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Rights-of-Way Vegetation Management

Oregon State University | Extension Service

Pesticide Licensing

Oregon Department of Agriculture, Pesticides Division

The Oregon Department of Agriculture (ODA) is the primary agency involved in pesticide regulation in Oregon. ODA enforces most activities regarding pesticide distribution and use in the state through the Oregon Revised Statute, ORS 634 (Oregon Pesticide Control Law) and the Oregon Administrative Rules, OAR Chapter 603-57.

Copies of these state pesticide regulations, pesticide license and insurance forms, or *A Guide to Pesticide Related Licensing in Oregon* may be requested from the Oregon Department of Agriculture, Pesticides Division, 635 Capitol Street NE, Salem, Oregon 97301, or they can be downloaded from the ODA website (**http://oregon.gov/ODA/PEST/index.shtml**).

For additional information, contact the Pesticides Division of the Oregon Department of Agriculture at 503-986-4635; fax: 503-986-4735; TTY: 503-986-4762.

Pesticide-related website features and information http://oregon.gov/ODA/PEST/index.shtml	
See your pesticide exam scores	Find test scores for pesticide examinations you have taken (updated continually; SSN and DOB required for access).
Pesticide products	Check on Oregon registration status of pesticide products; look up by product name or EPA Registration Number (updated weekly).
Look up a pesticide license	Check licensing status of companies or individuals with pesticide-related licenses or registrations (updated weekly).
Search for upcoming classes	Find training programs and activities that count toward renewal of Oregon pesticide applicator or consultant certification. Search by city, county, sponsor, date, credit hours, etc. (updated continually).
Check your credit hour report	Get an online report of classes you have attended (updated biweekly).
Where's the nearest testing center?	A listing of all pesticide testing locations and telephone numbers.
Pesticide licensing	This page takes you in steps through the certification and licensing process, from selecting the license type and examinations through checking your scores and recertification training records once you've become licensed.
Pesticide advisories/alerts	Notifications of time-sensitive pesticide issues.

Preface

Rights-of-Way Vegetation Management covers basic information on weed classification and biology; the management principles used to control vegetation along roadsides, railways, power lines, ditch banks, and other rights-of-way; factors affecting herbicide activity; and safe application of herbicides. This manual is a study guide for people working or consulting in herbicide use in rights-of-way vegetation management, for those who use or recommend herbicides as a vegetation control option, and for those requiring state certification (licensing) in the category of Rights-of-Way Vegetation Control. This manual and information in the study manual *Oregon Pesticide Safety Education Manual*, EM 8850, form the basis for the Rights-of-Way Vegetation Control Exam, administered by the Oregon Department of Agriculture. This publication will help you master the basic concepts of chemical vegetation management and learn the language used on herbicide labels. This manual does not give recommendations on pesticide use; other reference and technical materials are available for specific weed problems.

To understand the information in this manual, you must have a basic knowledge and understanding of pesticide laws and safety. See the *Oregon Pesticide Safety Education Manual*, EM 8850.

A practice test is located at the end of the manual. Read the practice test label prior to answering the label-related questions. After taking the practice exam, go back and review the material in the areas you had trouble with. The state passing score is 70 percent.

The tables in Chapter 3 list rights-of-way herbicides by their common names and some of their associated trade names. Before you use an herbicide, read the label and make sure that the specific type of site where you want to use the material appears on the label. Some rights-of-way herbicides can be used only on a few specific sites, such as ditch banks, versus industrial sites or asphalt. We have used trade names and common names throughout the text to help you become familiar with some of the more commonly used herbicides. No product endorsement is intended.

The glossary will familiarize you with terminology used in the text.

For further information on vegetation control and product recommendations for particular rights-of-way applications, consult the current *PNW Weed Management Handbook,* updated yearly by weed specialists at Washington State University, Oregon State University, and the University of Idaho and available from the Oregon State University Extension Service.

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Acknowledgments

The contents of this manual are adapted from the following:

- *Use of Chemicals to Manage Roadside Vegetation.* 1991. H.A. Holt. Purdue University Cooperative Extension. Modules 1–9
- *Agricultural Weed Management Principles*. 1993. C.M. Boerboom, C.A. Ramsay, and B. Parker. Washington State University Extension publication MISC0167
- *Right-of-Way Pest Control.* 1988. J. Doll, N. Neher, and R. Flashinski. University of Wisconsin
- *Avoiding the Development of Herbicide-resistant Weeds or How to Keep the Tools We Have.* 1991. A.P. Appleby and L.C. Burrill. Oregon State University Extension Service
- *Herbicide Mode of Action and Injury Symptoms.* 1991. J.L. Gunsolus and W.S. Curran. North Central Regional Extension publication 377
- *PNW Weed Management Handbook*. 2003. Oregon State University Extension Service, Washington State University Extension, and University of Idaho Cooperative Extension System
- *Right-of-way Category Manual.* C. Ogg. University of Nebraska–Lincoln. Chapter 4, Application Equipment (http://pested.unl.edu/catmans/row.skp/rowcont.htm)
- *Rights-of-way Vegetation Management*. 1996. C.A. Ramsay and R. Parker. Washington State University Extension publication MISC0185

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Contents

Introduction

Rights-of-way are distinct areas involved in common transport, including the following:

- Federal, state, and county highways and roads
- Electric utility lines (including transformer stations and substations)
- Pipelines (including pumping stations)
- Equipment yards
- Public airports
- Railroads
- Public surface drainageways
- Telephone and other communication networks
- Irrigation ditch banks
- Bicycle, bridle, snowmobile, and other public paths or trails (outside established recreational areas)

Rights-of-way weeds are undesirable plants (herbaceous or woody) that can become a hazard or nuisance or can harm humans, animals, or the environment. Some vegetation can cause safety and legal problems along roadsides and railways by hiding signs, reducing distance visibility, and reducing areas where motorists can pull off the road safely. Undesirable vegetation also hinders water drainage, speeds up roadbed degradation, causes snowdrifts, creates a fire hazard, and increases soil erosion. Woody plants that grow too tall can interfere with power supplies and present shock hazards in substations and other high-voltage areas. Several weeds are classified as state noxious weeds, and state law requires that these weeds be controlled.

Preventing weed emergence is very important to achieve weed-free rights-of-way. Managers also implement weed control measures to reduce the numbers of weeds present.

Vegetation management prolongs the life of the roadway and enhances its aesthetic nature for drivers. Weed control reduces repair costs of roads, railways, trails, drainage systems, and other rights-of-way.

An integrated management approach to rights-of-way vegetation control (Figure 1) can produce the greatest economic benefit while protecting the environment and meeting regulatory obligations. To design a management plan, you must survey the site to assess the species present, their stage of development, terrain features, and sensitive areas. Next, identify the management goals for the site: bare ground, grass and clover, or ornamentals, for instance.

Understanding the biology and ecology of undesirable vegetation will help you decide whether control is necessary. If it is, evaluate the suitability and potential effectiveness of various control tactics and determine the costs of these measures. Evaluate the impact of the desired control measures on the environment. Using certain herbicides might not be wise on a particular site because of environmental concerns. Similarly, some mechanical practices might cause severe damage to certain sites. After considering all of these factors, design and implement the management plan.

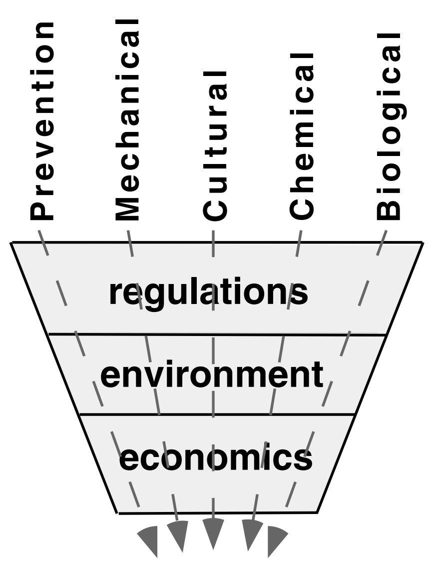


Figure 1.—Integrated vegetation management (IVM).

The best management plans often use an integrated approach, employing more than one method for weed control. Integrated vegetation management (IVM) uses several control methods to economically and effectively control undesirable vegetation.

If you select chemical control as a portion of your IVM strategy, follow the herbicide label instructions to ensure safe and effective application.

When managing weeds along rights-of way, practice a "good neighbor" policy to prevent misunderstanding and confrontational situations. Most rights-of-way are long and narrow and, consequently, the number of adjacent property owners is substantial. Even legal vegetation management practices can lead to public relations problems. Rights-of-way personnel must be aware of the vegetation management program objectives and operation. They must know how their work activities relate to the overall program.

1 Basic Weed Science

Origin of weeds

Weeds are classified as native or introduced according to their origin. Plant origin may determine weed management strategies.

Native weeds are plants that have historic origins in the area and were not introduced by human activity. Natural enemies, competition from other plants, and environmental conditions hold many native weed populations in check.

Introduced plants came from other parts of the country or world through activities of humans. Most of our problem weeds are introduced plants. Some escaped plants were intentionally introduced by humans as crops, forage, or ornamentals. They have subsequently spread beyond their intended areas. Dalmatian toadflax, Scotch broom, and kochia are examples of escaped ornamental plants. The Pacific Northwest often lacks the weeds' natural predators or limiting factors, such as climate, to hold introduced plants in check. This lack of natural control allows weeds to flourish and spread.

How weeds spread

Weeds spread when seed or living plant parts (roots, rhizomes, tubers, etc.) are moved into new territory. Some invading weed species have evolved special seed shapes or structures to aid their movement by wind, water, or animals (Figure 2). Also, many plants have vegetative parts that resprout new shoots and subsequently root. If these plant fragments are carried into new areas, they may grow and start new infestations. Rights-of-way provide a corridor for movement of weeds from place to place.

People unintentionally move and introduce weeds over long distances. Crop seed, equipment (road graders, recreational equipment, automobiles, trains, etc.) and livestock feed carry seed to new sites. Planting seed contaminated with weed seed is a major problem when renovating a site.

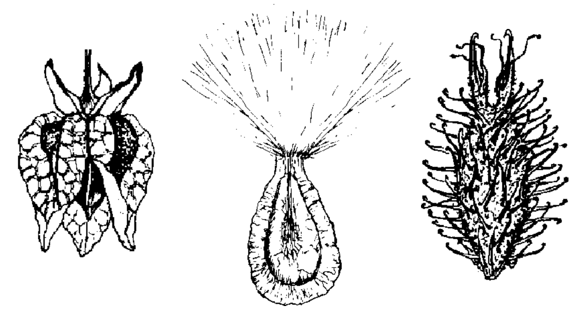


Figure 2.—Modes of weed seed dissemination.

Wind carries many seeds to new areas. Some weeds, such as dandelion, have a parachutelike attachment that carries the seed in the wind. For other weeds, the entire plant moves or tumbles with the wind, dropping seeds as it rolls; tumble mustard and Russian thistle are common examples.

Water from rain or irrigation and the subsequent surface runoff transport many seeds. Some seeds have an oily coating or an air bladder to aid flotation. Rivers, streams, and irrigation canals can move large numbers of seeds.

Mammals, birds, and humans carry seeds on their bodies, dropping them into new areas. Some seeds have burs, hooks, or barbs that cling to feathers, hair, fur, and clothing. Some seeds are ingested and excreted by wild or domestic animals. The seeds often survive and germinate after they have passed through an animal's digestive tract.

Table 1.—Number of seeds produced per plant.

Weed	Seeds per plant
Common mullein	223,200
Russian thistle	200,000
Scotch thistle	40,000
Italian thistle	20,000
Diffuse knapweed	18,000
Kochia	14,600
Canada thistle	5,000

Weed establishment and persistence

Weeds rapidly become problems when introduced into most rights-of-way settings if the environment is suitable. **Any practice that disturbs the soil or ground cover and leaves an opening for weeds to germinate will help weeds invade that area.** Prolific weed populations can grow from either established root stocks or germinating seed in the soil.

Weed seeds, depending on the species, can lie dormant in the soil for many decades. Scotch broom seed, for example, can remain dormant for more than 80 years before germination. This long seed viability helps guarantee species survival. Because weeds can produce large numbers of seed (see Table 1), and many seeds can survive in the soil for years, weed management must be planned and carried out for years, sometimes even decades.

Weed classification and life cycles

Accurately identifying weeds is the first step in an effective vegetation management program. Proper identification will help you develop a successful management plan. You may easily recognize some of the more common weeds; however, identifying some new weed species is a difficult task requiring a working knowledge of plant structures and classification.

Resources available to help you identify plants or weeds exist through the university and county Extension system, county noxious weed programs, and field personnel. Resources include plant identification keys (see page 6), picture guides, pamphlets, and weed identification computer software.

Major plant groups are designated according to structural characteristics common to all plants in each group. For instance, we generally divide weeds into three major groups: grasses, herbaceous broadleaves, and woody plants (Figure 3). This grouping excludes a few species, such as sedges (yellow nutsedge), ferns (brackenfern), horsetail, and scouring rush. One of the basic concepts to weed identification is knowing whether a weed is a grass, broadleaf, or woody plant and understanding its life cycle.

Grass seedlings have only one leaf when they emerge from the ground and, therefore, are called **monocotyledons**. Grass leaves generally are narrow and have parallel veins. Most grasses have fibrous root systems. The growing point on seedling grasses is located below the soil surface. It gradually moves up to the soil surface as the plant grows and matures. Much of roadside vegetation management is directed at establishing and maintaining healthy stands of desired grass species.

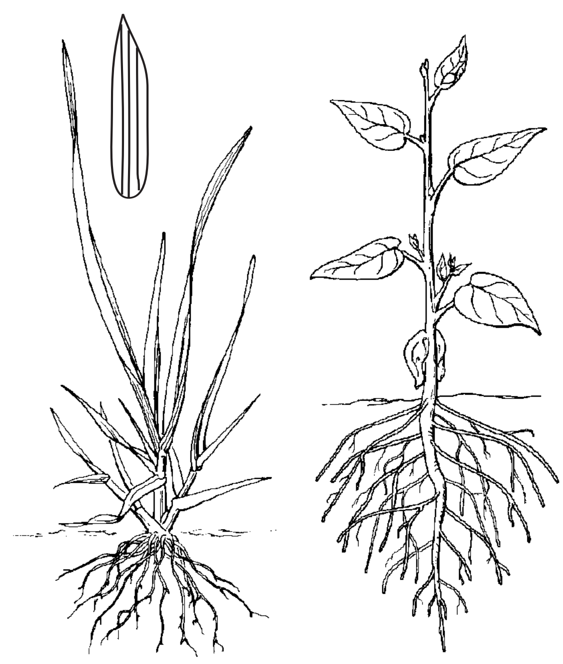


Figure 3.—Two major plant groups—grasses (monocotyledons) and broadleaves (dicotyledons).

Herbaceous broadleaf plants die back to the ground each winter. Broadleaf seedlings have two cotyledons (first leaves) and therefore are called **dicotyledons**. Their leaves are broad with netlike veins. Broadleaves usually have a taproot and a relatively coarse root system. They have growing points (buds) at the end of each stem and in each leaf axil. Broadleaf plants often are the target pest plants on road or rail rights-of-way since they frequently invade grass sites and bare-ground areas.

Sedges are perennial plants with triangular, jointless stems and narrow, grasslike leaves. They have a spiked inflorescence. Sedges are most common in moist environments.

Rushes are **monocotyledonous**, grasslike plants that are common in marshy or wet areas. They have cylindrical stems that often are hollow, and they grow in dense clumps.

Woody plants form wood and do not die back during the winter. They include brush, shrubs, and trees. These plants are broadleaves with two seed leaves and a coarse root system. Woody plants have a place in the roadside landscape, but they can present problems when they occur in the safety recovery zone, shade the road and retard drying and frost melting, reduce sight distance, cause pavement heaving from roots, and create snowdrifts. Woody plants are the major problem in power-line rights-of-way. Some of the woody plants that cause problems are native species.

Another type of classification is based on the plant life cycle, which greatly influences the weed management plan. Some control methods are more effective during certain stages of the weed's life cycle. Successful management depends on timing control measures to coincide with specific, vulnerable stages within the target weed's life cycle. Plants are classified by their life cycle as being annuals, biennials, or perennials.

Table 2.—Examples of common summer and winter annuals.

Summer annuals	Winter annuals
Green and yellow foxtails	Tumble mustard
Puncturevine	Downy brome
Russian thistle	Shepherdspurse
Crabgrass	
Kochia	
Common lambsquarters	

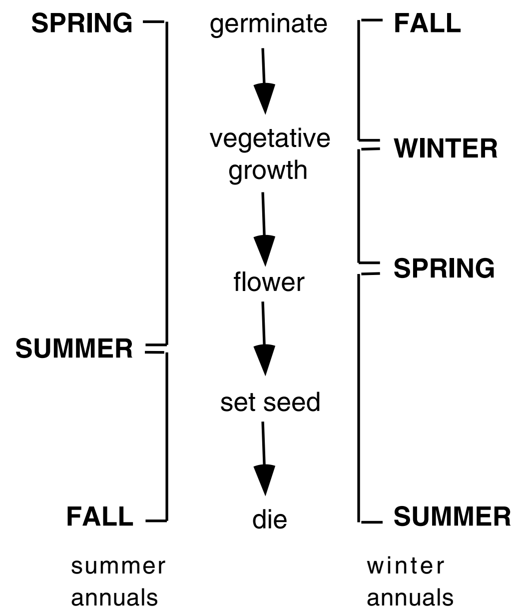


Figure 4.—Life cycle of annuals.

Annual plants complete their life cycle in less than 1 calendar year. Normally, annuals are the easiest type of weed to control, although they are the most common in disturbed areas.

Annuals are a continual problem due to an abundance of dormant seed, fast growth, and high seed production. They may cost more to control than perennial weeds due to great numbers of different species. Long-term control requires stopping seed production and exhausting the seed bank in the soil. There are two types of annual plants: summer annuals and winter annuals (see Table 2 for examples and Figure 4 for life cycles).

