution (20 acres x 1 pint per acre). You need to purchase at least 20 pints or 2½ gallons of the pesticide (20 pints ÷ 8 pints per gallon). Just make sure that when you spray the field your sprayer is still set up to apply 30 GPA.

If you have mixed too much pesticide for a job, use any extra tank mix or rinse water on areas with similar pest problems. In some cases, small amounts of excess pesticide can be diluted and reapplied to the treated area. Just make sure that you do not exceed labeled rates.

It is the responsibility of the applicator to properly dispose of any excess pesticide and its container. Disposal methods include, but are not limited to:

- Recycling
- Encapsulation
- Returning to the manufacturer

Some pesticide labels have different requirements than the regulations of Montana for disposing of empty containers. **The more restrictive requirements must be followed.** The following is the summary of Montana Pesticide Act Administrative Rules of Montana (ARM) 4.10.803 Rinsing Empty Pesticide Containers:

- All empty pesticide containers must be triple or power-rinsed except for aerosol containers, fiber drums with liners, paper, fiber and plastic bags, containers designated by labels for refilling, water soluble containers, compressed gas cylinders, and containers from retail pesticides labeled only for home, yard and garden uses.
- Rinsing must occur within 48 hours of the time the container is rendered empty.
- Use rinsate as diluent in pesticide containers.
- Do not reuse pesticide containers.

All containers, regardless of their type, retain residual amounts of pesticide and should be rinsed before disposal. In the case of highly toxic pesticides, remaining residues may present a hazard to humans. All plastic or metal pesticide containers MUST be triple or power-rinsed prior to disposal. The rinsate should be added back to the sprayer tank and used on a labeled site. Otherwise, the rinsate must be treated as a surplus pesticide and disposed of properly. Rinsate should never be dumped on the ground. Use the triple-rinse procedure to prepare containers for disposal:

1) Secure the lid on the container and agitate to ensure all inside surfaces are rinsed.

2) Pour the rinsate from the container into a spray tank and allow it to drain for 30 seconds.

3) Rinse two or more times until no visible residues are present.

The minimum amount of rinse material required for each rinse is based on the container size. For containers less than 5 gallons in size, the rinse solution should be ¼ of the container's total volume. For containers 5 gallons or greater in size, the rinse solution should be $^{1}/_{5}$ of the container's total volume.

For the power-rinse method:

- the minimum amount of rinse material must be ½ the volume of the container
- the minimum pressure of the rinse material needs to be 15 pounds per square inch
- the nozzle must be capable of rinsing all inner surfaces of the pesticides container
- rinsing needs to continue until no visible residues are present and allow the container to drain for 30 seconds.

Most pesticide containers composed of plastic can be recycled through programs sponsored by pesticide dealers and distributors. The containers must be triple-rinsed, drained dry, and have no visible residue. Labels and caps must also be removed. Plastic and metal pesticide containers that have been triple-rinsed are considered solid waste and can be disposed of in most sanitary landfills. Be sure to check with the landfill operators to determine local policies for accepting pesticide containers.

Applicators wishing to dispose of large volumes of pesticides should contact the **Montana Department of Agriculture – Pesticide Disposal Program at (406) 444-5400**.

Pesticide Spills

Should an accidental spill occur, remember to use the appropriate personal protective equipment (PPE) and follow the three C's:

1) Control the spill by stopping the source of the spill. For example, if the spill is due to a broken hose, close the valve or temporarily patch the hose to stop the leak. If the source of the spill is a container leak, place the leaking container in a larger, leak proof container.

2) Contain the spill so that it does not spread into sensitive areas. Build a dam or barrier around the spill with dirt, kitty litter, sawdust, or other absorbent materials. Spread these materials on the spill area to soak up the pesticide.

3) Clean up the materials that have absorbed the pesticides. Shovel them into a leak proof container for proper disposal. Do not flush the area with water or use a cleaning solution until talking with trained personnel. This will help avoid the risks of chemical reaction and possible groundwater contamination.