Summer annual plants germinate (sprout from seed) in the spring or summer. They grow, flower, set seed, and die before winter. The seeds lie dormant in the soil until the next spring or several springs later, when the cycle repeats itself.

Winter annual plants germinate in the late summer to early winter. They overwinter in a vegetative stage. In the spring or early summer, they flower, set seed, mature, and die, but live for less than 1 full year. The seeds lie dormant in the soil during the summer.

Table 3.—Examples of common biennials.

Tansy ragwort
Common mullein
Common burdock
Bull thistle
Poison hemlock

Biennial plants (Table 3) complete their life cycle within 2 years. In the first year, the plant forms basal leaves (rosette) and a taproot. The second year, the plant flowers, matures, and dies. There are no biennial grasses or sedges.

Sometimes people confuse biennials with winter annuals. Winter annuals normally live during 2 calendar years and during 2 seasons, but they complete their life cycle in less than 12 months.

Perennials live more than 2 years, and some may live almost indefinitely, resprouting from vegetative plant parts. Most reproduce by seed (sexually), and many spread vegetatively (asexually) as well. Because of these persistent, resprouting roots, rhizomes, stolons, tubers, and plant fragments, perennials are difficult to control. To prevent problems with these weeds, do not let perennial seedlings become established. Perennials are classified according to how they resprout: simple or creeping. Table 4 lists examples.

Simple perennials propagate and spread primarily by seed. They also can resprout from the taproot. The roots usually are fleshy and may grow very large. Dandelion and curly dock are common examples; if you cut them off below ground level, the plant can resprout from the taproot.

Creeping perennials reproduce primarily by vegetative (asexual) propagation: creeping roots, creeping stolons (aboveground horizontal stems), or creeping rhizomes (belowground horizontal stems). See Figure 5. Depending on species, they also can reproduce by seed or spores. Canada thistle and field bindweed propagate new shoots from creeping roots. Bentgrass and bermudagrass propagate new plants from stolons or rhizomes. Quackgrass and Johnsongrass sprout new growth from rhizomes. Yellow nutsedge also produces rhizomes, but the rhizomes end with underground tubers that propagate new plants.

Table 4.—Examples of common perennials.

Simple	Creeping
Common dandelion	Leafy spurge
Curly dock	Field bindweed
Buckhorn plantain	Canada thistle
Broadleaf plantain	Bermudagrass
Dalmatian toadflax	Johnsongrass
Pokeweed	Quackgrass
	Yellow nutsedge

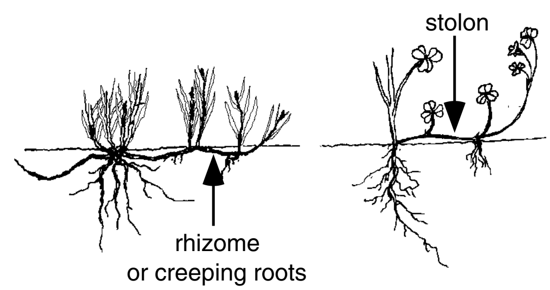


Figure 5.—Vegetative propagation by creeping perennials.

Once an area is infested, creeping perennials and woody plants that send up new shoots from the roots often are the most difficult weeds to control. Control might require repeated mowing or cutting, herbicide application(s), or combinations of the above.

Using a plant identification key

It is impossible to know all plant species that grow in the Pacific Northwest. Plant identification keys are useful tools for accurate weed identification, but often are complicated and difficult to use for the beginner. A few simple steps can result in effective use of these powerful tools.

- Become familiar with botanical terms that are used to describe parts of a plant. The terms used often are overwhelming. A good plant identification key will have a glossary. Use it as a reference as you work through the key, and practice with a weed you already know.

- Most keys limit their scope to a grouping of plants, such as shrubs, or more often, a particular geographic area. Be sure to choose a key that is specific to the area and plant type that you are identifying.
- Keep in mind that some plant characteristics vary depending on location, environment, and other variables, while other characteristics are fairly dependable for a given species. Give the more constant characteristics heavier weight in choosing a path than the variable characteristics. Common dandelion, for example, may vary in height depending on water and nutrient availability, mowing, and other variables, but it always has a yellow flower.
- Inspect the whole plant and get the "big picture" before you start using the key.
- Most keys are called "dichotomous" keys. They give you two choices: yes, a characteristic is present; or no, it is not present. Read both characteristics before you make a choice.
- If you have trouble choosing which path to take within a key, try both. Usually, one will lead to an obvious characteristic that rules out that route.

Some noxious weeds in Oregon

Canada thistle

Scientific name: *Cirsium arvense*
Life cycle: Perennial
Growth habit: Upright
Family: Asteraceae (Sunflower family)

Canada thistle is a creeping perennial that reproduces by seed and horizontal roots that may extend as long as 12 feet. New plants sprout from underground vegetative tissue. Stems are hollow, and dark green leaves slightly clasp the stems. Plants range from 1 to 5 feet tall. Leaves are oblong to lance-shaped (long and tapering from the base), deeply toothed, with sharp spines. Small flower clusters are lavender to purple in color. Flowers can produce 40 to 80 seeds per flower head.

Dalmatian toadflax

Scientific name: *Linaria dalmatica*
Life cycle: Perennial
Growth habit: Upright
Family: Scrophulariaceae (Figwort family)

Dalmatian toadflax grows from a single stem branching above the middle of the plant. It usually grows to 2 feet tall with waxy, dark green leaves that clasp around the stem in a heart-shaped pattern. Vertical roots have been found as deep as 6 feet, and horizontal roots may extend 10 feet or more. Dalmatian toadflax spreads by seed and rhizomes. Flowers are bright yellow in color and sometimes tinged with orange. It often is called wild snapdragon. It frequently comes in wildflower seed mixtures and escapes from ornamental sites to invade grasslands, pastures, and roadsides. Dalmatian toadflax originated in the Mediterranean.

Diffuse knapweed

Scientific name: *Centaurea diffusa*
Life cycle: Annual or biennial
Growth habit: Bushy
Family: Asteraceae (Sunflower family)

Diffuse knapweed has an overall bushy or ball shape up to 2 feet in diameter. During the first year after seed germination, the plant forms a rosette on a slender, elongated taproot. In the second year, a single flower stalk elongates, branches, flowers, and sets seeds. Diffuse knapweed was introduced from eastern Europe or Asia. It prefers disturbed areas but can be found invading grasslands.

Giant hogweed

Scientific name: *Heracleum mantegazzianum*
Life cycle: Perennial
Growth habit: Upright
Family: Apiaceae (Parsley family)

Giant hogweed is a member of the parsley or carrot family and closely resembles cow parsnip. It can grow 10 to 15 feet tall. Other identifying characteristics include hollow stems and stalks that are 2 to 4 inches in diameter. Stems are reddish-purple with spots on stalks. Both stalks and stems have coarse, white hairs. Leaves are up to 5 feet wide, with deeply incised leaflets. Giant hogweed forms a large, flat umbel inflorescence (flat cluster of flowers). It also has a tuberous root system that forms new buds each year. Giant hogweed prefers moist soils and rapidly outcompetes desirable vegetation in ravines, ditch banks, and along waterways. Giant hogweed was introduced as an ornamental from Asia.

Field horsetail

Scientific name: *Equisetum arvense*
Life cycle: Perennial
Growth habit: Upright
Family: Equisetaceae (Horsetail family)

Field horsetail is distinguished by succulent, hollow, jointed stems. It reproduces by spores and underground tubers. Field horsetail grows from single hollow, brownish stems growing to 2.5 feet in height. Scalelike appendages form leaves in whorls around stems at each stem node, giving the plant a bottlebrush appearance. Field horsetail is poisonous to horses, cattle, and sheep.

Gorse

Scientific name: *Ulex europaeus*
Life cycle: Perennial, evergreen
Growth habit: Upright, woody shrub
Family: Fabaceae (Pea family)

Gorse ranges from 3 to 10 feet tall, sprouting outward from root crowns. Bright yellow, pealike flowers are 0.5 to 0.75 inch long and appear on the ends of the branches, blooming in late February and March. Sharp, thorny spines develop as the plant matures. Gorse can tolerate a wide range of light and moisture conditions and is found mainly in the coastal regions of Oregon. It prefers disturbed, infertile soil areas such as roadsides, fencerows, and utility rights-of-way. Gorse spreads mainly by seed, but can spread vegetatively and resprout from stumps and root cuttings. Seeds are hard, impervious to water, and can lie dormant in the soil for up to 30 years. Seeds and foliage contain flammable oils that are a fire hazard.

Hoary cress (Whitetop)

Scientific name: *Cardaria draba*
Life cycle: Perennial
Growth habit: Upright
Family: Brassicaceae (Mustard family)

Hoary cress is a creeping perennial that reproduces by seed and an extensive creeping root system. The roots spread horizontally and vertically, with new shoots sprouting from root stocks. Hoary cress grows 1 to 2 feet tall. Leaves are alternate, grayish-green, and oblong shaped. The base of the upper leaves clasps around the stem. Leaf margins can be smooth or shallowly toothed. Stems branch toward the upper part of the plant. Numerous small, dense, white flowers with four petals form on the stems, creating a flat, white appearance. Seeds are egg shaped and reddish-brown and are produced from heart-shaped pods. Hoary cress was introduced in alfalfa seed from Europe.

Japanese knotweed

Scientific name: *Polygonum cuspidatum*
Life cycle: Perennial
Growth habit: Upright, shrubby
Family: Polygonaceae (Buckwheat family)

Japanese knotweed grows quickly and aggressively in large clumps and can reach over 10 feet in height. Stems are stout, semiwoody, hollow, and smooth, with swelling where the leaf meets the stem (nodes). Leaves are broadly oval at the base and taper at the tips. Leaves normally are about 6 inches long and 3 to 4 inches wide. Tiny, greenish-white flowers form in branched sprays in summer. Winged fruit form after flowering, with small, shiny, triangular seeds. Spreads from seed and prolific rhizomes. Adapts to a variety of soil types and moisture conditions. Introduced from Asia as an ornamental.

Leafy spurge

Scientific name: *Euphorbia esula*
Life cycle: Perennial, forb
Growth habit: Erect
Family: Euphorbiaceae (Spurge family)

Leafy spurge stems grow erect and are branched above. Leaves are alternate, smooth, narrow (0.12 to 0.4 inch) and oblong (1.25 to 4 inches) with a prominent vein. Leaves and stems produce a milky latex sap when torn or broken. Flowers are unisexual and greenish-yellow in color and form umbel flowers that are framed by heart-shaped bracts. The fruit capsule has three compartments that produce smooth, mottled seeds gray to brown in color. Leafy spurge grows and spreads quickly from seed and a rhizomatous root system. It is toxic to cattle, but can be safely grazed by sheep and goats. It was introduced from Eurasia as an ornamental plant.

Musk thistle

Scientific name: *Carduus nutans*
Life cycle: Biennial
Growth habit: Upright, erect
Family: Asteraceae (Sunflower family)

Musk thistle germinates in late summer or early fall. Seedlings form a rosette with a large, fleshy taproot. In the second year, it grows vegetatively, bolts, flowers, and sets seed. Stems branch from the base and can reach 7 feet tall. Leaves are waxy and dark green with a light-green midrib. Leaf bases extend around the stem in a "winglike" appearance. Stems and leaves have sharp, stiff spines on the margins. Rosette leaves are deeply lobed (toothed) and up to 1 foot in length. Upper leaves are simple, alternate, and deeply lobed with five points per lobe. Flowers are large (1.5 to 3 inches) and dark purplish, rising from the end of each stem and nodding downward as they mature. Musk thistle spreads mainly by seed.

Perennial pepperweed

Scientific name: *Lepidium latifolium*
Life cycle: Perennial
Growth habit: Upright
Family: Brassicaceae (Mustard family)

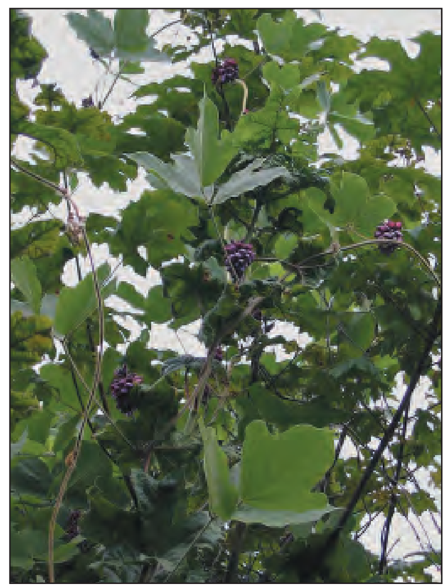
Perennial pepperweed is a deep-rooted, creeping perennial with an extensive root system. It can range from 3 to 5 feet tall and reproduces from seed and rootstock. Lower leaves are oblong with toothed margins. Leaves are grayish-green and have a thick, waxy cuticle layer. The upper leaves do not clasp the stem as do the leaves of hoary cress. Flowers are small, dense, and white and form near the ends of the stems. Seeds are small and reddish-brown in color and can be slightly flat and rounded. Perennial pepperweed was introduced from southern Europe or western Asia.

Puncturevine

Scientific name: *Tribulus terrestris*
Life cycle: Summer annual
Growth habit: Prostrate, branching
Family: Zygophyllaceae (Caltrop family)

Puncturevine stems are hairy and form from a prostrate crown (growing flat on the ground). Stems branch from the base to form dense mats up to 6 feet in length. Leaves form five to eight pairs of leaflets and are hairy. Flowers are small, 0.25 to 0.5 inch wide, and yellow with five petals. Puncturevine spreads by seeds, which have sharp, stout spines that can puncture auto and bicycle tires. Seeds remain viable in the soil for 10 years or more. Sharp spines on puncturevine seeds can cause mouth sores and foot lesions in livestock. Puncturevine also produces a chemical (a steroidal saponin) that causes photosensitivity in sheep.

Kudzu



Scientific name: *Pueraria lobata*
Life cycle: Perennial
Growth habit: Vine, subshrub
Family: Fabaceae (Pea family)

Kudzu was introduced into the United States from Asia and is a competitive legume plant. The leaflets are found in groups of three (2 to 5 inches in length) and are two- or three-lobed, tapering to a point. Stems have a rough, barklike covering and large, purple flowers. Seed pods are 1.75 to 2 inches long, papery, and covered with fine hair. Plants reproduce from seed and runners from root nodes. Left uncontrolled, kudzu will overgrow trees, shrubs, power lines, transmission towers, grain silos, and abandoned buildings. Kudzu has an extensive root system and can grow as much as 60 feet per year. Roots can reach a depth of 12 feet into the soil and weigh as much as 300 pounds.

Purple loosestrife

Scientific name: *Lythrum salicaria*
Life cycle: Perennial
Growth habit: Upright, bushy
Family: Lythraceae (Loosestrife family)

Purple loosestrife is a semiaquatic, erect, herbaceous perennial growing 4 to 10 feet in height. It can quickly outcompete and replace native vegetation along wetlands, marshes, rivers, lakes, streams, creeks, and irrigation systems by forming dense homogeneous stands. Stems are square and woody with opposite, lanced-shaped leaves. Flowers are reddish-purple and about 1 inch in diameter. Mature purple loosestrife plants can produce 2 to 3 million seeds per year, and seeds can remain viable in the soil for several years. It also can reproduce vegetatively through underground stems. Purple loosestrife was introduced into the U.S. for ornamental and medicinal uses.

Russian knapweed

Scientific name: *Centaurea repens*
Life cycle: Perennial
Growth habit: Upright
Family: Asteraceae (Sunflower family)

Russian knapweed grows about 1 to 3 feet in height. Stems are erect and openly branched, forming dense colonies. Basal leaves are deeply lobed, and upper leaves are linear to oblong. Flowers range from pink to purple and are numerous. They are solitary on leafy branchlets. Bracts on flower heads are pale and have papery margins forming pointed tips. Russian knapweed reproduces from seed and underground rhizomes. It is unpalatable to livestock and wildlife because of its bitter taste. It is found in rangeland, pastures, fields, roadsides, fencerows, and wasteland.

Russian thistle (Tumbleweed)

Scientific name: *Salsola kali*
Life cycle: Summer annual
Growth habit: Upright, bushy
Family: Chenopodiaceae (Goosefoot family)

Russian thistle forms a well-branched, round, bushy plant growing to 3.5 feet in height from a taproot. When young, stems are slender and succulent, becoming woody as the plant matures. Stems are either green or reddish in color. Dark green leaves are soft, slender (1 to 2.5 inches long), and alternate. As the plant matures, leaves drop and are replaced by short, stiff spines. Greenish-white or pink flowers are small and inconspicuous in the leaf axils. When the plants mature, they break off at the soil level and blow about with the wind, spreading seeds as they tumble along. Russian thistle was introduced from Russia in contaminated flax seed. Russian thistle occasionally causes poisoning in livestock due to an accumulation of nitrates.

Scotch broom

Scientific name: *Cytisus scoparius*
Life cycle: Perennial, evergreen
Growth habit: Upright, woody shrub
Family: Fabaceae (Pea family)

Scotch broom is a highly branched, woody shrub ranging from 3 to 10 feet tall. Branches are stiff, angled, and dark green in color with few leaves. Upper leaves are simple; lower leaves are three parted. The pealike flowers are about 0.75 inch long, showy, and bright yellowish-orange, and they bloom from April to June. Seed pods are flat, brown to black in color, and resemble a peapod. Each pod contains several oval, dark green or greenish-brown, shiny seeds. Seeds can remain viable in the soil for 60 years or more. Scotch broom was imported from Europe as an ornamental shrub and quickly escaped and spread. Scotch broom produces several substances that can be toxic to livestock.

Scotch thistle

Scientific name: *Onopordum acanthium*
Life cycle: Biennial
Growth habit: Upright, erect
Family: Asteraceae (Sunflower family)

Scotch thistle can reach up to 10 feet tall. During the first year, it germinates and forms a rosette and large, fleshy taproot. It bolts in the second year, produces flowers, sets seed, and dies. It is heavily branched in a bushlike appearance. Rosette leaves can be 2 feet long and 1 foot wide. Leaves are coarsely lobed and hairy, giving the plant a gray, velvety appearance. Leaves are spiny and extend down the stem, forming “wings.” Flowers are reddish-purple.