Call the Montana Department of Agriculture, (406) 444-5400, to report any spills in excess of 5 gallons of total mix. Find out what, if any, reports need to be filed. They will be able to identify what safety steps are necessary to thoroughly decontaminate the ground and how to properly dispose of the contaminated materials. To help prevent exposure in the future, cleanup work clothes and personal protective equipment should be cleaned before work resumes. Finally, take corrective measures to help ensure that another pesticide spill will not occur.

PESTICIDE RESISTANCE

Resistance occurs when there is an ability of a pest to tolerate the toxic effects of a pesticide. Pesticide resistance is an inherited trait that is received by offspring from the parent genetic material. With most pesticide control measures, small groups in the pest population can tolerate certain pesticides. Once the other susceptible pests are killed off, only the tolerant ones will reproduce to produce more resistant pests. As the pesticide is repeatedly used, the percentage of resistant individuals will increase until most of the population is resistant. If a pest becomes resistant to a pesticide, it can become **cross-resistant** to another chemically related pesticide. Chemically related pesticides kill pests by the same mode of action.

How to manage resistance:

- Use an IPM program
- Practice crop rotation
- Use chemically unrelated pesticides
- Use pesticides only when needed

ENVIRONMENTAL HAZARDS

The environment is everything around us: air, soil, water, plants, animals, houses, restaurants, and even office buildings. Anyone who uses a pesticide, indoors or outdoors, must consider how that pesticide will affect the environment.

The pesticide applicator must ask two questions:

1) Will the pesticide affect the immediate environment where it is being used?

2) What are the dangers that the pesticide will move off-site and cause harm to other parts of the environment?

Responsible pesticide users know and follow good practices that achieve effective pest control with very little risk of environmental damage. While pesticide label statements are intended to alert you to particular environmental concerns, the lack of a particular label precautionary statement does not necessarily mean that the product does not pose a hazard to the environment. Use good judgment.

The EPA is looking closely at environmental effects when it considers new registration applications. It is also re-examining existing pesticide registrations. More and more pesticide labels list environmental effects, such as contamination of ground water or toxicity to birds or aquatic invertebrate animals, as a reason for a restricted-use status.

There are two sources of environmental pollution **(Fig. 4-13). Non-point-source** pollution comes from a wide area. The movement of pesticides into streams after broadcast applications is an example of non-point-source pollution. **Point-source** pollution comes from a specific, identifiable place (point). A pesticide spill that moves into a storm sewer is an example of point-source pollution.

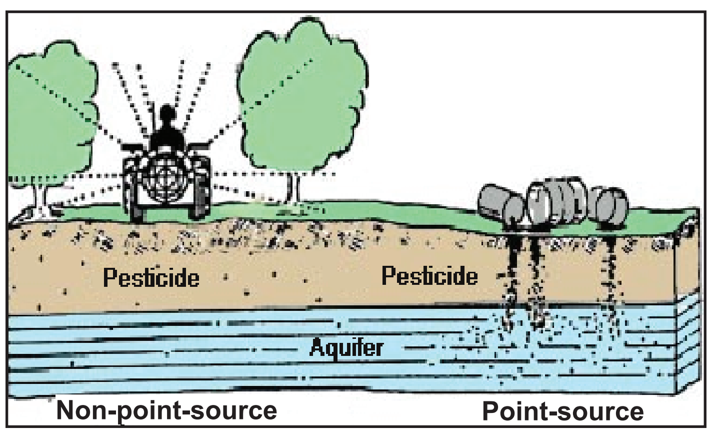


Figure 4-13.

Contamination from point sources includes:

- Pesticide storage sites where leaks and spills are not correctly cleaned up.
- Spills that occur while mixing or loading pesticides into application equipment.

- Wash water and spills at equipment cleanup sites.
- Improper disposal of containers, water from rinsing containers, and excess pesticides.