Spotted knapweed

Scientific name: *Centaurea maculosa (C. stoebe)*
Life cycle: Biennnial, short-lived perennial
Growth habit: Upright
Family: Asteraceae (Sunflower family)

Spotted knapweed grows up to 4 feet tall with slender, branching stems that are covered with fine hair. During the first year seed germinates in spring or fall and forms a rosette; in the second year the flower stalk elongates, flowers, and sets seed. Flowers are pink to purple, with one flower per shoot tip. Tips of the flower and seed heads are black. Spotted knapweed spreads mainly by seed. Rosette leaves are deeply lobed (divided). Leaves on shoots are short and narrow. The root system consists mainly of a stout taproot. Spotted knapweed prefers dry conditions, but can adapt to higher moisture areas. It is found in dry meadows, pastures, stony hillsides, rights-of-way, and floodplains.

St. Johnswort (Klamath weed)

Scientific name: *Hypericum perforatum*
Life cycle: Perennial
Growth habit: Upright
Family: Clusiaceae (St. Johnswort family)

St. Johnswort originated in Europe and also is called Klamath weed. Stems are smooth, heavily branched, and rising from a woody base. St. Johnswort typically grows 1 to 2 feet tall. Leaves are small, narrow, and oblong. They are smooth and covered with tiny, clear dots that appear as holes in the leaves when held up to light. Stems and leaves at or near the base of the plant can be reddish in color. Flowers are yellow with five petals, occasionally rimmed around the edges with black dots. St. Johnswort contains a toxic substance that causes livestock (especially those with white hair) to become sensitive to strong sunlight. The condition usually is fatal.

Tansy ragwort

Scientific name: *Senecio jacobaea*
Life cycle: Biennial
Growth habit: Upright
Family: Asteraceae (Sunflower family)

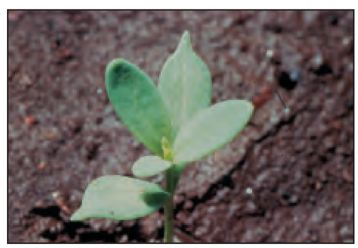
Tansy ragwort has a small to medium taproot, grows from 1 to 6 feet tall, and reproduces only from seed. Stems are simple, single, and branched near the tops. They produce golden-yellow ray flowers (12 to 15) in clusters about 1 inch in diameter. Leaves typically are dark green and are alternate and deeply lobed. Lower leaves have long stalks, while upper leaves lack stalks. Tansy ragwort is poisonous to cattle and horses; toxins accumulate in animal tissue, causing irreversible liver damage. Tansy ragwort was introduced from Europe and can be found in rangeland, pastures, and wasteland.

Woolly distaff thistle

Scientific name: *Carthamus lanatus*
Life cycle: Winter annual
Growth habit: Upright
Family: Asteraceae (Sunflower family)

Woolly distaff thistle, also referred to as distaff thistle, germinates from fall to early winter and flowers from late spring to summer. It grows up to 4 feet tall, with extensive branching on the upper two-thirds of the plant. Stems are rigid, ribbed, white or pale green, with tiny hairs that give them a woolly appearance. The leaves are deeply lobed (toothed) and have short spines at the ends. Flowers are yellow with red veins, and the flower heads are surrounded by bracts with sharp spines. Woolly distaff thistle spreads by seed, and plants have a simple taproot. They prefer areas that receive 16 to 24 inches of rainfall a year and can adapt to different soil types. Woolly distaff thistle threatens rangeland, pastures, and winter grain crops in Oregon. It is native to Eurasia.

Yellow toadflax



Scientific name: *Linaria vulgaris*
Life cycle: Perennial
Growth habit: Upright
Family: Scrophulariaceae (Figwort family)

Yellow toadflax can grow more than 3 feet tall and spreads from seed and rhizomes. Stems are erect, smooth, light green in color, and leafy, with little branching. Leaves are narrow and smooth and attach directly to the stem. Flowers look similar to snapdragon flowers. Yellow toadflax flowers are bright yellow with an orange throat and long spur. Yellow toadflax often is referred to as wild snapdragon or "butter and eggs." Roots are well branched, woody rhizomes. Originally introduced into the U.S. as an ornamental, yellow toadflax prefers open areas such as rangeland, roadsides, wasteland, grain fields, and disturbed areas. It is mildly toxic to livestock.

Yellow starthistle

Scientific name: *Centaurea solstitialis*
Life cycle: Annual
Growth habit: Erect, rigid, branching
Family: Asteraceae (Sunflower family)

Yellow starthistle grows 1 to 3 feet tall and branches from the base of the plant, giving the plant a bushy appearance. The plant has bright yellow, ray-type flowers, one per stem. Straw-colored spines up to 1 inch long extend from below the flower head. Mature plants look grayish-green in color due to the white, woolly hairs on the stems. Yellow starthistle germinates in fall or spring and spreads by seed.

Review questions (answers on back of page)

1. Give three examples of weeds.

2. Name four ways in which weeds spread.

3. True or false: Weeds are more problematic in disturbed soils.

4. Name three plant characteristics that generally can be used to distinguish herbaceous broadleaf weeds from grassy weeds.

5. Name three summer annual weeds.

Answers to review questions

1. Three weeds mentioned in this manual are Dalmatian toadflax, Scotch broom, and kochia. Many other weeds exist in the Pacific Northwest.
2. People, wind, water, and animals all have the potential to spread weed seeds.
3. True. Weeds typically are more problematic in disturbed areas, including areas where the soil has been tilled.
4. Broadleaf weeds have the following characteristics: netlike leaf veins and growing points at the end of each stem and in each leaf axil. In contrast, grass weeds have the following characteristics: parallel leaf veins, fibrous root system, and a single growing point that is located near the soil surface. Other differences between grasses and broadleaf plants exist.
5. Green foxtail, yellow foxtail, puncturevine, Russian thistle, crabgrass, kochia, and common lambsquarters are mentioned in this manual. Any three of the above would be correct.

2 Vegetation Management Strategies

Integrated control

Integrated Vegetation Management (IVM) stresses the control of undesirable vegetation and enhances the environment for desirable plants. Seldom does a single control method give the desired results, especially long-term. To achieve environmentally and economically sound results, most managers design an integrated approach using preventive, cultural, mechanical, biological, and chemical control measures.

The basis for any weed control plan is to properly identify the weed so you can learn about its biology (see Chapter 1). Once you understand the strengths and weaknesses of the weed in relation to where it is growing, you can determine the control methods and evaluate the benefits and risks of each. IVM practices relevant to rights-of-way may include scouting, making maps, using thresholds, and developing a unified program with few side effects.

Scouting is the routine observation of the right-of-way to record pertinent information on desired and undesired species. Inventory highways, utility lines, and ditch banks. Conduct power line inventories once a year. Some rights-of-way may require up to three scoutings in a year. Suggested scouting times are late spring, midsummer, and early fall to assure that early- and late-season vegetation is detected.

Identify and record the prevalent species on a mile-by-mile basis. Make special note of noxious weed species that require more intensive control measures. Note any significant differences in disturbed areas and soil conditions (such as slope, texture, or poorly drained areas). Record the approximate height of undesired vegetation. Indicate the presence of any "sensitive areas" (streams, home gardens, orchards, schools, high-value or specialty crops) that require different management strategies. Maintain these records for several years to monitor rate of vegetation growth (especially brush), the effectiveness of your management practices, the appearance of new species, and any other developments or changes.

"Reading" the landscape requires personnel to develop an eye for interpreting what the environment reflects in terms of vegetation changes. Annual weeds, found in non-bareground managed areas, indicate either recent disturbance to the site or a site so nutritionally depleted it cannot support adequate perennial ground cover. The presence of reed canarygrass, cattails, rushes, and sedges reflects wet, poorly drained areas that may have standing water. St. Johnswort and diffuse knapweed reflect sandy, well-drained soils. Foxtail barley or rabbitfoot clover along the pavement may indicate high salt levels.

These and other responses to the environment can be useful clues to use in implementing a management program. For example, use of highly soluble soil-residual herbicides around guardrails when diffuse knapweed is present may endanger both surface and groundwater sources if indeed the soil is very sandy and the water table is shallow.

Reseed sites heavily infested with annual or biennial weeds to reestablish the dominance of perennial species. Select grasses and other plants that are adapted to the rainfall area where they will be grown; rainfall varies from 6 to more than 100 inches per year in the Pacific Northwest.

Thresholds are levels of infestation at which control practices are justified. They vary greatly in rights-of-way, depending on the weed species present, land use, and the manager's perception. Noxious weeds have a low threshold to prevent seed production. Road shoulders have a different threshold than utility rights-of-way. Managers may view vegetation density differently. One manager may have a zero tolerance for weeds around signposts, while another may be willing to allow vegetation to grow to perhaps 2 feet before controlling the vegetation.

Evaluate your results after using any vegetation management practice. Inspect the area carefully. Keep in mind the type and species of vegetation treated, the soil type, and weather during and after application. Know the objectives of the control program when evaluating the results. In some cases, suppression of treated vegetation is sufficient; in others, selective control is desired; and in still others, total vegetation control is the goal.

Some evaluations may take a while, especially when evaluating long-term residual applications. Initial herbicide activity and possible injury to adjacent desirable vegetation can be determined 2 to 4 weeks after application, with the exception of fall-applied residual herbicides. Evaluate fall-applied herbicide treatments the following spring and summer.

Routinely review the results and modify the plans as needed. Experiment with alternative approaches before adopting them on a large-scale basis. Monitor the results for several seasons before passing judgment on the merits or drawbacks of new methods.

Landscape preparation

When preparing a new landscape along rights-of-way, reduce future weed problems by planning a low-maintenance, highly competitive planting. Select plants that grow well under the environmental conditions (soil type, pH, light, water, temperature) of that site. If desirable vegetation can become established and outcompete invading weeds, the battle is in your favor. New plantings may require extra attention the first few years, including weed control, irrigation, and fertilization.

When replanting desirable vegetation in an area where residual herbicides have been applied, consider conducting a soil bioassay. Soil bioassays are a simple and effective method to ensure that future plantings will not be affected by previous herbicide applications.

Sample soil in multiple locations where desirable species will be planted and place the soil in several small pots. Plant the desired species in the sample pots and place the pots in adequate light for growth (such as a windowsill). Provide water as necessary. Monitor desirable plant growth for unusual injury that might be caused by residual herbicides.

Prevention

The best way to manage weeds is by keeping them out of a new planting or existing site. If they are not present, they do not require control. Use the following tactics to stop new weeds from infesting an area.

- Prevent new weeds from becoming established by stopping seed production. Control them prior to seed set. If new weeds are perennials, prevent them from developing roots or rhizomes that can start new plants.
- Make sure weed seeds and perennial plant parts are not carried into the area with contaminated machinery.
- Plant certified seed (seed certified free of noxious weed seeds) to prevent contaminating a new planting or when overseeding an established stand.
- Inspect straw, hay, and any other mulching material to assure that it does not contain highly undesirable weeds or seeds. Or, require certified weed-free straw.

Mechanical control

Mechanical techniques are the oldest methods of vegetation control. They include hand-pulling, blading, grubbing, and mowing.

Hand-operated methods include power weeders, string trimmers, chain saws, brushhooks, machetes, hoes, and shovels. Mechanical tools are sharp and produce noise, so take care to protect eyes, ears, legs, and feet.

These methods are commonly used for areas where obstacles prohibit the use of other vegetation control measures. Trees and woody brush often are cut, and the cut surface may be treated with herbicides to prevent resprouting. Selective trimming and cutting of woody brush and trees is necessary to clear overhanging and encroaching tree limbs to provide clearance for vehicles, power lines, and other utility transmission lines. These control methods typically are labor-intensive and expensive when compared to other methods.

Mowing and brush cutting are important in vegetation management. A variety of methods are used, such as flail, reel, sickle, and rotary mowers. Mowers range in size from 4 to 6 feet wide for two-lane local and county roads to 12 to 24 feet wide for large-scale interstate mowing. Brush cutting usually is done with machines that are heavier versions of grass mowers.

Cutting and mowing cut all vegetation in their path but do not affect plant roots. Consequently, many trees, shrubs, and perennials resprout in greater numbers, while annuals and biennials may be controlled. Cut or mow carefully to avoid injuring desirable plants. Consider safety of nearby motorists since mowers throw rocks and other debris. Close cutting and sod scalping can occur, causing erosion along roadways. Cut material can smother the grass, become a fire hazard, and block culverts and drains during heavy rains. Turf that is cut too short encourages invasion of annual weeds.

Cultural control

Cultural practices can include burning, flooding, mulching, tillage, and planting of competitive desirable vegetation.

Vegetation management in rights-of-way usually can be based on ecological principles rather than on farming or agronomic principles. Often we can maintain the competitive advantage of our desired species over weeds.

Activities that encourage the growth and development of desirable vegetation without involving mechanical or chemical methods fall in this category. Examples include using adapted species, overseeding, fertilizing, liming (if required), and mulching. Overseeding can fill in the stand with new plants. Fertilization is an effective way to encourage desirable plant cover, which in turn prevents the growth of weeds and woody plants. Liming soils changes the pH. It can reduce the ability of some plants to use the site, and it favors desirable plants. Mulches exclude light and are particularly useful in landscape plantings.

Fire removes undesirable plants from ditch banks, roadsides, and waste areas. Controlled burning also removes fire hazards and clears waterways. Green plants may require two burnings, one to dry them out and a second to burn the dried weeds. Fire will not kill weed seeds buried in the soil, but can destroy some seed on plants and in surface litter under favorable conditions. Permits may be required; check with appropriate local authorities.

Some plant materials can prevent weeds from becoming established because of competition and allelopathy. These processes are the most effective and common weed control method. **Competition** is the interaction between plants for space, nutrients, moisture, and light. **Allelopathy** occurs when one plant produces chemicals that inhibit the establishment and growth of others. Allelopathic weeds include Canada thistle and the knapweeds. The makeup of plant communities on the roadside is likely to be a result of both processes. Plants living and growing in groups or communities are rivals throughout their lives. Taller plants shade shorter plants; dense grass stands prevent other plants from becoming established.

Hydroseeding is commonly used to establish new vegetation along rights-of-way. Wildflowers provide a variety of colors and sometimes are used as competitors. They make the site attractive to the taxpaying public and prevent or slow weed invasions. Select seed mixes carefully to prevent the introduction of new invasive weeds.

Table 5.—Selected weeds and biological weed control agents used in Oregon.

Weed	Biological control agents
Scotch broom	Flower moth, seed weevil, twig miner
Tansy ragwort	Flea beetle, seed fly, cinnabar moth
Dalmatian toadflax	Flower beetle, foliage worm, capsule weevil, root-boring moth, root-galling weevil, stem-boring weevil

Biological control

Biological control uses living organisms (insects, animals, or pathogens) to control undesirable vegetation. Insect examples include the cinnabar moth to control tansy ragwort and the *Chrysolina* beetle to control St. Johnswort. Table 5 lists some currently used biological control agents in Oregon. Currently, the use of disease organisms is very limited. Although biological controls are inexpensive to maintain, their populations always lag behind the development of the weed population. They also are very specific. The inability to adequately control a variety of weeds in a timely manner on rights-of-way limits their effectiveness as a management tool. Biological controls usually are regional programs, and rights-of-way are incidental beneficiaries. Most biological control organisms require a long period of time for establishment and little vegetation disturbance. Noxious weeds need immediate attention.

Chemical control

Chemical methods include the application of herbicides and plant growth regulators, both of which are considered to be pesticides. By selecting the proper herbicide application method, rate, and timing, it is possible to: (1) selectively control broadleaf plants, grasses, or trees and not injure other plants, (2) control all vegetation for short or long time periods, (3) suppress grass seed head production, and (4) reduce the growth of foliage. Proper use of chemicals is important because plants on or off the rights-of-way can be injured by inappropriate actions.

Review questions (answers on next page)

1. What is scouting, and what information should be recorded?

2. What is a threshold?

3. What are some drawbacks of mechanical control?

4. Give an example of biological control.

5. True or false: Using herbicides interferes with the goals of Integrated Vegetation Management (IVM).

Answers to review questions

1. Scouting is the process of routinely observing the right-of-way for weeds. The types of weeds present should be recorded on a mile-by-mile basis. Any noxious weeds that might require special control techniques should be recorded.
2. A threshold is the level of infestation at which control practices are justified.
3. Hand-operated methods of mechanical control can be labor-intensive, costly, and dangerous. Mowing does not kill the plant roots, so regrowth is possible.
4. See Table 5.
5. False. Chemicals can be used as part of an overall IVM program.

3 Herbicide Activity and Selectivity

To select the best herbicide for a particular weed, you must understand the following:

- How herbicides enter and move in plants
- How herbicides kill or injure plants
- How herbicides can be used to kill only the targeted weeds, not desirable vegetation (selective control)

Uptake and movement—contact versus translocated

Herbicides need to be absorbed by the plant and are applied either: (1) directly to the foliage, or (2) to the soil where the roots or emerging shoots absorb the herbicide. Herbicide movement and activity within a plant differ among plant species and herbicides. For this reason, some herbicides work well on certain species, while having little effect on others. **Herbicides need to kill only the shoots of annual or biennial broadleaf weeds, but must move to the roots to control perennials.**

Contact herbicides are applied directly to plant foliage and kill only plant parts they contact directly (Figure 6). They do not move (translocate) throughout a plant. They generally disrupt cell membranes. Activity often is very quick, with visible damage occurring in a few hours. **You must get even herbicide distribution over the entire weed. Only the areas the chemical contacts will die.**

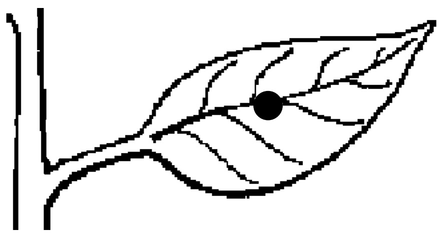


Figure 6.—Contact herbicides do not move within the plant; they affect only contacted plant tissues.

Contact herbicides effectively control some annual weeds, but only burn off the shoots of perennial weeds, leaving the underground system to resprout. Repeated applications to perennial weeds may deplete the food reserves in underground plant parts, eventually causing death. Diquat and paraquat are examples of contact herbicides.

Translocated (systemic) herbicides are absorbed through the foliage, stem, shoots, or roots and move throughout plants (Figure 7). Generally, if absorbed from the soil by roots, translocated herbicides move with water transported to the stem and leaves. Most of the foliar-applied translocated herbicides are sprayed onto leaves and move with sugars to actively growing plant parts such as shoot tips and roots. As a result, injury often is seen first in developing tissues.

Some of these chemicals are selective and control broadleaf weeds in grass stands or vice versa. Because they can move within the plant, some of these chemicals effectively control perennial weeds and do not have to be applied uniformly over the whole plant to produce good results. Most herbicides are translocated herbicides. Some examples are 2,4-D, MCPA, picloram, diuron, clopyralid, glyphosate, and dicamba.

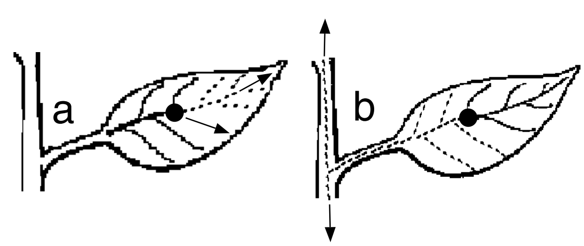


Figure 7.—Translocated herbicides move to the leaf and stem tips (a), or move upward or downward in the plant within the conductive tissues (b).

Modes of herbicide action

Herbicide mode of action includes all processes from absorption into the plant to action at the specific target site. It refers to how an herbicide works to kill a plant or to prevent or stop plant growth. Understanding how herbicides control weeds often is useful in selecting and applying the proper herbicide for a particular weed. It also may be useful in recognizing herbicide injury in plants. There are seven major modes of action. Common names and trade names are listed in Tables 6–14.

Note

Tables 6–14 contain a sample of rights-of-way products that are commercially available at the time of publication. Check with your supplier or chemical representative for recommendations to fit your needs.

Trade-name products and services are mentioned as illustrations only. This does not mean that the Oregon State University Extension Service either endorses these products and services or intends to discriminate against products and services not mentioned.

Table 6.—Growth regulator herbicides.

Growth regulator herbicides disrupt the hormone balance and protein synthesis in plants, causing growth abnormalities. Growth regulators selectively kill broadleaf weeds in grass stands. Grasses generally are tolerant to these chemicals, but injury can occur if herbicides are applied at the wrong growth stage or at high rates. These herbicides translocate to the growing points of the plants, and injury symptoms appear in new plant tissue. An early symptom often is **epinasty**, which is abnormal bending or twisting of shoot tips. Growth regulators are foliage applied, but some root absorption may occur.

Common name	2,4-D (multiple formulations—amine, ester)
Trade name	Several trade names
Chemical family	Phenoxy acetic acid
Uses	Postemergence control of broadleaf weeds
Application	Postemergence
Mode of action	Growth regulator
Uptake/translocation	Primarily foliar uptake with translocation throughout plant
Symptomology	Twisting of stems and petioles, stem elongation, and leaf cupping (epinasty), followed by plant death
Cautions	Do not allow 2,4-D to drift or contaminate water for irrigation or domestic use. Some formulations volatilize at lower temperatures than others. Check temperature restrictions.

Common name	MCPA
Trade name	Several trade names
Chemical family	Phenoxy acetic acid
Uses	Postemergence control of broadleaf weeds
Application	Postemergence
Mode of action	Growth regulator
Uptake/translocation	Primarily foliar uptake, with translocation throughout the plant
Symptomology	Twisting of stems and petioles, stem elongation, and leaf cupping (epinasty), followed by plant death
Cautions	Do not allow MCPA to drift or contaminate water for irrigation or domestic use.

Common name	Dicamba
Trade name	Banvel, Clarity
Chemical family	Benzoic acid
Uses	Postemergence control of broadleaf weeds
Application	Postemergence
Mode of action	Growth regulator
Uptake/translocation	Primarily foliar uptake (some root uptake) with translocation throughout the plant
Symptomology	Twisting of stems and petioles, stem elongation, and leaf cupping (**epinasty**), followed by plant death
Cautions	Do not allow dicamba to drift or contaminate water for irrigation or domestic use. Do not allow dicamba to contact roots of desirable species. Known to leach and move through surface runoff. Volatilizes during warm temperatures.

Common name	Clopyralid
Trade name	Transline
Chemical family	Pyridine
Uses	Clopyralid controls actively growing broadleaf weeds.
Application	Postemergence
Mode of action	Growth regulator
Uptake/translocation	Absorbed by foliage and roots and translocated throughout the plant.
Symptomology	Twisting of stems and petioles, stem elongation, and leaf cupping (**epinasty**), followed by plant death
Cautions	Do not allow clopyralid to drift or contaminate water for irrigation or domestic use. Do not use treated vegetation for compost or mulch.

Common name	Picloram
Trade name	Tordon
Chemical family	Pyridine
Uses	Applied to actively growing weeds and brush. Provides residual weed control.
Application	Postemergence
Mode of action	Growth regulator
Uptake/translocation	Foliar and root uptake, with translocation throughout the plant
Symptomology	Twisting of stems and petioles, stem elongation, and leaf cupping (**epinasty**), followed by plant death
Cautions	Most formulations are restricted-use pesticides. Follow label restrictions carefully. Known to leach through soil into groundwater. Do not use on permeable soil, particularly where there is shallow groundwater.

Common name	Fluroxypyr
Trade name	Vista
Chemical family	Pyridine
Uses	Postemergence control of broadleaf weeds
Application	Postemergence
Mode of action	Growth regulator
Uptake/translocation	Primarily foliar uptake (some root uptake) with translocation throughout the plant
Symptomology	Twisting of stems and petioles, stem elongation, and leaf cupping (**epinasty**), followed by plant death
Cautions	Do not allow fluroxypyr to drift or contaminate water for irrigation or domestic use.

Common name	Triclopyr
Trade name	Garlon, Pathfinder II
Chemical family	Pyridine
Uses	Apply to actively growing annual and perennial broadleaf weeds and brush. Provides residual weed control.
Application	Postemergence
Mode of action	Growth regulator
Uptake/translocation	Foliar and root uptake and translocation throughout the plant
Symptomology	Twisting of stems and petioles, stem elongation, and leaf cupping (**epinasty**), followed by plant death
Cautions	Do not allow herbicide to drift. Well-established perennials may require retreatment.

Lipid inhibitors.

Lipid inhibitors prevent the production of fatty acids that make cell membranes required for new plant growth. Lipid inhibitors are effective against most annual and perennial grasses; broadleaf plants are tolerant. They translocate through the plants from foliar applications. Symptoms of activity usually are cessation of growth, yellowing (**chlorosis**), or browning of leaves.

Table 7.—Amino acid synthesis inhibitors.

Amino acid synthesis inhibitors prevent the production of amino acids that form proteins fundamental to normal plant development. Depending on the product, these chemicals can be either foliage or soil applied. Symptoms of activity may include stunting, yellowing (**chlorosis**), or purpling of leaves.

Common name	Chlorsulfuron
Trade name	Telar
Chemical family	Sulfonylurea (Su)
Uses	Controls weeds prior to emergence or when very young. Adequate soil moisture is needed for optimum herbicide activity. Sometimes used for growth suppression and seed head inhibition.
Application	Preemergence or early postemergence
Mode of action	Amino acid synthesis inhibitor
Uptake/translocation	Foliar and root absorption. Chlorsulfuron taken up by roots is translocated throughout the plant to growing points.
Symptomology	Yellowed growing points, followed by browning of plant tissue and plant death. Injury symptoms usually appear within 1 to 2 weeks of application.
Cautions	Do not apply to frozen ground or to saturated soils. Agitation is required for proper herbicide mixing. Selected weed biotypes have become resistant. Injury to sensitive vegetation may occur if treated soil is washed, blown, or moved from treatment site.

Common name	Metsulfuron
Trade name	Escort
Chemical family	Sulfonylurea (Su)
Uses	Apply to actively growing weeds or brush
Application	Postemergence
Mode of action	Amino acid synthesis inhibitor
Uptake/translocation	Foliar and root uptake, with translocation primarily from the roots in the xylem
Symptomology	Growing points become yellowed 1 to 2 weeks after application, followed by general plant yellowing and death.
Cautions	Do not allow metsulfuron to drift to desirable broadleaf species. Agitation required. Selected weed biotypes are resistant to sulfonylurea herbicides.

Common name	Sulfometuron
Trade name	Oust
Chemical family	Sulfonylurea (Su)
Uses	Nonselective control of many annual broadleaf weeds and some grasses and perennial broadleaf weeds. Precipitation is required for optimum preemergence weed control.
Application	Preemergence or early postemergence
Mode of action	Amino acid synthesis inhibitor
Uptake/translocation	Preemergence applications absorbed by roots; postemergence applications absorbed by roots and shoots. Translocated in the xylem and phloem.
Symptomology	Growing points turn chlorotic (yellow) 1 to 3 weeks after application, followed by general yellowing. Growing points and stems in some species turn reddish purple.
Cautions	Do not allow herbicide to drift to crops or desirable plants. Do not apply during heavy rain or on wind-erodible soils. Biotypes of some weed species have become resistant to sulfonylurea herbicides. Can persist in the soil for a growing season or more.

Common name	Glufosinate-ammonium
Trade name	Finale
Chemical family	None
Uses	A nonselective, postemergent, contact herbicide with some systemic activity
Application	For postemergent control of annual and perennial grasses, sedges, and broadleaf weeds. Thorough spray coverage is important.
Mode of action	Amino acid synthesis inhibitor
Uptake/translocation	Symptoms appear where the contact occurs.
Symptomology	Visible effects occur within 2 to 4 days after application under good growing conditions. Includes yellowing (chlorosis) or death (necrosis) of leaf tissue.
Cautions	Avoid all contact, including drift, with foliage; green tissue; or green, thin, or uncalloused bark of desirable vegetation. Use of this product in areas with coarse soils and a high water table may result in groundwater contamination.

Common name	Glyphosate
Trade name	Several trade names (Roundup, Glyphos, Rodeo, Accord, etc.)
Chemical family	Amino acid derivative
Uses	A nonselective herbicide that controls many annual, biennial, and perennial weeds
Application	Postemergence
Mode of action	Amino acid synthesis inhibitor
Uptake/translocation	Absorbed by foliage and translocated to active growing points or underground tissue
Symptomology	General foliar yellowing within 7 to 20 days after application, followed by general necrosis (plant death). Foliage sometimes turns reddish or purple in some species. Woody species sometimes display condensed growth or multiple shoots.
Cautions	Repeated application may be necessary for well-established perennial weeds.

Common name	Imazapyr
Trade name	Arsenal, Chopper, Stalker
Chemical family	Imidazolinone
Uses	Imazapyr controls several annual and perennial broadleaf and grass weed species, as well as brush and tree species, with some residual control. (The herbicide provides weed control for some time past the time of application.)
Application	Postemergence applications are most successful, although imazapyr also provides residual weed control.
Mode of action	Amino acid synthesis inhibitor
Uptake/translocation	Absorbed by foliage and roots and transported in the xylem and phloem throughout the plant
Symptomology	Growth ceases soon after application, but yellowing plant symptomology (**chlorosis**) might not appear for up to 2 weeks after application. General plant yellowing is followed by necrosis.
Cautions	Avoid herbicide contact with desirable plant roots and foliage. Do not apply to frozen or saturated soils. Heavy rainfall after application can result in off-target movement.

Common name	Imazapic
Trade name	Plateau
Chemical family	Imidazolinone
Uses	Selective control of winter and summer annual and perennial grasses, broadleaves, and vines. With adequate soil moisture, imazapic provides residual control of susceptible germinating seedlings.
Application	Pre- and postemergence. Postemergence application is the method of choice in most situations, particularly for perennial species.
Mode of action	Amino acid synthesis inhibitor
Uptake/translocation	Rapidly absorbed through the leaves, stems, and roots and translocated rapidly throughout the plant. Adequate soil moisture is important for optimum activity.
Symptomology	Chlorosis appears first in the newest leaves, and necrosis spreads from there.
Cautions	This chemical demonstrates the properties and characteristics associated with chemicals detected in groundwater. **Do not** apply if rainfall is threatening. This product has high potential for runoff for several months or more after application. Runoff of this product is reduced by avoiding applications when rainfall is forecasted to occur within 48 hours.

Table 8.—Seedling growth inhibitors.

Seedling growth inhibitors interfere with new plant growth, stopping normal seedling root or shoot development. They must be applied to the soil to act on emerging weed seedlings. Symptoms may include stunted or swollen roots on emerging seedlings, or seedlings that never emerge.

Common name	Dichlobenil
Trade name	Casoron, Norosac
Chemical family	Nitrile
Uses	Dichlobenil controls several annual, biennial, and perennial grass and broadleaf weeds. Apply during late fall or early winter so that precipitation will incorporate the herbicide into the soil.
Application	Soil-applied with incorporation by precipitation. Do not remove old weed growth before application.
Mode of action	Seedling growth inhibitor
Uptake/translocation	Readily absorbed by foliage and roots. Translocation is rapid when absorbed by roots, but slower when absorbed by foliage.
Symptomology	Seedling weed growth is inhibited to the extent that weed seed germinates, but seedlings rarely emerge above the soil surface.
Cautions	Do not apply to frozen or saturated soil. Can volatilize when applied to wet soils in high temperatures. Do not use on permeable soils.

Common name	Oryzalin
Trade name	Treflan, Oryzalin, Surflan
Chemical family	Dinitroaniline
Uses	Oryzalin controls several annual broadleaves and grasses.
Application	Preemergence
Mode of action	Seedling growth inhibitor
Uptake/translocation	Root uptake with minimal translocation
Symptomology	Some weed seeds germinate, but seedlings fail to emerge from soil. Emerged seedlings have stubby, thickened roots and brittle stems.
Cautions	Weeds present at the time of application should be controlled by means other than oryzalin.

Common name	Pendimethalin
Trade name	Stomp, Pendulum
Chemical family	Dinitroaniline
Uses	Controls several grass and broadleaf weeds.
Application	Preemergence
Mode of action	Seedling growth inhibitor
Uptake/translocation	Root uptake with minimal translocation (The active site for the herbicide is in the roots.)
Symptomology	Some weed seeds germinate, but seedlings fail to emerge from soil. Emerged seedlings have stubby, thickened roots and brittle stems.
Cautions	Toxic to fish. Emerged and established plants should be controlled by other means.

Common name	Prodiamine
Trade name	Endurance
Chemical family	Dinitroaniline
Uses	For selective control of grass and broadleaf weeds. Provides residual control of many grasses and broadleaf weeds. Adequate soil moisture is important for optimum activity.
Application	Preemergence
Mode of action	Seedling growth inhibitor
Uptake/translocation	Absorbed by the roots to inhibit weed seed germination and root development
Symptomology	Stunted or swollen roots on emerging seedlings, or seedlings that do not emerge
Cautions	Drift or runoff from treated areas may be hazardous to aquatic organisms in adjacent sites.

Table 9.—Photosynthesis inhibitors.

Photosynthesis inhibitors interfere with photosynthesis (conversion of water and carbon dioxide to sugar in the presence of sunlight). The result is a buildup of toxic products. The triazine, urea, and uracil herbicides are primarily root absorbed and translocated to leaves with water; symptoms generally occur first along the leaf margins and tips of older leaves.

Nitrile and benzothiadiazole herbicides do not translocate and must be applied postemergence for contact action. Symptoms include yellowing (**chlorosis**) or death (**necrosis**) of leaf tissue.

Common name	Bromacil
Trade name	Hyvar
Chemical family	Uracil
Uses	Bromacil controls several annual and perennial grasses, broadleaves, and shrubs. Rain is necessary after application for weed control.
Application	Applied primarily preemergence.
Mode of action	Photosynthesis inhibitor
Uptake/translocation	Absorbed by roots and translocated in xylem to leaves and growing points. Less actively absorbed by foliage and stems.
Symptomology	Yellowing of leaves, followed by plant death and browning.
Cautions	Selected weeds have become resistant to bromacil, but not in Oregon. Bromacil has a long soil-residual effect, so it is important not to let it come in contact with the roots of desirable vegetation. Easily moves from target site after a heavy rainfall. May leach through the soil profile. Do not apply to saturated or frozen soil.

Common name	Diuron
Trade name	Several trade names (Karmex, Diuron, Direx)
Chemical family	Urea
Uses	Applied in fall or late winter (east of Cascades) or early spring (west of Cascades) for control of several annual and perennial broadleaf and grass weeds. Higher rates are necessary for perennial weed control.
Application	Preemergence or postemergence
Mode of action	Photosynthesis inhibitor
Uptake/translocation	Absorbed primarily by roots and to a lesser extent by foliage. Rapidly translocated from roots to shoots, but little diuron moves from the foliage to the roots.
Symptomology	Yellowing around leaf veins, followed by general plant yellowing and browning.
Cautions	Diuron resistance has occurred in Oregon in annual bluegrass (*Poa annua*).

Common name	Tebuthiuron
Trade name	Spike
Chemical family	Urea
Uses	Applied in fall east of Cascades and in spring west of Cascades for annual and perennial broadleaf weed control and unwanted woody vegetation
Application	Primarily preemergence, some postemergence activity
Mode of action	Photosynthesis inhibitor
Uptake/translocation	Absorbed primarily by roots
Symptomology	General leaf chlorosis (yellowing) and browning, followed by defoliation
Cautions	Do not allow herbicide in soil to contact roots of desirable plant species. Residual herbicide activity can prevent regrowth of desirable species. Grass in and around treatment area may be temporarily damaged. Soil containing tebuthiuron can move off-target by wind, water, or mechanical means and can damage sensitive plants. Known to leach through the soil into groundwater under certain conditions.