Applicators in Montana must become aware of the potential for environmental contamination during every phase of pesticide operation. Whenever you release a pesticide into the environment, you must consider whether sensitive areas in or near the pesticide application site will be affected. Sensitive areas are sites or living things that are easily injured by a pesticide and include:

- Areas near the habitats of endangered species and areas near apiaries (honeybee sites), wildlife refuges, or parks.
- Areas near ornamental gardens, food or feed crops, or other sensitive plantings.

Are there conditions in the environment at the pesticide use site that might cause the pesticide to move offsite? Can you change any factors in your application or at the pesticide use site to reduce the risk of environmental contamination? Always take special precautions to avoid direct application to any sensitive area.

Pesticide Movement

Pesticides move in many ways, but most importantly:

- In air, by small droplets produced by pesticide application equipment and with wind.
- In water, through runoff or leaching.
- On or in objects, plants, or animals (including humans) that move or are moved offsite.

Pesticide movement away from the release site in the air is called **drift**. Drift can be in the form of pesticide droplets, vapor, dust, or even pesticide-bound soil that is blown or transported out of the target area. There are two forms of drift that you should be aware of: **physical** drift and **chemical** drift.

Physical drift is the movement of spray droplets outside the target area. Physical drift is influenced by:

Droplet size – A small nozzle tip opening coupled with high spray pressure produces more small droplets that can drift.
Spray Tip Height – The more distance between the spray tip and target, the greater the impact wind has on drift.
Operating Speed – At faster speeds, small droplets are trapped in the area behind the sprayer.
Wind Speed – While not important in the drift formation, wind has the greatest impact on the movement of small droplets.
Air Temperature/Humidity – In temperatures over 77°F with low relative humidity, larger droplets become smaller due to evaporation. Smaller droplets can then move more readily with wind.
Pesticide Properties and Spray Output Volumes – Always use higher output volumes when practical.

Before applying pesticides, always read the label for certain restrictions and recommended volumes.

ALWAYS READ THE LABEL

C**hemical**, or vapor drift (as volatilization or vaporization) occurs when a liquid pesticide molecule is heated by the air and escapes as a gas. Most volatile pesticides should never be sprayed at temperatures greater than 85°F. **Always consult the pesticide label for temperature restrictions.**

ALWAYS READ THE LABEL

For example, twice as much 2,4-D ester will volatilize at 80°F than at 70°F. When there are no label restrictions, a general rule-of-thumb is to never spray when temperatures will exceed 85°F. During the early morning, the ground air is cooler than the above air. Pesticide vapors may move more slowly out of the treatment site because the warm air prevents the cool air from rising. This inversion affects non-target organisms **(Fig. 4-14)**.

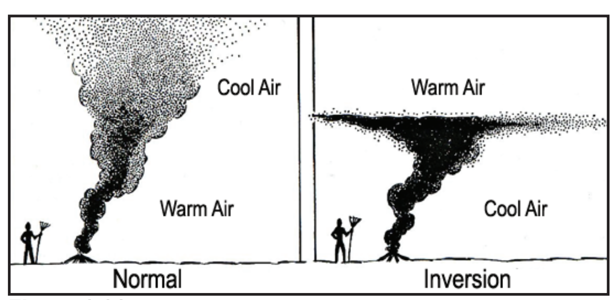


Figure 4-14.

A good spray drift management program includes using common sense, good judgment, and a well-trained applicator. These include:

- •Use as coarse a spray as permitted and still obtain good coverage and control.
- •Do not apply pesticides in windy or gusty conditions greater than 10 MPH.
- •Do not spray when wind is likely to drift onto bodies of water or to other sensitive areas.
- •Choose an application method and a formulation that is less likely to cause drift.
- •Choose the formulation carefully. Water-based sprays volatilize more quickly than oil-based sprays, but oil-based sprays can drift farther because they are lighter, especially above 85° F.
- •When possible, avoid spraying at temperatures above 85°F. Follow label instructions regarding temperature, humidity, and proximity to sensitive locations.
- •Know your surroundings. Know the location of sensitive areas close to the target area.
- •Use drift control/drift reduction adjuvants.
- •Apply pesticides early in the morning or late evening. Wind speed is the lowest and humidity is higher.
- •Do not spray during temperature (air) inversions, a condition in which colder air next to the ground is trapped by a layer of warmer air above. Pesticides in the air can get trapped and can move with the slightest wind. Inversions may occur during the passage of a cold front or by high-pressure areas.
- •The wrong wind direction can cancel out everything else you have done to reduce drift.
- •Do not apply pesticides near lakes, reservoirs, ponds, rivers, streams, marshes, etc.
- •Service and calibrate your equipment regularly. Small leaks under pressure can produce very fine droplets.

ALWAYS READ THE LABEL

Pesticide Losses In Water

Pesticide particles and liquids may be carried off-site in water by **(Fig. 4-15)**:

- •Runoff and leaching, from nearby applications.
- •Spills, leaks, back-siphoning from nearby mixing, loading, storage, and equipment clean-up sites.
- •Improper disposal of pesticides, rinsewater (rinsate), and containers.

ALWAYS READ THE LABEL

Runoff is the movement of water across a sloping soil surface at a faster rate than it can enter the soil profile. Runoff water can carry pesticides in the water itself or when pesticides are bound to eroding soil particles. Over-irrigation and poor timing of pesticide applications can lead to the accumulation of excess surface water and subsequent pesticide runoff. Runoff can also occur if a pesticide is applied to a saturated soil, resulting from a previous rain or irrigation.

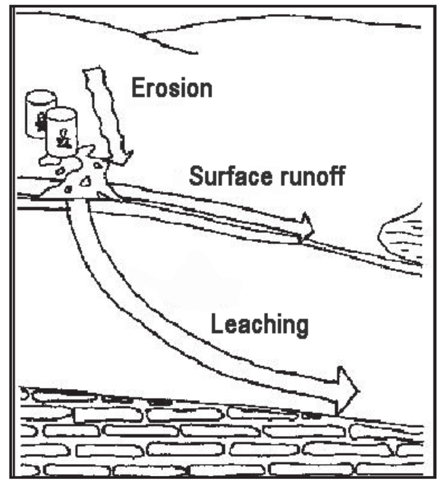


Figure 4-15.

Leaching is the movement of pesticides through the soil profile, and depends on how well a pesticide will bind to soil particles, as well as soil properties such as soil texture, organic matter and soil permeability. Pesticides generally form strong chemical bonds to clay and silt, and are less likely to leach. In these medium and fine-textured soils, water moves more slowly, allowing more time for pesticides to bind to soil and be degraded. By contrast, pesticides generally don't bind very well to permeable, coarse, sandy soils. These soils have large pore spaces that allow water and pesticides to move rapidly between soil particles during rainfall or irrigation.

Pesticides can also move away from the application site when they are on or in objects or organisms that move offsite. Pesticides may stick to shoes or clothing, to animal fur, or to blowing dust, and can be transferred to other surfaces.

When pesticide handlers bring home or wear home contaminated personal protective equipment (PPE), work clothing, or other items, residues can rub off on carpeting, furniture, and laundry items and onto pets and people.

Protecting Non-target Organisms

Pesticides can harm non-target organisms present during application. Honey bees and native pollinating insects can be poisoned in or near the target site.

Reduce pollinator poisoning by:

- Using the least harmful pesticide formulation. Granular formulations are the least dangerous to pollinators. Microencapsulated pesticides are the most hazardous because they can be taken back to the hive or nest like a pollen grain.
- Not applying insecticides when crop or weeds are in bloom. Mowing of weed blooms will cause pollinators to forage elsewhere.
- Minimizing spray drift (use appropriate nozzles and watch for windy conditions).
- Timing insecticide applications carefully. Evening applications are the best because pollinators are rarely foraging at this time. Do not apply pesticides during midday as pollinators are foraging for pollen and nectar.
- Make sure hives and nests are moved or covered during application.