Common name	Hexazinone
Trade name	Velpar
Chemical family	Triazine
Uses	Controls several annual, biennial, and perennial broadleaf and grass species and several woody plant species.
Application	Preemergence and postemergence
Mode of action	Photosynthesis inhibitor
Uptake/translocation	Absorbed by roots and translocated to aboveground portions of the plant when applied preemergence. Postemergence applications to foliage are absorbed by leaves but are poorly translocated to other parts of the plant. Postemergence applications are better absorbed with the addition of a nonionic surfactant.
Symptomology	General yellowing of the plant, followed by necrosis (death).
Cautions	Do not apply to frozen or saturated soils. Use lower rates on sandy soils or soils with low organic matter. Do not spray where the roots of desirable trees and shrubs extend. Surface movement is possible with heavy rainfall.

Table 10. Cell membrane disruptors.

Cell membrane disrupters destroy plant tissue by disrupting plant cell membranes. These products are contact herbicides having little or no mobility in the plant, and they must be applied postemergence. They are excellent for rapid foliage burn-down and control of annual weeds. Symptoms include rapid wilting and browning (**necrosis**) of plant tissue.

Common name	Diquat
Trade name	Diquat, Quick Kill, Reward
Chemical family	Bipyridylium
Uses	Diquat is a nonselective (injures or kills most plant species), postemergence herbicide. Controls seedling annual weeds and injures the top growth of perennial or established weeds. Good coverage is needed for best results.
Application	Postemergence application
Mode of action	Cell membrane disruptor
Uptake/translocation	Rapidly absorbed by foliage. Contact herbicide with little translocation from the point of application.
Symptomology	Rapid wilting and desiccation within hours of application.
Cautions	Diquat is moderately toxic to humans and requires protective equipment for handling and application.

Table 11. Pigment inhibitors.

Pigment inhibitors prevent plants from forming **chlorophyll** (green pigments) used in photosynthesis. Without chlorophyll production, the affected leaves turn white or translucent. Emerging weeds appear white prior to dying. Because emerged plants constantly replace chlorophyll, pigment inhibitors turn plants white following treatment.

Common name	Norflurazon
Trade name	Solicam, Predict
Chemical family	Pyridazinone
Uses	Norflurazon controls several annual broadleaf and grass weed species.
Application	Preemergence. Moisture is needed to activate this product.
Mode of action	Pigment inhibitor
Uptake/translocation	Root uptake and translocation to growing points in the xylem
Symptomology	Distinctive bleaching or whitening as plants emerge from soil.
Cautions	Solicam can volatilize when applied to a dry soil surface. Existing weeds should be controlled by other means prior to norflurazon application. Known to leach through soil into groundwater. Use of this chemical on permeable soils, especially those with shallow water tables, may result in groundwater contamination.

Table 12. Plant growth regulators.

Plant growth regulators are pesticides that suppress plant growth, thus reducing mowing and maintenance requirements. They often reduce sucker and sprout growth in perennials and can prevent seed head formation in grasses. Treated plants look stunted and compact in growth.

Common name	Mefluidide
Trade name	Embark
Chemical family	Unknown
Uses	Used to reduce mowing, trimming, and pruning frequency and for seed head suppression of certain turf grasses, trees, and shrubs.
Application	Postemergence
Mode of action	Plant growth regulator
Uptake/translocation	Mainly foliar absorbed and translocated to growing points. Leaf absorption is increased with the use of surfactants or high humidity. Accumulates mainly in the older leaves. Mode of action is not well understood. Growth and development of meristematic tissue is inhibited.
Symptomology	Foliar growth inhibition. Turf treated with Embark may seem less dense, and temporary yellowing may occur. Low concentrations can stimulate growth and tillering in grasses.
Cautions	Results may be reduced if rainfall or irrigation occurs within 8 hours of application. Do not allow animals to graze treated areas. Damage to plants may occur if applications are made to plants that are stressed, diseased, or otherwise unhealthy.

Table 13. Miscellaneous herbicides.

Common name	Fosamine
Trade name	Krenite
Chemical family	Unknown
Uses	Foliar-applied in late summer or early fall for brush control before fall leaf coloration
Application	Postemergence
Uptake/translocation	Foliar uptake with minimal translocation. Mode of action is not well understood. Inhibits bud growth.
Symptomology	Plants fail to refoliate in the spring following application.
Cautions	Complete spray coverage is necessary for adequate control.

Table 14. Commonly used rights-of-way premixed products.

Common name	2,4-D + triclopyr
Trade name	Crossbow
Chemical family	Pyridine, phenoxy acetic acid
Uses	Selective foliar control of broadleaf weeds and woody plants. Cut stump treatment of woody species.
Application	Postemergence
Uptake/translocation	Foliar and root uptake and translocation throughout the plant
Mode of action	Growth regulator
Symptomology	Twisting of stems and petioles, stem elongation, and leaf cupping (epinasty) followed by death
Cautions	Do not allow herbicide to drift. Well-established perennials may require retreatment.
Common name	Bromacil + diuron
Trade name	Krovar IDF
Chemical family	Uracil, urea
Uses	Nonselective control of annual and perennial grasses, broadleaves, and woody plants. Moisture is necessary for herbicide activation and optimum control.
Application	Applied primarily for preemergence control.
Uptake/translocation	Primarily root-absorbed and translocated with water through the xylem to leaves.
Mode of action	Photosynthesis inhibitor
Symptomology	Interferes with photosynthesis (conversion of water and carbon dioxide to sugar in the presence of sunlight). The result is a buildup of toxic products in the plant. Symptoms generally occur along the leaf margins and tips of older leaves first.
Cautions	Due to long residual activity, Krovar should not be allowed to come in contact with roots of desirable trees and shrubs. Due to low soil adsorption, Krovar should not be applied if heavy rainfall is expected shortly after application. Injury to crops may result if treated soil is washed, blown, or moved onto land used for crop production.

Common name	Chlorsulfuron + sulfometuron methyl
Trade name	Landmark
Chemical family	Sulfonylurea
Uses	Preemergence and postemergence activity for the control of many annual and perennial grasses and broadleaf weeds. Best results are obtained when the application is made at or before the early stages of weed growth, before weeds have an established root system. For preemergence control, moisture is required to activate Landmark.
Application	Preemergence and postemergence
Uptake/translocation	Foliar and root absorbed, accumulating in the growing points. Translocated in the xylem when root absorbed and in the phloem after foliar application.
Mode of action	Amino acid inhibitor
Symptomology	Injury symptoms usually appear within 1 to 2 weeks, with the growing points turning yellow or reddish-purple followed by chlorosis (yellowing) and necrosis (dead tissue).
Cautions	Selected weed biotypes have become resistant to Landmark's active ingredients. To avoid weed biotype resistance, this product should be alternated or tankmixed with products of other modes of action and with other types of control measures. Do not apply to frozen or saturated ground. Injury to crops may result if treated soil is washed, blown, or moved onto land used for crop production.

Common name	Diuron + imazapyr
Trade name	Sahara
Chemical family	Urea, imidazolinone
Uses	Controls most broadleaf and grass annuals, biennials, and perennials. Woody plants also controlled. Residual control.
Application	Preemergence and postemergence
Uptake/translocation	Foliar- and root-absorbed. Translocated throughout the plant. Accumulates in the growing points.
Mode of action	Photosynthesis inhibitor, amino acid inhibitor
Symptomology	Growth ceases soon after application, but yellowing may not appear for up to 2 weeks after application. Yellowing around leaf veins, followed by general plant yellowing (chlorosis) and browning (necrosis).
Cautions	Diuron resistance has occurred in Oregon in annual bluegrass (*Poa annua*). Avoid herbicide contact with desirable plant roots and foliage. Do not apply to frozen or saturated soils. Heavy rainfall after application can result in off-target movement.

Selective versus nonselective activity

The selectivity of an herbicide refers to whether a plant is susceptible (injured or killed) or tolerant (not injured). An advantage of chemical vegetation control is that some herbicides kill only selected weeds. Herbicides that control weeds while doing little or no damage to desirable vegetation are **selective** herbicides. Selective herbicides are commonly used in rights-of-way management. For example, use broadleaf herbicides to maintain a dense grass stand. **Nonselective** herbicides kill or injure almost all plants—weeds as well as desirable vegetation. These products are used for bare ground or special areas. Some nonselective herbicides persist for long periods of time, maintaining residual control. They are commonly applied along the edges of asphalt and in equipment yards.

Selectivity depends on many interrelated factors. It is influenced by the herbicide and rate of application, as well as by how and when the herbicide is applied and under what environmental conditions. Even closely related plants may respond differently to applications of the same herbicide. Selectivity may be lost through applicator mistakes or by applying herbicides when desirable plants have been under stress or are at the wrong growth stage. **You must understand the reasons for herbicide selectivity to avoid injuring desirable vegetation.** Herbicide selectivity is determined by both plant and chemical factors.

Plant factors

The uniqueness of each plant species is the result of its particular combination of structures and chemical processes (physiology). The extent to which an herbicide affects any plant species depends on the plant structure and physiology.

Structure

To be effective, the herbicide must enter the plant. Leaf angle, size, hairiness, and thickness of wax and cuticle greatly affect the retention and absorption of foliar-applied herbicides (Figure 8). Plants with upright leaves, extremely hairy leaves, or hard-to-wet (waxy) leaves are less likely to retain sprays. These differences may help make a plant either herbicide-susceptible or tolerant. Plant size also makes a difference. Older, larger plants often require higher dosages or rates than seedlings.

Plant physiology

Selectivity primarily depends on how the plant responds after the herbicide enters the plant. To kill susceptible weeds, the herbicide interferes with vital plant processes (see “Modes of herbicide action”). Some plants can quickly metabolize, detoxify, or excrete certain herbicides, thus tolerating the herbicide. In plants that cannot metabolize the herbicide fast enough, injury or death occurs. In certain cases stress, such as cold weather, can slow a plant’s ability to metabolize herbicides, and some injury may occur.

Chemical and application factors

Several physical factors affect herbicide selectivity:

- How much herbicide is applied
- The particular formulation used
- Where the herbicide is applied
- When the herbicide is applied
- Addition of adjuvants

Application rate

Some herbicides are selective at lower rates of application; however, when the same herbicide is applied at a higher rate the herbicide becomes nonselective. Trees and shrubs may tolerate low doses that effectively control annuals and biennials. For example, diuron is selective at low rates

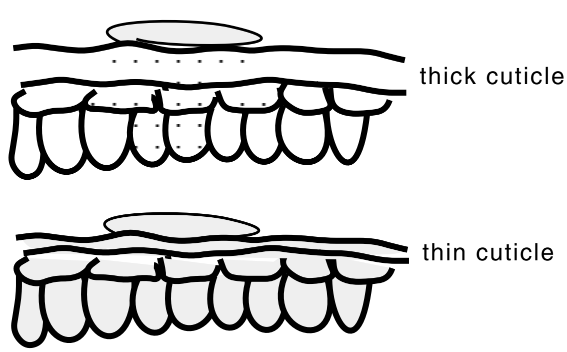


Figure 8.—Cuticle thickness affects herbicide penetration.

Rate effect example

Plants controlled	Herbicide rate
annual broadleaf weeds	0.5 pint per acre
simple perennials	1 pint per acre
creeping perennials	1 quart per acre

and provides nonselective residual control at higher rates (see box above).

Formulation

How the herbicide is formulated influences selectivity. One example is using a granular formulation to control nonemerged weeds among emerged plants. In this case, the formulation allows the herbicide to bounce or roll off the plants and fall to the soil. It then becomes available for uptake from the soil by emerging weed seedlings. A number of herbicides are available in both granular and liquid formulations.

Application timing

Many herbicides are effective only if applied at the proper time. The time of application is usually given on the label. You must understand the following label terms regarding application timing.

Preplant is any application made before seeding or transplanting in landscape plantings. Preplant treatments generally are applied to the soil and incorporated into the soil to prevent weed emergence (Figure 9). Mechanical means, rainfall, or overhead irrigation can be used to incorporate the herbicide into the soil.

Preemergence is a treatment made prior to the emergence of the weed or crop and commonly applied to the soil. If weeds are present, you may need to mix the preemergent herbicide with a postemergence foliar herbicide. Preemergence herbicides also need to be incorporated into the soil

Postemergence is any treatment made after emergence of a weed. This treatment usually is a foliar application. Young weeds are controlled more easily than established weeds.

Placement

Accurate placement of nonselective herbicides can minimize or eliminate injury to desirable plants. An example is the use of diuron to control weeds along rights-of-way planted with trees and shrubs. Although diuron is toxic to trees and shrubs, placing and keeping the herbicide in the soil above the shrub and tree root zone controls shallow-germinating weeds (Figure 10). Leaching might move the herbicide into the root zone of desirable plants and cause injury.

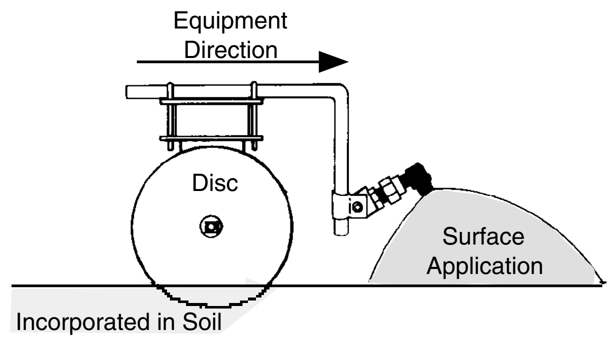


Figure 9.—Preplant herbicides are applied before seeding and usually are incorporated into the soil.

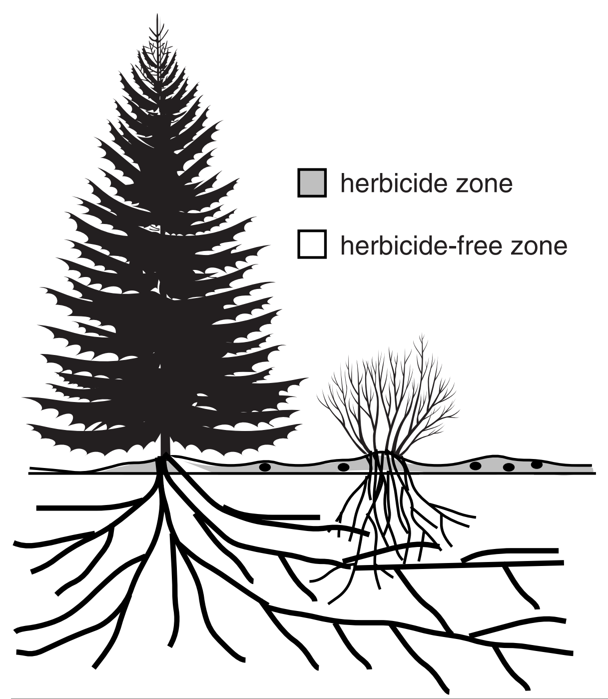


Figure 10.—Selectivity is achieved by keeping the herbicide in the zone where weed seeds germinate, which is above the tree and shrub root zone.

There are several ways to properly place the herbicide for selectivity. You can use different kinds of application equipment employing tree injection devices, shields, directed sprays, and wiper or roller treatments. You also can selectively apply chemical to the conductive tissue just inside the bark (**cambium layer**) by cut stump and frill treatments.

Directed sprays limit herbicide contact with desirable plants. Usually the spray is directed to the lower part of the weed stem or trunk to keep spray off desirable plant leaves while spraying weeds.

Wiper treatments apply contact or translocated herbicides selectively to weeds. Wicks made of rope, rollers covered with carpet or other material, or absorbent pads (sponge or fabric) are kept wet with herbicide solution. The herbicide is "wiped" onto the weeds, but does not touch the desirable plants because of height differences in the vegetation. This treatment is for tall weeds growing above the vegetation or weeds growing under or between trees.

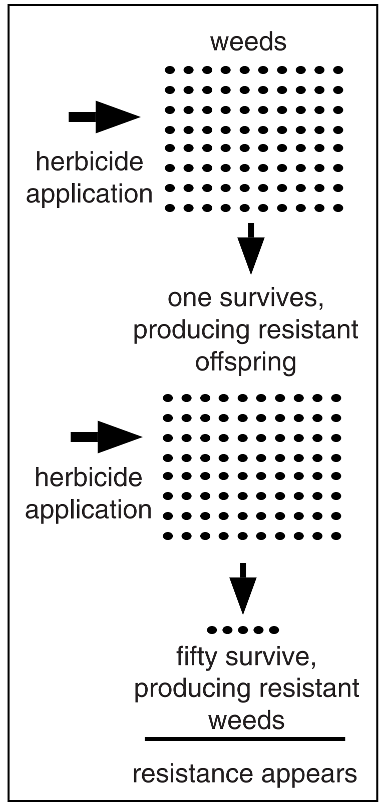


Figure 11.—Development of an herbicide-resistant weed.

Herbicide resistance

Herbicide-resistant weeds are becoming increasingly important. You must know the difference between weeds that are naturally tolerant and weeds that have become resistant to herbicides over time. As with any herbicide treatment, some weeds are tolerant and survive, while susceptible weeds die. Weeds previously susceptible to that herbicide are now resistant. Tolerant weeds occur naturally, while resistant weeds appear after people continually use the same herbicide, or herbicides with the same mode of action, year after year.

The first reports of herbicide resistance in North America came from Washington in the mid-1960s when a nursery owner could no longer control common groundsel with simazine. Several other weed species have since developed resistance to triazine herbicides such as atrazine, simazine, and others. Weed populations have developed resistance to several herbicide groups (similar modes of action). Since few new herbicides are being developed, we cannot afford to lose the use of current herbicides to resistant weeds. We must use strategies to prevent resistance development.

Resistant weeds result from natural genetic variations in individuals in a weed population in which an herbicide may not affect a few of the plants. Thus, they are resistant. Resistant plants may be very few, perhaps only one for a thousand plants of that weed species.