Insecticides can also poison beneficial parasites and predators near the target site. Pesticide runoff can harm fish and other aquatic animals and plants in ponds, streams, and lakes. Aquatic life also can be harmed by careless tank filling or draining, and by rinsing or discarding used containers along or in waterways. Limiting pesticide use and selecting the least harmful pesticides is the best way to avoid the poisoning of other valuable organisms. Pesticide labeling statements will alert you to a pesticide's effect on non-target species.

ALWAYS READ THE LABEL

Harmful Effects from Residues

Degradation processes in the soil convert most pesticide residues to inactive, less toxic, and harmless compounds and include: **1)** Microbial degradation, or the breakdown of pesticides by fungi, bacteria, and other microorganisms that use pesticides as a food source, **2)** Chemical degradation of pesticides by non-living processes including temperature, moisture and pH. Many organophosphate and carbamate insecticides are particularly susceptible to breakdown under alkaline conditions (pH greater than seven). Some herbicides such as the sulfonyl ureas (SU) degrade under acidic conditions (pH less than seven), and **3)** Photodegradation, or the breakdown of pesticides by sunlight.

BEST MANAGEMENT PRACTICES

The methods used to apply pesticides are another factor determining leaching potential. The great complexity of soils, environmental conditions, chemical pesticides, and pesticide-soil-water interactions make it difficult to accurately determine the fate of a pesticide once it has entered the environment. However, based on research, experience and scientific deduction, reliable conclusions can be drawn that will help managers make wise decisions about what pesticides to use in certain situations and the possibilities of risks to the environment.

Use Prevention - Identify the target pest and understand its life cycle. Use pesticides only when necessary and only in amounts that will adequately control the pest. When possible, select least toxic pesticides that are less persistent. Integrated Pest Management (IPM) is a recommended alternative to purely chemical pest control. IPM integrates available pest control techniques in an economically and ecologically sound manner. IPM uses scientifically sound strategies, such as economic thresholds and pest monitoring to determine the proper time for pesticide applications.

Identify the vulnerability of the soil - Well-drained or sandy soils, low in organic matter, have a high potential for leaching and groundwater contamination. Clay soils have a high potential for runoff and surface water contamination.

Consider the presence of surface water, groundwater and well sites - Keep pesticides away from water sources, including wells. Maintain a buffer of at least 100 feet to all water sources and do not allow pesticide to runoff into any water source. Establishing thick vegetation, such as turf or pasture grasses, or leaving an untreated border are two ways to provide a buffer zone.

Become familiar with pesticides that may leach - Check the pesticide label for warnings about potential to leach to groundwater.

Consider the vulnerability of the area - Determine the relative susceptibility of the soil to leaching and depth of the water table. Sinkholes, ground squirrel burrows and large soil fractures can be especially troublesome as they allow surface water to quickly reach groundwater with little natural soil filtering.

Follow the directions on the pesticide label - Many pesticide labels contain use instructions or precautions to avoid groundwater contamination. If you do not follow the label directions, you risk contaminating the groundwater. Always read pesticide labels carefully.

Apply the pesticide at the appropriate time - Fewer applications are required if they are carefully timed relative to stages in the pest's life cycle. Information on proper timing of pesticides is available from the label, research documents or from the manufacturer.

Measure the pesticide properly and carefully - Avoid the temptation to use more pesticide than the label directs. It only increases the cost of pest control, the resistance of pests to chemical controls, and the risk of groundwater contamination.

Calibrate and maintain equipment properly – Check and calibrate equipment often. If you cannot accurately calibrate a sprayer or cannot mix pesticides accurately and safely, then you have no business applying any pesticide. Also, small leaks under pressure produce fine droplets that contribute to drift.

Direct the application to the target site - Avoid over-spraying and limit drift in sensitive areas to reduce the risk of surface and groundwater contamination.

Store and dispose of pesticides properly - Store pesticides in their original containers in a cool, well-ventilated, secured and protected location away from pumps and water sources. Triple-rinse or pressure rinse pesticide containers and dispose of rinse water to a site listed on the pesticide label. Follow the label for proper disposal of leftover pesticide so it does not cause groundwater problems. Buy and mix only what you need.

Avoid back-siphoning - Prevent back siphoning of pesticide-contaminated water into the water source by keeping the end of the fill hose above the water level in the spray tank **(Fig. 4-16)**. Install a backflow device (such as an air gap or check valve) on the filling pipe to prevent backflow.

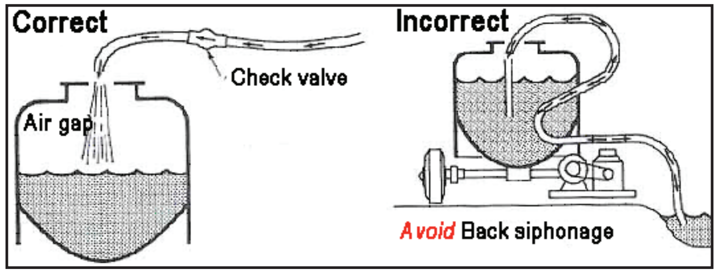


Figure 4-16.

In Montana, any applicator using water to mix, load or clean pesticide application equipment must use a backflow prevention device or other procedures (air gap, check valve, etc) to prevent contamination of water resources.

Maintain records of pesticide use - Maintain records of all pesticides applied. Remember, you are required to keep records of all restricted-use pesticides that you apply. Make sure you follow the proper format for keeping records of restricted-use applications.

Be wary of rainfall or irrigation after pesticide applications - Rainfall or irrigation can introduce recently applied pesticides into ground water. This is especially critical for clay soils that are subject to rapid runoff or sandy soils that can contribute to leaching.

APPLICABLE PESTICIDES

There are hundreds of pesticides to choose from on the market. Selecting the appropriate pesticides for a job will require additional knowledge of the pest, site, and herbicide properties and safety requirements. The following should be considered when selecting a pesticide for each individual pest problem:

1) Determine whether invasive pests threaten management goals on the site and use pesticides only if they can be used safely and will do more management good than harm.

2) Develop safety protocols for storing, mixing, applying, and disposing of unused pesticides and containers BEFORE obtaining pesticides.

3) Follow all federal, state and local regulations regarding pesticide use. You MUST read and follow product labels. It is a violation of federal law to use a pesticide in a manner inconsistent with its label.

4) Contact your State Department of Agriculture or County Agriculture Commissioner for information about state and local regulations regarding applicator permits and posting requirements.

5) Check with the legal staff for your program BEFORE obtaining pesticides if you have any questions about regulations or liability issues.

6) Restricted pesticides may be applied only by persons who have all certificates and licenses required by the state and/or county.

7) Site conditions to be considered include accessibility, proximity to open water, depth to groundwater, the presence of rare species and other conservation targets, and the site's sensitivity to trampling that could occur when the pesticides are being applied.

8) Applicators MUST wear all protective gear required on the label. Health and safety are of foremost concern.

PRACTICE QUESTIONS

1. The pesticide label contains information on:

A. Ways to protect the applicator
B. Ways to protect the environment
C. Ways to protect the crop
D. All of the above

2. Non-point-source pollution is generally easier to trace back to the origin than point-source pollution.

A. True
B. False

3. Keeping pesticides from polluting groundwater is harder than cleaning up polluted water.

A. True
B. False

4. Back-siphoning can occur if there is no air gap between the water level and the hose.

A. True
B. False

5. Pesticide use poses a threat to fish, wildlife, and birds.

A. True
B. False

6. The inherited ability of a pest to tolerate the toxic effects of a pesticide is called:

A. Pesticide resistance
B. Pesticide toxicity
C. Pesticide use
D. Pesticide management

7. Rotating pesticides from different chemical families to kill a particular pest is one way to:

A. Manage pesticide resistance
B. Calibrate spray equipment
C. Encourage pest buildup
D. Minimize drift

8. The ability of a pest to develop resistance to pesticides it has never encountered is called:

A. Mechanical control
B. Cross-resistance
C. Toxic action
D. Microencapsulation

9. If a pest can resist the toxic action of one pesticide, it can usually resist other pesticides that act in the same way.