An effective herbicide may control 999,999 plants out of a million, but one resistant plant may survive and produce resistant seed. If the same herbicide is used next year, 50 resistant plants may grow in the site and produce more seed (Figure 11). When the same herbicide or one with the same mode of action is used the following year, control is still excellent, but the number of resistant plants increases each year until poor control is noticed. To make matters worse, in most cases, resistant weeds can survive high rates of the herbicide. Generally, resistance is genetically dominant (i.e., if a resistant plant and a sensitive plant cross, the offspring will be resistant). Fortunately, resistant weeds usually are susceptible to other herbicides with different modes of action.

Consequently, we must avoid practices that favor herbicide-resistant weeds. Use the following resistance management strategies.

- **Use other methods of weed control along with herbicides.** Options include mowing, delayed seeding to allow mechanical control of the first flush of weeds, cultivating, planting competitive vegetation, and mulching.
- **Rotate among herbicide families.** To be effective, an herbicide must have a different mode of action than the one originally used. Weeds that developed resistance to sulfometuron methyl (Oust) often are resistant to imazapyr (Arsenal, Chopper, Contain), metsulfuron methyl (Escort), and chlorsulfuron (Telar).
- **Resist the temptation to use higher rates when weed control starts to decline.** If the uncontrolled individuals in the population are genetically resistant, increasing the herbicide dosage will not kill them. It will simply eliminate the susceptible types, allowing the most resistant types to flourish. Using higher than normal rates may make resistance develop faster.
- **Kill all the targeted weeds if possible.** Hand weeding a large land area is not possible. However, in small areas, it may be extremely cheap in the long term. If a new herbicide provides 99 percent control the first year, the remaining 1 percent probably escaped, but they might be genetically resistant. Eliminate them while they are few in number.
- **When combining herbicides, use two chemicals with different modes of action.** Herbicide combinations generally are used to increase the number of weed species controlled. For example, sulfonylurea herbicides are regularly tankmixed with other herbicides with different modes of action. Using combinations will slow the development of resistance only in those weeds that **both** herbicides control. The species controlled by only one of the herbicides can develop resistance as rapidly as if that herbicide were used alone.

Use these different methods of vegetation control **before** resistance occurs. Once resistance develops, large numbers of resistant seed survive in the soil. Eliminating the resistant type 1 year will not solve the problem. Once you notice an herbicide-resistant weed problem, you likely will have the problem forever.

If you are not sure which herbicides have the same modes of action, refer to *How Herbicides Work: Uptake, Translocation, and Mode of Action* (OSU Extension publication EM 8785), or check with your local Extension agent, herbicide supplier, or product representative. Any of these professionals can assist you.

Review questions (answers on back of page)

1. On which type of weeds are contact herbicides most effective?

2. Most herbicides are contact or translocated (circle one).

3. How are translocated herbicides able to control weeds that regrow from underground parts such as rhizomes or tubers?

4. Describe the basic way growth regulators work to kill plants (mode of action).

5. Roundup (glyphosate) is in which major mode-of-action group?

6. What property of 2,4-D makes it dangerous to apply on hot days?

7. Casoron is in which major mode-of-action group?

8. Name three active ingredients that are among those most likely to leach into groundwater.

9. When an herbicide kills one species of plant while not affecting another species, it is called _________.

10. Name four factors that might affect herbicide selectivity.

Answers to review questions

1. Annual weeds are more likely to be controlled by contact herbicides. Biennials and perennials may be controlled by contact herbicides if they are sprayed in the seedling stage. Complete coverage is required for best results when applying contact herbicides to any type of weeds.
2. Most herbicides are translocated.
3. In translocated herbicides, the herbicide enters the plant through the foliage or roots and is transported to other parts of the plant. In contrast, contact herbicides never reach these areas of the plant, and the plant can resprout at a later date.
4. Growth regulators change the hormone balance and protein synthesis in plants, thus causing the plant to grow abnormally.
5. Amino acid synthesis inhibitors.
6. 2,4-D has a high volatility. On hot days, the chemical can turn into vapor and damage nearby sensitive vegetation.
7. Seedling growth inhibitor.
8. Many correct answers: tebuthiuron, picloram, bromacil, etc.
9. Selective.
10. Application rate, formulation, timing, and placement.

4 Factors Influencing Herbicide Performance

Two major factors influence the performance (**efficacy**) of a given herbicide. Efficacy refers to how well an herbicide application works to control the target plants. First, the herbicide must be *available* to be **absorbed** by the weed. Environmental factors, such as soil and climate, affect herbicide availability. Second, weeds must absorb, and in some cases translocate, the herbicide. The growth stage of the plant and environmental conditions affect herbicide uptake and translocation in the plant. Both factors, availability and uptake, are necessary to allow enough herbicide to enter the weed and kill it.

Environmental influences on herbicide availability

Soil properties and climatic factors, such as temperature, humidity, and precipitation are the dominant factors that affect herbicide performance.

Soil factors

The following are properties of soils and ways they may interact with soil-applied herbicides.

Adsorption

Chemical compounds, including herbicides, have electrical charges and tend to bind or **adsorb** to the negatively charged sites on soil particles and organic matter (Figure 12).

In this case, **adsorption** is the attraction or adhesion of herbicide molecules to the soil particle surface, a process similar to the attraction of iron filings to a magnet or lint to a nylon surface.

Herbicide molecules are inactive when adsorbed to the soil. Roots can **absorb** only herbicide molecules that are in solution with soil water. Molecules tightly bound to soil particles are not available; they cannot be **absorbed** by plant roots or degraded by microorganisms. All herbicide molecules usually are not bound to the soil at the same time. Some may be bound while others are dissolved in soil water (solution). The bound molecules can be released into the solution or vice versa. Most herbicides bind to soil when it is dry and dissolve in soil water when it is available.

Herbicides vary greatly in how tightly they bind (**adsorb**) to the soil. Paraquat and glyphosate bind so tightly to clay that they usually have no soil activity. The strength of binding between the herbicide molecule and soil particle greatly affects herbicide movement in the soil and the availability for root absorption.

Soil texture

Different soil types have different capacities to bind herbicides. When using soil-applied herbicides for selective or nonselective control, it is essential to know the soil properties and follow the soil-related directions on the herbicide label.

Sand is coarse and does not have many charge or binding sites. Sand has less surface area for the same volume of soil than silt or clay; therefore, fewer adsorptive sites are available. Lower herbicide rates generally are used on sandy soils.

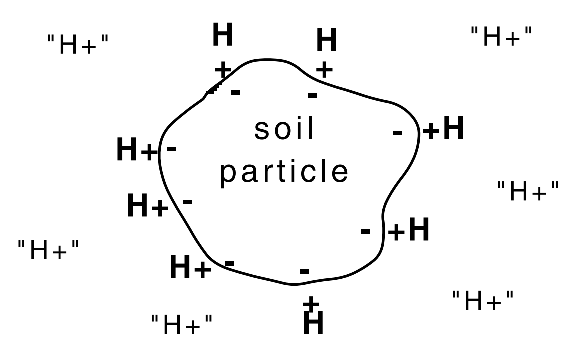


Figure 12.—Polar (+ charged) herbicide (H+) adsorbs to (-) charged sites on soil particles. Nonadsorbed herbicide ("H+") is free and available to plants.

Silt is intermediate in surface area per given volume of soil. It has more adsorptive sites than sand but many times fewer than clay and organic matter. Medium application rates often are listed on the label.

Clay is fine and has a large surface area per given volume of soil, resulting in more adsorptive sites than sand or silt (Figure 13). Higher use rates are listed on the label.

Organic matter has many times more adsorptive sites to tie up both positively and negatively charged herbicides. Organic matter acts like a magnet and has more influence on herbicide adsorption than any other soil factor.

Remember, sandy soil has few adsorptive sites to tie up herbicide molecules, and most herbicides tend to leach through a sandy soil profile. Soil with high clay and organic matter levels tends to tie up and hold herbicides.

Some herbicides readily leach through sandy soils, diluting the herbicide. Leaching can result in injury to deep-rooted plants, poor weed control, and groundwater contamination. Selectivity may be lost in loamy sand and sandy loam soils, because a high concentration of herbicide may move to a depth where both desirable plants and weeds are killed. In loam and silt loam soils, the herbicide usually is held near the soil surface; the deeply rooted plants are not injured, and weeds are controlled. Organic soils tie up the herbicide near the soil surface; the soil may adsorb so much herbicide that there is not enough available to control weeds. Clay soil properties range between silt loam and organic soil. Clay also is frequently found in very sandy soils.

To be available for absorption by weeds, soil-applied herbicides must move into the weed root zone or the zone where weed seeds germinate. They must be present in the soil-water solution or be present as a soil vapor. You can move some herbicides into the soil solution by adding water to the soil (either rainfall or watering), by mechanical incorporation with tillage equipment, or by injecting the herbicide directly into the soil (soil injection). Although several products work well in dry soil after being mechanically incorporated, herbicides generally should not be applied until moisture is or soon will be available.

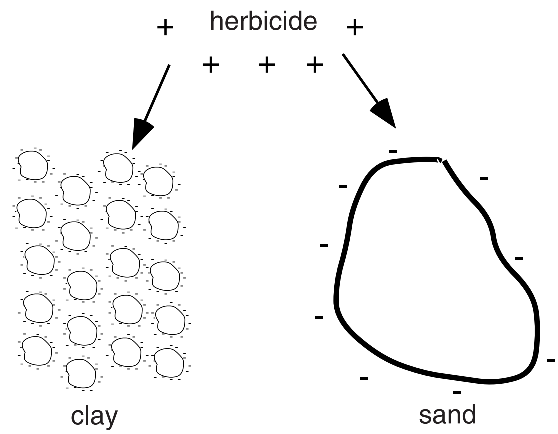


Figure 13.—Clay has more total surface area, thus more adsorption sites than sand.

Some nonselective herbicides may be used selectively based on their soil placement. This selectivity depends on different rooting depths of desirable plants and weeds.

Climatic factors

Climatic factors, including temperature, humidity, precipitation, and wind, influence weed control and safety to desirable vegetation.

Temperature

Temperature influences all plant activities: water absorption, transpiration, respiration, germination, and growth. Plant growth tends to increase when temperatures rise and decrease when temperatures fall. Most plant growth occurs in the 50° to 100°F temperature range. The more actively a plant is growing, the easier it is to control with an herbicide.

Always read the label to see whether you must monitor temperature before applying a particular herbicide. Such statements usually are found under the “Directions for Use” or “Use Precautions” headings. Label directions might say: “Do not apply if temperature is likely to fall below 40°F during or shortly after treatment” or “Do not spray when daytime temperatures are expected to exceed 90°F within the next 2 or 3 days.”

High and low temperatures place stress on desirable plants that can adversely affect plant growth and the ability to tolerate an herbicide. Herbicides may injure desirable plants under abnormal temperatures. For many herbicides, weed control results are the same, regardless of temperature, if the herbicide enters the plant. Do not apply volatile herbicides when high temperatures are present or expected soon after application, because volatility increases as temperature rises.

Precipitation

Rainfall occurring soon after a foliar-applied herbicide treatment may wash off the chemical and reduce control. Herbicide labels indicate the rain-free period required. Rain moves soil-applied herbicides into the soil solution, but excess rain can leach herbicides through or past the target area in the soil. When the herbicide moves through as a concentrated front, weeds may grow above the herbicide zone. In western Oregon, soil-applied herbicides are commonly applied in the spring after the heavy winter rains; in eastern Oregon, soil-applied herbicides are applied in the fall prior to the rainy period.

Water-stressed weeds are less susceptible to foliar-applied herbicides than nonstressed weeds. This may be due to a thicker **cuticle** layer on the leaves or a slowdown in plant metabolism. **The more actively a weed is growing, the easier it is to control with herbicides.**

Humidity

A foliar-applied herbicide can enter the leaf more readily under conditions of higher humidity because the leaf is more succulent and has a thinner wax layer and cuticle. Spray droplets remain liquid on the leaf surface with high relative humidity, allowing more time for the chemical to enter the leaf. With low humidity, wax layers and cuticles are thicker, and evaporation is faster.

Wind

Wind can intensify the effects of drought and high temperature stress. Hot, dry winds cause leaf surfaces to thicken and wax layers to harden. These factors make herbicide penetration into leaves more difficult. Wind also increases drift, reducing the herbicide dose to the target weeds.

Growth stage influences on herbicide activity

Weeds develop through four growth stages: seedling, vegetative, flowering, and maturity. One growth stage generally is most vulnerable to a certain type of weed control strategy. If chemicals are not applied during the optimum growth stage, changing the method or increasing the herbicide rate (but not over the labeled rate) might be necessary. In general, plants are most susceptible to postemergence herbicides during two growth stages:

- As seedlings, when rapid growth takes place
- In perennials, once past the seedling stage, when a period of rapid growth has ended and food reserves are temporarily depleted or exhausted

The seedling growth stage is susceptible in all weeds—annuals, biennials, and perennials. Most weeds start from seed. Seedling weeds are small and more easily controlled than any other growth stage, whether using mechanical or chemical control.

Annual plants

Seedling stage. For best results with postemergence herbicides, control seedlings as soon as possible after emergence because they are easiest to kill at this stage (Figure 14).

Vegetative stage. Plants in the vegetative growth stage use most of their energy resources to produce stems, leaves, and roots. Control is still feasible but more difficult than at the seedling stage. Usually this stage requires higher rates of herbicide.

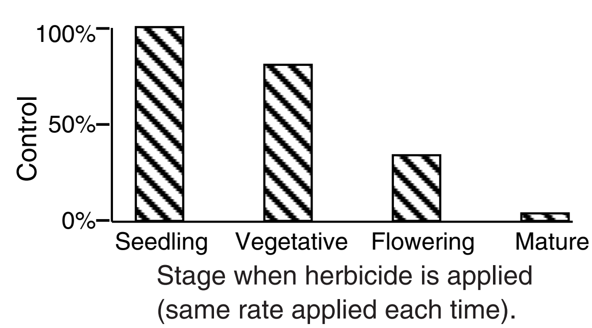


Figure 14.—Herbicide control of annual weeds.

Flowering. During this time, most weed energy resources go into seed production. It is most difficult to kill older, annual plants with chemicals. Foliar herbicide applications at this stage may prevent seed production.

Maturity. Maturity and seed set complete the life cycle of annuals. Chemical control is not effective or practical at this stage.

Biennial plants

Biennials take 2 years to develop through the same growth stages as annuals. The first year, the plant forms basal leaves (**rosette**) and a taproot; the second year it bolts, flowers, matures, and dies. For best results, control biennial weeds as seedlings (Figure 15). Control of the rosette stage is second best. Control decreases as plants mature.

Perennial herbaceous plants

Perennial weeds vary in growth habits—differing in development rate, root reserve depletion, dieback of shoots after flowering, and regrowth after flowering. The following discussion provides general guidelines for controlling perennial weeds. Exceptions depend on the specific weed and herbicide. For many perennial weeds, the herbicide label states the best application timing.

Seedling stage. Perennials are easiest to control during the seedling stage, just as annuals and biennials are (Figure 16). However, successful control of established perennial plants requires translocation of herbicide into the plant's underground system (roots, rhizomes, tubers) to kill the entire plant. Two key facts will help you understand perennial weed control.

- Plants store sugars in their roots during winter. In the spring they use the sugars to grow shoots, depleting the root reserves. In the summer and fall after flowering, the plants restock the roots with sugars for next year's growth.
- Foliar-applied, translocated herbicides move with the flow of plant sugars. Therefore, to move herbicides down into the roots, apply them when the flow of sugars is downward into the roots, usually during summer and fall regrowth.

Vegetative stage. Chemical control generally is poor during this stage but improves when the weed reaches the bud stage. Until the bud stage, most sugars are moving up the stem to support new growth, so little herbicide is moving to the roots. However, a few herbicides will work during this stage.

Flowering. At this stage, the plant's energy goes into production of flowers and seeds. Food is transported and stored in the roots; this continues through maturity. Chemical control is most effective just prior to flowering (bud stage) with 2,4-D and similar materials. However, on some species of weeds, glyphosate is most effective during early to midflowering. Check the herbicide label for timing.

Maturity. After they set seed, the shoots of many perennials either die or become fairly inactive. Most herbicides are ineffective at this stage. The underground roots and stems remain alive through the winter and send up new shoots the following spring.

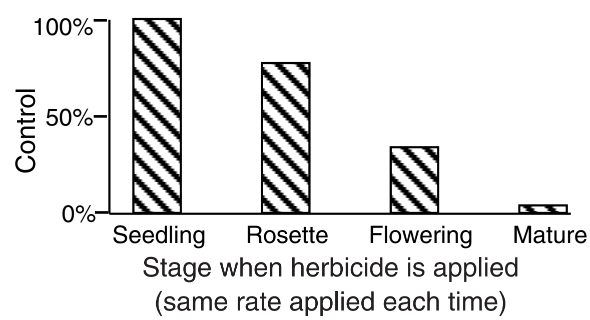


Figure 15.—Herbicide control of biennial weeds.

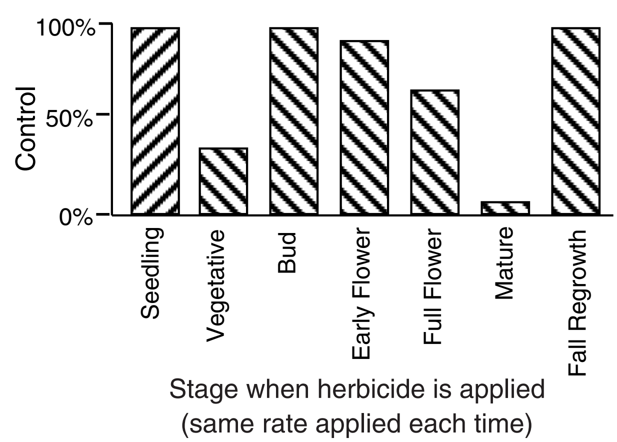


Figure 16.—Herbicide control of perennial weeds.