A. True
B. False

10. If weeds are in bloom near plants that must be sprayed with insecticide, which is the best practice to avoid killing pollinators?

A. Wait for the weeds to finish blooming
B. Spray without regarding the weeds
C. Mow the weeds and then spray
D. None of the above

11. If bees are in an area to be sprayed, what is the best time of the day to spray?

A. Early morning
B. Midday
C. Evening
D. None of the above

12. Which pesticide form is the least hazardous to bees?

A. Dust
B. Granules
C. Microencapsulation
D. Sprays

13. Granular applicators are designed primarily for:

A. Foliar application
B. Soil application
C. Spot application
D. Basal application

14. Tree injectors are most often used with:

A. Insecticides
B. Fungicides
C. Herbicides
D. Rodenticides

15. A spray tank should have:

A. An opening for filling
B. A shut-off before the pump
C. A drain plug at the lowest point
D. All of the above

16. Tree injectors treat several trees at the same time.

A. True
B. False

17. High-pressure sprayers can:

A. Provide high volume at high pressure
B. Penetrate dense foliage
C. Increase spray drift
D. All of the above

18. Spot applications are used to spray herbicide on the soil at the base of undesirable brush.

A. True
B. False

19. After the inside of the spray tank has been rinsed with water, the water should be:

A. Sprayed on any site as long as it has plant material growing on it
B. Sprayed on any bare soil
C. Sprayed on a site that appears on the pesticide label
D. Stored

20. Extreme hot or cold temperature can degrade pesticides during storage.

A. True
B. False

21. Flashback can occur with which of the following pesticide application methods?

A. Directed spray
B. Foliar application
C. Frill or hack and squirt
D. Soil incorporation

22. Prior to disposal, a plastic pesticide container should be:

A. Triple or power-rinsed within 48 hours of becoming empty
B. Stored in a separate locked building, room, or enclosed area used exclusively for storage of pesticides until disposal can occur
C. Punctured after triple rinsing
D. All of the above

23. Cut-stump pesticide treatments are most effective when applied:

A. Within hours after cutting
B. Within days after cutting
C. Within weeks after cutting
D. Within months after cutting

24. Pesticides can corrode certain materials from which spray tanks are made.

A. True
B. False

25. All spray pumps are resistant to the corrosive effects of pesticides.

A. True
B. False

26. The burst strength of spray system hoses should be greater than the:

A. Peak operating pressure
B. Volume of spray delivered
C. Length of the hose
D. Temperature during the application

27. Low-pressure sprayers are very useful for:

A. Penetrating dense foliage
B. Delivering pesticide over large areas
C. Spot treatment
D. All of the above

28. Clothing that is completely saturated with pesticides should be ____________________.

A. washed twice.
B. washed once and then line dried.
C. properly discarded.
D. None of the above.

APPENDIX A

PRACTICE QUESTION ANSWERS

I. Introduction

1. A	**2.** C	**3.** C	**4.** B
5. A	**6.** A	**7.** B	**8.** B
9. A	**10.** D	**11.** B	**12.** C

II. Montana Forest Pests

1. D	**2.** B	**3.** B	**4.** A
5. D	**6.** D	**7.** B	**8.** D
9. D	**10.** C	**11.** A	**12.** A
13. C	**14.** D	**15.** D	**16.** B
17. C	**18.** A	**19.** B	**20.** A
21. E	**22.** A	**23.** A	**24.** A
25. B	**26.** B	**27.** B	**28.** D