Fall regrowth. Some perennials produce shoots in the fall just prior to frost. These shoots make more sugars for storage in the roots. Applying herbicides to fall regrowth is very effective.

Read the label regarding application timing. Timing will depend on the product you are using and the target weeds. For best control of established perennials, plan herbicide applications based on the yearly growth cycle of the specific species and on the herbicide being used. Control is best with dicamba and phenoxy herbicides during the period just prior to flowering (bud stage) or during fall regrowth. Clopyralid is better when used even earlier. Glyphosate is best at full flower.

An advantage of fall applications of foliar-applied, translocated herbicides is environmental safety. Avoid herbicide spray or vapor drift; it is a very serious problem. However, if some drift occurs in the fall, many desirable plants in croplands, yards, and gardens have completed their life cycle or are dormant and thus are more likely to escape herbicide injury. Apply herbicides to foliage before a killing frost to ensure chemical translocation.

Woody plants

Woody plants, like perennial weeds, vary in their growth habits. They differ in development rate and root reserve depletion. The best growth stage for control depends on the herbicide and the plant. If you want to kill the entire shrub or tree, the chemical must translocate to the roots, whether applied to foliage or to the basal portion of the plant, injected into the stem, or applied to the soil. For example, to control blackberries with glyphosate, application is most effective in September or October. Use of triclopyr amine for blackberries works best in midsummer. If glyphosate is used on red alder, a July application is best. In general, best woody plant control occurs when the majority of the sap flow is not moving *up* the tree. Check label directions or the *PNW Weed Management Handbook* for recommendations and timing.

Spraying or painting the surface of a cut stump with a herbicide, immediately after cutting an unwanted tree, will prevent the stump from sprouting. For effective control, the herbicide must be placed where the tree sap flows (cambium)—the conductive tissue located near the outside rings of the stump. The heartwood, or stump center, does not have to be treated since it does not transport sap.

Review questions (answers on back of page)

1. What term is used to describe the binding of herbicide molecules to soil particles?

2. Name four basic components of soil that determine texture.

3. In which soil texture is leaching most likely to occur?

4. How can humidity change the effectiveness of an herbicide application?

5. What growth stage of plants generally is the easiest to control?

6. What is a rosette?

7. Perennials can be controlled effectively at several growth stages. What are they?

Answers to review questions

1. Adsorption.
2. Sand, silt, clay, and organic matter.
3. Sand.
4. Low humidity can dry the herbicide droplets on the leaf surface before they have a chance to penetrate the leaf. Also, plants that grow in dry climates typically have a thicker wax layer, which can impede herbicide penetration.
5. Seedling growth stage.
6. The rosette is the main vegetative stage of biennial plants. This stage grows low to the ground and forms a circular pattern.
7. Seedling, vegetative, early bud, and fall regrowth. Treating weeds at the flowering stage might control the plant, but it usually does not prevent the plant from producing viable seed.

5 Special Precautions When Using Herbicides

Drift

This term refers to pesticide movement through the air to areas not intended for treatment. It presents a potential hazard to sensitive vegetation (desirable plants), wildlife, people, livestock, and aquatic areas next to treated areas. Movement of pesticide away from the target area can be a costly problem facing pesticide applicators. Drift damage also may result in fines, loss of certification, and lawsuits.

Rights-of-way control presents unique considerations. Highway traffic can create erratic wind currents, making applications along roadways more challenging. Landscapes vary greatly near rights-of-way, requiring applicators to be aware of their surroundings at all times.

Particle drift. Any herbicide can drift. When herbicides are applied as sprays, air currents acting on the suspended spray droplets can carry some spray through the atmosphere beyond the intended target. Particles smaller than 150 microns (the size of fog or mist) present the greatest drift hazard. Several factors affect the direction, distance, and amount of spray drift:

- Application equipment (nozzle type, pump pressure)
- Size of the droplets
- Boom height
- Type of spray (invert oil or water based)
- Spray additives
- Wind direction and velocity
- Temperature inversions

High temperature and low relative humidity may cause spray droplets to rapidly evaporate into smaller droplets that are more likely to drift. Even if no wind is obvious, temperature inversions combined with slight air currents can result in substantial drift of fine droplets. Temperature inversions are weather conditions where warm air traps a cool layer of air next to the ground. Fine herbicide droplets or vapor can remain suspended in the cool air for long periods and can drift with slight breezes or move downslope. Read and follow drift precautions stated in the "Environmental Hazards" and "Directions for Use" sections on the product label.

Vapor drift. In addition to droplet or physical drift, certain herbicides volatilize (change to a gaseous form), producing fumes that may cause damage. The potential for volatilization increases as temperature increases and humidity decreases. Since stone and asphalt surfaces become much hotter than the surrounding air temperature, these sites have a higher volatility potential than plant foliage. Read and follow drift precautions stated in the "Environmental Hazards" and "Directions for Use" sections on the product label.

Herbicide formulations and hazards

Phenoxy (2,4-D, MCPA) and growth regulator (dicamba) herbicides are commonly used in rights-of-way vegetation management. You must consider many factors to obtain satisfactory control with these products, such as weed species, herbicide formulation to be used, and environmental conditions existing at the time of application.They are highly effective herbicides on many broadleaf weeds, but equally active on broadleaf crops and other desirable vegetation. Plants such as grapes, peas, and tomatoes are particularly sensitive to phenoxy and growth regulator herbicides. Prior to making an application, study the area surrounding the target site and know where the material might drift.

Several nonphenoxy herbicides also cause problems if they drift off-target, either as particle drift or treated soil. Sulfonylurea compounds

(Oust, Telar, Escort), glyphosate (Roundup), and imidazolinone compounds (Stalker, Chopper, Arsenal) are used for pre- or postemergence control of rights-of-way weeds. Several agricultural crops, such as peas and lentils, are particularly susceptible to sulfonylurea herbicides. These materials presently have no additional regulations regarding their use. Make sure you follow label directions and heed the precautionary statements regarding application.

Surface water protection

Everyone should be sensitive to the risk of water contamination. Areas requiring treatment can be next to open water. Herbicide runoff into water can occur. The chemical can be dissolved or suspended in water, adsorbed by soil particles subject to erosion, or drift into water.

When treating next to surface water, consider using an herbicide registered for both sites. Do not spray over water or allow chemical to enter the water. Treat culverts and drainage inlets carefully. Don't treat up to the water's edge. Strips of green vegetation serve as biofilters, catching eroding soils and reducing the potential movement of your chemical into the water source.

Runoff of chemicals usually is not excessive unless soil erosion occurs or the product is applied to frozen ground. Soil erosion occurs most often when it rains soon after an application.

If using open water to fill the spray tank, use extreme care. First fill a nurse tank and then fill the spray tank from the nurse tank. This prevents direct contamination from the spray tank to the water source. Constantly monitor the filling process. Stop the process when the tank is full or at the desired level. Be careful not to let the tank overfill and spill on the ground or into water.

Remember—good handling practices prevent surface water contamination. Triple rinse your containers immediately after emptying them and dispose of or recycle the containers properly.

Groundwater protection

We must prevent herbicides from leaching into groundwater to protect our water supply and the herbicide registration. Several herbicide characteristics affect leaching:

- Strength of adsorbtion to soil particles
- Solubility in water
- Persistence

Site conditions also play a major role in vulnerability to contamination. High rainfall, some types of irrigation, coarse soil with low organic matter, and use of residual herbicides in areas with shallow water tables increase the risk of groundwater contamination to a particular site.

Herbicides with a known potential to leach through the soil profile have a groundwater advisory statement in the "Environmental Hazard" section of the product label. Read this section. If a label has a groundwater precaution about leaching, be particularly careful in handling and applying the product. If possible, select a less leachable product.

Poor mixing and loading techniques, such as mixing too close to a water source (well), tank overflow, and lack of antibacksiphon devices on water fill lines, can be culprits in contamination.

Contaminated equipment

Crops, ornamentals, or other desirable plants have been injured or killed because applicators used spray equipment contaminated with herbicides from previous applications. To minimize contamination problems, consider dedicating one sprayer only for a particular use (e.g., bare ground) and another sprayer for another use (e.g., broadleaf control).

Thoroughly clean, maintain, and calibrate all application equipment regularly so it will be accurate and dependable. The application equipment you use can affect weed control greatly. Check hoses and pumps for leaks. Inspect nozzles and shut-off valves to make sure they work properly. Clean equipment as directed by the operator's manual and the herbicide label. Do not allow herbicides formulated for suspension solutions to stand for any length of time in a sprayer without constant agitation. They will settle out and cake in the bottom of the tank and hoses, making reagitation or cleaning difficult.

To prevent incompatibility of different herbicides in a spray mix, add chemicals in the following order: wettable powders, flowables, soluble powders, surfactants, and then emulsifiable concentrates. If you use a buffer to alter the pH of the water, add it first. If mixing two chemicals for which tank-mixing is not specifically recommended on the labels, conduct a jar test for compatibility first.

Soil-residual herbicides

Residual herbicides persist in the soil and remain active over a period of time. They are applied to the soil and are effective against germinating seeds and emerging seedlings. These chemicals generally are absorbed by roots or shoots and vary in their solubility in water. Many remain close to the soil surface.

In rights-of-way management, we often want the residual activity to last for several months. This residual control either leaves the ground bare or allows established vegetation a competitive advantage. Nonselective control that removes most or all vegetation often is necessary around sites such as substations, equipment yards, storage areas, grain bins, buildings, warehouses, railroads, or petroleum storage areas. Vegetation in these areas can be a fire hazard, shock hazard, public nuisance, health hazard, or breeding area for rodents, and can reduce safety and facility security.

Depending on soil type, rate of application, and herbicide, soil-residual herbicides can control weeds for several weeks to a year. Residual activity depends on the chemical and its degradation rate, leaching, soil clay and organic matter content, species tolerance, and application rate. Long-term residual herbicides were called "soil sterilants" in the past. This term is misleading since they do not sterilize the soil. They do not kill fungi, bacteria, and other microorganisms as some soil fumigants do. A better term is "bare-ground treatments," since residual herbicides kill only plant life. At lower application rates, some of these compounds provide selective weed control. At higher application rates, they generally are nonselective. Examples of soil-residual herbicides include diuron, tebuthiuron, and bromacil.

Observe the following precautions when using bare-ground or residual herbicides.

- Understand the soil type prior to making application.
- Understand the influence of rain and irrigation.
- Do not apply where the root systems of desirable trees or shrubbery exist or may extend later.
- Do not apply to frozen ground. The herbicide will not move into the soil and may run off.
- Avoid spray drift during application.
- Use extreme caution when applying residual herbicides on slopes. Heavy rain and runoff may move the herbicide downslope and damage adjacent vegetation or pollute streams and rivers. Erosion may occur because the soil is bare.
- Prevent humans, animals, and equipment from moving soil from treated areas.

Soil persistence

Residual activity also is important because of potential injury to future plantings. Several factors affect herbicide persistence in the soil.

Photodegradation. Sunlight can break down some herbicides such as napropamide and the dinitroaniline compounds (Figure 17).

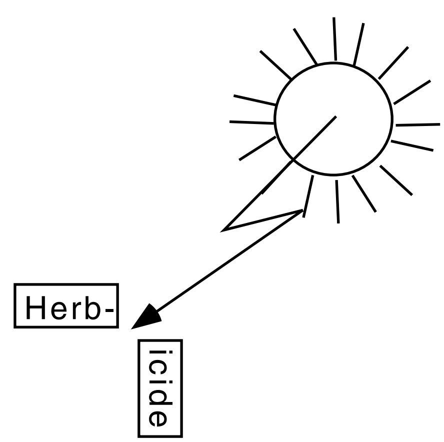


Figure 17.—Photodegradation.

Incorporating the herbicide into the soil (mechanical, rain, irrigation) after application often extends the persistence of soil-active, photosensitive herbicides. Read the herbicide label for precautions.

Microbial degradation. When soil microorganisms such as bacteria and fungi use herbicides as part of their food supply, they decompose or break down the chemicals. Some herbicides are degraded rapidly (easily used by the microorganisms), while others resist degradation. Soil microbes are most active in warm, moist soil. Some herbicide uptake and degradation by microbes is passive, and the herbicide is not really used as a food source.

Chemical degradation. Some herbicides break down in the soil through natural chemical reactions. Chemical degradation generally involves reactions such as oxidation, reduction, and hydrolysis, and it occurs most readily in warm, moist soil. Soil pH often influences the rate of chemical degradation.

Adsorption to soil and organic matter. Soil particles and organic matter can tie up the herbicide and make it less available for absorption by plant roots. (See "Environmental influences on herbicide activity," page 47.) To review briefly:

- Soils high in clay content require higher rates of soil-applied herbicide than sandy soils.
- Soils high in organic matter require higher rates of soil-applied herbicides.
- Organic matter over a certain level renders soil-applied herbicides ineffective.
- In soil with high organic matter, the adsorbed herbicide may be released from the organic matter so slowly that the chemical does not control weeds.
- Injury to newly planted material from herbicide carryover is more likely in soils with less clay and organic matter, as less herbicide is bound to the soil. Be careful when applying materials to sandy soils (both new and established plantings).

Leaching. Herbicides may move or leach through the soil profile with water. Leaching usually is less if the soil dries out ("setting" the herbicide) after the initial amount of moisture is used to move the chemical to the desired depth. Several factors influence leaching:

- Initial soil moisture content
- Subsequent water passing through the soil
- Herbicide adsorption on soil particles and organic matter
- Solubility of the herbicide in water

Herbicides leach more readily through coarse, sandy soils low in organic matter.

Volatilization. A compound is volatile if it changes from a solid or liquid to a gas at ordinary temperatures. Some herbicides are very volatile; others are relatively nonvolatile. As herbicides volatilize, they are lost to the atmosphere as gases. Incorporate volatile herbicides into the soil by overhead irrigation, rain, or mechanical incorporation to reduce herbicide loss.

Removal by plants. Plants absorb and subsequently metabolize many herbicides, removing them from the soil.

pH. The acidity or alkalinity (pH) of the soil affects persistence and solubility of some herbicides. For example, alkaline conditions enhance the persistence of sulfonylurea and triazine products.

Review questions (answers on back of page)

1. What is the difference between particle drift and vapor drift?
2. What weather conditions are likely to produce particle drift?
3. Name three factors that affect herbicide leaching.
4. Why should pesticide spray formulations that go into suspension not be left standing without agitation?
5. What are some important precautions to take when using bare-ground or residual herbicides?
6. What is photodegradation?
7. What are some other ways pesticides can be degraded or removed from the soil?

Answers to review questions

1. Particle drift involves the off-target movement of spray droplets or dust particles, while vapor drift involves the movement of pesticide that has volatilized (turned into a gaseous state).
2. Hot and dry conditions can quickly evaporate the water from large pesticide droplets, turning them into much smaller droplets that are more likely to drift. Temperature inversions are particularly dangerous for drift since droplets can remain suspended for a long time.
3. Strength of adsorption to soil particles, solubility in water, chemical persistence.
4. The herbicide could settle out and cake in the bottom of the tank, making cleaning very difficult.
5. Know the soil type prior to making the application. Do not mix, apply, or clean spray equipment near wells, areas with shallow water tables, or other bodies of water. Understand the influence of rain and irrigation. Do not apply these types of pesticides where the root systems of desirable vegetation may be present or may extend in the future. Do not apply to frozen or saturated ground, and avoid spray drift during application. Use extreme caution when applying pesticides to slopes, and take measures to prevent humans, animals, and equipment from moving treated soil from the area.
6. The breakdown of herbicides when they are exposed to sunlight.
7. Microbial degradation, chemical degradation, adsorption to soil and organic matter, volatilization, removal by plants.

6 Applying Herbicides Safely and Accurately

Successful weed management relies on integrating the best weed control strategies. When management includes herbicides, select the herbicide and application method that ensure effective weed control with minimal adverse environmental effects. Consider potential drift, leaching, and residual activity. Know what susceptible vegetation is nearby and select an appropriate application method. Use application equipment that can deliver the herbicide to the target area uniformly, and keep the equipment in good working order to ensure accurate application.

Calibrate your equipment to deliver the proper volume to the target area. Then, calculate the amount of herbicide and carrier (if needed) necessary for the job from the application rate specified on the label. Improper calibration or calculation leads to poor weed control or injury to desirable vegetation because the applicator puts on too little or too much chemical. In addition, misapplication is not environmentally and economically wise.

Make the application at the best time for weed control and protection of desirable vegetation, such as prior to emergence. Consider growth stages and stresses on both weeds and desirable plants.

Methods of application

You often have a choice of application methods. The method you choose depends primarily on the product. Other factors include the characteristics of the weed or site, available application equipment, and the relative cost and effectiveness of alternative methods. The principal objective with any herbicide application is to effectively bring the chemical into contact with the targeted weed(s).

Following are the most common types of herbicide applications. Some applications may use more than one type.

- **Preplant incorporation** is the application and incorporation of herbicide prior to planting. It uses tillage equipment or overhead moisture to mix the herbicide with the soil. The herbicide then is available to kill germinating weed seeds.
- **Preemergence application** puts herbicide directly in or on the soil before weeds or desirable vegetation emerge. It also may be a foliar application to weeds, prior to emergence of desirable vegetation.
- **Postemergence application** puts the herbicide on plant foliage. At the time of foliar applications, plants should not be under moisture, heat, or other stress. Avoid drift to nearby sensitive vegetation.
- **Broadcast treatment** or blanket application is a uniform treatment of an entire area. It can be made preplant, preemergence, or postemergence.
- **Spot treatments** are applied to a localized or restricted area, usually to control a small weed infestation requiring special attention. Nonselective or residual herbicides sometimes are used on perennial weed infestations to prevent their spread.
- **Band treatment** usually means treating a strip. This reduces chemical cost because the treatment band covers less area than a broadcast application. It may be made preplant, preemergence, or postemergence. It often is used with mechanical controls.
- **Directed sprays** keep herbicides off desirable vegetation. Such sprays usually are directed at or just above the ground line, treating only the lower part of the plant stem or trunk or vegetation at the base of a tree.