III. Forest Pest Management

1. B	**2.** A	**3.** D	**4.** D
5. D	**6.** B	**7.** A	**8.** D
9. A	**10.** B	**11.** A	**12.** E
13. F	**14.** C	**15.** A	**16.** A

IV. Pesticides

1. D	**2.** B	**3.** B	**4.** A
5. A	**6.** A	**7.** A	**8.** B
9. A	**10.** C	**11.** C	**12.** B
13. B	**14.** C	**15.** D	**16.** B
17. D	**18.** B	**19.** C	**20.** A
21. C	**22.** D	**23.** A	**24.** A
25. B	**26.** A	**27.** C	**28.** C

APPENDIX B

STATEWIDE NOXIOUS WEEDS

The 27 noxious weeds in Montana are divided into three categories based on number of acres infested in the state and management criteria. This unique classification system is modified and updated as needed by the Statewide Noxious Weed List Advisory Committee, and determined by Rule of the Montana Department of Agriculture under the provisions of the Montana County Weed Control Act. The Committee uses established criteria to review requests for additions to the list. Recommendations from the Committee are made to the Director of the MDA. Weeds on federal and regional weed lists are reviewed for inclusion on the Montana state list based on their potential to invade and spread within the state.

The following are Montana noxious weeds as of March 2007. Additional species may be added or removed from the list over time.

Category 1: Widespread Noxious Weeds

This category includes 14 generally widespread noxious weeds infesting about 8.1 million acres in the state. These weeds are capable of rapid spread and limit desirable land uses. Management criteria include public awareness and education, containment and suppression of existing infestations and prevention of new infestations.

Canada Thistle (*Cirsium arvense*)
Field Bindweed (*Convolvulus arvensis*)
Whitetop or Hoary Cress (*Cardaria draba*)
Leafy Spurge (Euphorbia esula)
Russian Knapweed (*Centaurea repens*)
Spotted Knapweed (*Centaurea maculosa*)
Diffuse Knapweed (*Centaurea diffusa*)
Dalmatian Toadflax (*Linaria dalmatica*)
St. Johns wort (*Hypericum perforatum*)
Sulfur Cinquefoil (*Potentilla recta*)
Common tansy (*Tanacetum vulgare*)
Oxeye Daisy (*Chrysanthemum leucanthemum*)
Houndstongue (*Cynoglossum officinale*)
Yellow toadflax (*Linaria vulgaris*)

Category 2: Established New Invaders

This category includes eight noxious weed species infesting about 101,000 acres in the state. These weeds have recently been introduced into Montana and/or are rapidly spreading from current infestations. Management criteria include awareness and education, prevention of movement into noninfested areas, monitoring and containment of known infestations, and eradication where possible.

Dyers Woad (*Isatis tinctoria*)
Purple Loosestrife or Lythrum (*Lythrum salicaria*, *L. virgatum*)
Tansy Ragwort (*Senecio jacobea*)
Meadow Hawkweed Complex (*Hieracium pratense, H. floribundum, H. piloselloides*)
Orange Hawkweed (*Hieracium aurantiacum*)
Tall Buttercup (*Ranunculus acris*)
Tamarisk or Saltcedar (*Tamarix* spp.)
Perennial pepperweed (*Lepidium latifolium*)

Category 3: Nonestablished New Invaders

There are five noxious weeds within this category. These weeds have either not been detected in the state or may be found in small, scattered, localized infestations. Management criteria include public awareness and education, prevention of introduction and movement into non-infested areas, early detection, and immediate action to eradicate infestations.

Yellow Starthistle (*Centaurea solstitialis*)
Common Crupina (*Crupina vulgaris*)
Rush Skeletonweed (*Chondrilla juncea*)
Eurasian watermilfoil (*Myriophyllum spicatum*)
Yellow flag iris (*Iris pseudacoru*)

APPENDIX C

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