Directed spray methods include the following.

- **Basal sprays** thoroughly wet the lower 18 inches of stems and the exposed roots of target plants, usually trees or brush. Depending on the herbicide and formulation chosen, you may make basal treatments anytime during the year on most species. It doesn't matter whether the plants are dormant or actively growing. Basal treatments allow application during the growing season when you need to treat areas close to susceptible crops (e.g., legumes, grapes).
- **Thin-line** treatments are a modified basal-stem application. Apply undiluted herbicide concentrate in a pencil-thin band around each stem.
- **Cut-stump** treatments are made to freshly cut stump surfaces so that herbicide moves down into the roots to control resprouting. Cut surfaces begin to dry within minutes of cutting.
- **Frill or hatchet** methods involve cutting the bark with downward ax cuts around the base of a tree (Figure 18). Spray or squirt the herbicide into the cambium area (growing wood area inside bark) immediately after making the cuts.
- **Tree injection** tools speed the frill or notch treatment and, when properly used, do a satisfactory job.
- **Soil treatments** can control woody plants. They require rainfall to move the chemical into the soil as deep as the feeder roots. Therefore, apply them just before or early in the rainy season. These treatments usually persist in the soil for more than 1 year. Effects develop slowly and may not be apparent until the year after treatment.
- **Invert emulsion** applications use a water-in-oil mixture to reduce drift. Since the majority of the mixture is an oil, it is quite viscous (thick) and more difficult to apply.

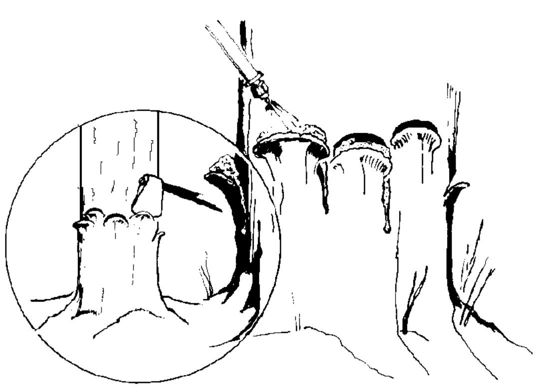


Figure 18.—Frill treatment.

Notice that many herbicide treatments also utilize mechanical, cultural, and other control methods. The most effective weed management programs use more than a single control method.

Application equipment

Pesticide application equipment is as important to your pest control program as the selection of the pesticide itself. By proper selection and use of application equipment, you often can prevent problems such as drift, nonuniform coverage, failure of a pesticide to reach the target, and movement to nontarget areas.

Sprayers

The primary function of any sprayer is to deliver the proper amount of chemical uniformly over the target area. When selecting a sprayer, make sure its components are able to withstand the deteriorating effects, if any, of the formulations you use. Also consider durability; cost; and convenience in filling, operating, and cleaning.

Hydraulic sprayers

Water is most frequently used as the means of carrying pesticide to the target area with hydraulic spraying equipment. The pesticide is mixed with sufficient water to obtain the desired application rate with a specific nozzle and size, nozzle spacing at a specified pressure, and travel speed. The spray mixture flows through the spraying system under pressure and is released through a nozzle onto the target area.

Vehicle-mounted sprayers

Low-pressure, vehicle-mounted sprayers normally are designed to deliver low to moderate volumes at 15 to 100 pounds of pressure per square inch (psi). The spray mixture is applied through a boom equipped with nozzles. The boom usually is mounted on a tractor, truck, trailer, or specially designed equipment, or the nozzle(s) can be attached to a hand-held boom by a hose. Roller-type pumps often are used on small tank sprayers (50 to 200 gallons), but sprayers with large tanks (200 to 1,000 gallons) usually have centrifugal pumps.

Backpack sprayers

Small-capacity backpack sprayers are useful in many right-of-way areas. They are well suited for treating individual brush plants, and for basal and cut surface applications. Tanks usually hold 3 to 5 gallons. The sprayers can be fitted with a single nozzle or with a boom with up to three nozzles. Some are filled to about three-fourths of the tank capacity with liquid, and air then is pumped into the remaining space. Initial pressure is 30 to 60 psi, but pressure drops continuously as the spray is applied unless a pressure regulator is used.

Other backpack sprayers have a lever that is pumped during the spraying operation to activate a plunger or diaphragm pump. They have a small air chamber to reduce the surging of the spray mixture as the lever is pumped. The boom can be equipped with a pressure gauge so that nearly constant pressure can be maintained during spraying.

Calibration of hand-held equipment for application on an area basis is difficult because operator speed and sprayer pressure are difficult to keep constant. These factors are not important, however, when applications are made to foliage or stems on a volume-to-volume basis. Equipment calibration is discussed in Chapter 7.

Miscellaneous equipment

Selective applicators

Roller and rope-wick applicators were developed for use with systemic herbicides. These systems are effective only when the weeds are taller than the desired vegetation. Several herbicides are registered for this form of application.

The roller system consists of a carpet-covered roller, which contains the herbicide. As the roller moves through the right-of-way and contacts tall weeds, the herbicide is transferred to the plants. The herbicide solution is applied to the carpet only when needed, either by a drip boom or low-pressure nozzles. A wiper constructed of belting uniformly distributes the solution on the carpet. Although no drift or splash occurs, the roller may become saturated with solution and drip onto desired vegetation.

The rope-wick applicator functions much like the roller system except that it has no moving parts. The herbicide solution is placed inside a PVC pipe, and rope inside the pipe “wicks” the solution to the outside. This applicator uses a small amount of herbicide and drips very little. Hand-held units are available for small-scale use.

Roller and wick applicators are not designed to control dense stands of weeds. Performance on hard-to-kill weeds is improved by treating two sides of the stems and leaves. Neither unit should be used for long periods while slanting to one side or the other. Doing so may cause the roller to drip on the lower end or wicks to dry out on the upper end.

Spot guns

Adjustable, industry-quality spot guns are recommended to apply several right-of-way 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

Granular applicators apply coarse, dry, uniformly sized particles to the soil. Several types of dry spreaders exist: pneumatic whirling disks (seeders, fertilizer spreaders), multiple gravity feed outlets (lawn spreaders, fertilizer spreaders), multiple air-driven feed outlets, and ram-air (aircraft). Some applications use shaker cans and hand distribution of pellet or gridball formulations.

Although they vary greatly in design, granular applicators normally consist of a hopper to hold the herbicide, a mechanical-type agitator at the base of the hopper to provide a uniform and continuous feed, and some type of metering device, usually a slit-type gate, to regulate the granule flow.

Components of sprayers

You must be thoroughly familiar with a sprayer's components to properly select, maintain, and operate the sprayer. The following discussion applies primarily to vehicle-mounted sprayers, but it also applies generally to backpack sprayers.

The major components of a sprayer are the supply tank, pump, flow control, and nozzles. Other important components include strainers, pressure gauges, hoses, and fittings.

Tanks

Because a sprayer tank holds the spray mixture, it must be made of material that is resistant to corrosion from pesticide formulations that you might use. Suitable materials include stainless steel, polyethylene plastic, and fiberglass. Some pesticides corrode aluminum, galvanized, and steel tanks; therefore, do not use these materials.

The filler opening should be large enough for you to easily fill the tank and inspect it for cleanliness. The cover should form a watertight seal when closed to minimize spills. Some tanks have a screen just under the cover to remove dirt and other materials during filling. The tank opening also should have a support device to hold the water hose above the filler opening to prevent backsiphoning. All tanks should have a drain plug at their lowest point.

Tank capacity markings must be accurate so that you can add the correct amount of water. Many tanks have capacity marks located so that they are visible from the tractor operator's position. A clear plastic tube (sight gauge) is mounted on metal tanks. Always check the capacity marking with clean water before using the sprayer. For example, put the sprayer on a scale and add 834 pounds of water. The water line should be at 100 gallons since the weight of water is 8.34 pounds per gallon. Check all tank markings using the same procedure.

Pumps

The heart of the spraying system is the pump. It must deliver the necessary flow to all nozzles at the desired pressure to ensure uniform distribution. To compensate for pump wear, pump flow capacity should be 20 percent greater than the largest flow required by the nozzles and hydraulic agitation.

When selecting a pump, also consider resistance to corrosive damage from pesticides, ease of priming, and the available power source. The materials in the pump housing and seals should be resistant to chemicals, including organic solvents.

Pesticide sprayers commonly use roller, piston, diaphragm, and centrifugal pumps. Each has unique characteristics that make it well suited for a particular situation. Roller and piston pumps are positive-displacement pumps; that is, the volume of output per revolution is always the same, regardless of speed or pressure. In contrast, the output per revolution of centrifugal pumps varies with speed and pressure. Diaphragm pumps are semipositive displacement pumps.

Agitators

An agitator is required to mix the components of the spray mixture uniformly and, for some formulations, to keep the material in suspension. Some pesticides and additives such as ammonium sulfate may need to be preslurried in water before being added to the spray tank. If agitation is inadequate, the application rate of the pesticide may vary as the tank is emptied. When using backpack sprayers, body movement usually is sufficient to keep the pesticide uniformly mixed in the spray tank.

Vehicle-mounted sprayers should have hydraulic or jet agitation to discharge the spray mixture at a high velocity into the tank. Liquid for agitation should come from the discharge side of the pump and not the bypass line of the pressure-regulating valve.

The quantity of flow required for agitation depends on the chemical used. Little agitation is needed for solutions and emulsions, but intense agitation is required for wettable powders. For jet agitators, a flow of 6 gallons per minute for each 100 gallons of tank capacity is adequate. The jet should be submerged to prevent foaming. Wettable powder suspensions can wear the inside of the tank if the jet stream passes through less than 12 inches of liquid before hitting the tank wall.

Strainers

Proper filtering 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, line, 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 a small opening.

A 12- to 20-mesh strainer should be used in the tank filler opening, and 40- to 50-mesh is suggested for the line strainer. For positive and semipositive displacement pumps (roller, piston, and diaphragm), the line strainer should be located between the pump inlet and tank. For centrifugal pumps, it should be located immediately after the pump outlet. Many designs put a 5- to 10-mesh strainer before centrifugal pumps to keep particles that may have fallen into the spray tank from entering the pump. Dirt has a smaller impact on centrifugal pumps than on other pumps. The area of the inline strainer should be several times larger than the area of the suction line.

Nozzle strainers sometimes are installed to ensure that the nozzles do not clog. These strainers vary in size, but common sizes are 50- and 100-mesh. Try to use nozzles that do not require smaller than 50-mesh nozzle strainers. Flood nozzles often are used without strainers. Nozzle suppliers can recommend the proper strainer. Consider using self-cleaning strainers.

Hoses

Use synthetic rubber or plastic hoses that have a burst strength greater than peak operating pressures, resist oil and solvents present in pesticides, and are weather-resistant. There should be as few restrictions and fittings as possible between the pressure gauge and nozzles.

The suction line, often the cause of pressure problems, must be airtight, noncollapsible, as short as possible, and have an inside diameter as large as the pump intake. A collapsed suction hose can restrict flow and cause damage to pump seals.

Table 15.—Proper hose sizing.

Pump output (gallons/ minute)	Inside hose diameter (inches)	
	Suction line	Pressure line
1–12	¾	⅝
13–25	1	¾
26–50	1¼	1
51–100	1½	1¼

Sprayer lines must be properly sized for the system (see Table 15). The proper size of lines varies with the size and capacity of the sprayer. A high, but not excessive, fluid velocity should be maintained throughout the system. If lines are too large, the velocity may be so low that the pesticide will settle out and clog the system; if lines are too small, an excessive drop in pressure will occur. A velocity of 5 to 6 feet per second is recommended. Table 14 provides suggested hose sizes for various flow rates.

Support booms

Most sprayers have booms that support hoses, stainless steel tubing or pipe, or PVC pipe. Booms keep nozzles at the desired spacing and height. Boom strength and stability are important in obtaining uniform spray application. Booms extending well beyond the sprayer frame should have release mechanisms that allow the boom to swing back when encountering an obstruction. Boom height should be adjustable from about 1 to 4 feet above the soil surface. If the field terrain is rolling, gauge wheels or a boom leveling system may be used to maintain a relatively constant boom height at the ends.

Flow control assembly

The flow control system directs the flow of the spray mixture and ensures that enough flow reaches the nozzles at the desired pressure. The major component is a pressure shut-off valve or a throttling valve.

With a positive displacement pump system, the pressure is controlled by the pressure regulator or relief valve, which has an adjustable, spring-loaded ball or diaphragm. It opens when the desired pressure is exceeded and directs excess flow back to the tank. This flow should not be used for agitation. Flow for agitation should come from the line ahead of the relief valve and at system pressure.

The output of a centrifugal pump is regulated by a throttling valve, which is a simple gate or globe valve. A pressure-regulating valve is not required.

For accurate pressure control, special throttling valves require several turns to open completely. Electrically controlled throttle valves are available that permit remote operation. A second valve located in the agitation line is used to control flow to the hydraulic agitator.

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. For a more convenient indication of nozzle pressure, you may prefer to attach a small hose from the boom to a pressure gauge at the driving position. Check the pressure gauge annually with a gauge known to be accurate. The total range of a pressure gauge should be two times the maximum expected reading. When selecting a gauge, be sure the internal materials will resist corrosion from the spray mixture.

Nozzles

Nozzles control the volume of pesticide applied, the uniformity of application, the completeness of coverage, and the amount of drift. While many nozzle types are available, each one is designed for specific uses. Regular flat-fan, flood, and cone nozzles are preferred for weed control in rights-of-way.

A variety of materials is used to manufacture nozzles. Brass is inexpensive, but it wears rapidly, causing a change in application rate and spray pattern. The worn nozzles usually have a higher flow and a greater concentration of spray directly below the nozzle. Nylon has good corrosion resistance, but only fair abrasion resistance, and it may swell when exposed to some liquids. Stainless steel nozzles are noncorrosive and resist abrasion. Nylon nozzles with stainless steel inserts offer an alternative to solid stainless steel at a reduced cost. Disk-type, hollow-cone nozzles are available in tungsten carbide, which is highly resistant to corrosion and abrasion. Regular flat-fan nozzles are available in ceramic, another highly resistant material. Hardened plastic nozzles are very resistant to abrasion but not as expensive as tungsten carbide or ceramic nozzles.

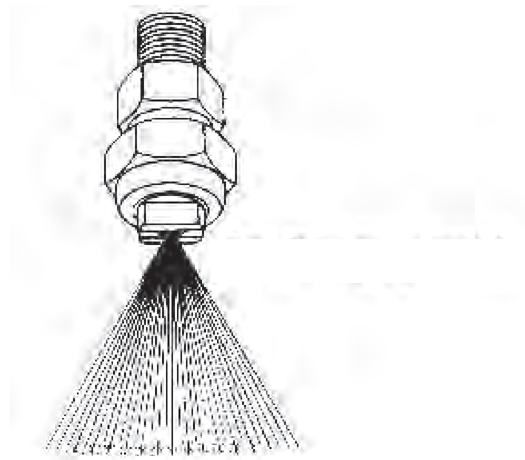


Figure 19.—Flat-fan spray nozzle.

Flat-fan nozzles

Flat-fan nozzles produce a flat spray pattern and are widely used for broadcast spraying herbicides (Figure 19). Because the outer edges of this pattern receive less volume, adjacent spray patterns must overlap 30 to 50 percent, depending on spray angle, to ensure uniform coverage. To achieve 50 percent overlap, the nozzle must spray an area 50 percent wider than the nozzle spacing on the boom. For example, nozzles spaced on 20-inch centers must spray an area 30 inches wide to get 50 percent overlap.

The normal operating pressure for most flat-fan nozzles is 30 to 60 psi, but low-pressure flat-fan nozzles can operate at pressures from 15 to 20 psi. Lower pressures create larger droplets and reduce drift. Extended range nozzles maintain a uniform pattern over a wider pressure range than regular flat-fan nozzles. Drift reduction flat-fan nozzles also are available.

Common angles of discharge are 65, 80, and 110 degrees. The angle of discharge and nozzle spacing determine the proper nozzle height for uniform application (Table 16).

Nozzle sizes are based on the size of the nozzle opening. Manufacturers use a coding system to describe the nozzle discharge at a standard pressure. Most flat-fan nozzles have a single discharge opening, but flat-fan nozzles with two openings have been developed. In one type, the discharge from one opening is directed slightly forward and the discharge from the second opening is directed slightly rearward. This design provides improved pesticide coverage of dense foliage. In another type, the discharge from one opening is directed downward and to one side, while the discharge from the second opening is directed downward and to the other side. The overlapping patterns are designed to produce a uniform, yet very wide, spray pattern.

Off-center nozzles. Off-center flat-fan nozzles are commonly used for rights-of-way herbicide application. These nozzles are ideal for negotiating signs, guardrails, and other obstacles. They produce a wide, off-center spray pattern extending from one side of the nozzle (Figure 20). This design allows the spraying of up to a 30-foot swath without the use of a boom. The coverage is relatively uniform when the nozzles are mounted at the proper height and operated within a pressure range of 15 to 40 psi.

Table 16.—Selecting the proper nozzle height.

Spray angle (degrees)	Nozzle height (inches)	
	20-inch spacing	30-inch spacing
65	22–24	33–35
80	17–19	26–28
110	15–18	20–22

Figure 20.—Off-center nozzle.

The spray from these nozzles, however, is more susceptible to drift than that from nozzles mounted on a spray boom. Off-center nozzles produce small droplets immediately under the nozzle, but deposit extremely large droplets at the outer edge of the swath.

Hydraulically controlled booms with special off-center nozzles have been developed. Nozzles are chosen so that the rate of application per acre is approximately the same regardless of which nozzle is operating, as long as speed and pressure remain constant. The nozzles are controlled by switches mounted in the truck cab. The operator selects the nozzle that produces a spray width appropriate for the particular roadside situation, without changing truck speed or application rate. Figure 21 shows a typical boom setup using off-center nozzles.

The off-center nozzle assembly should be set up so that the spray-pattern width increases in proportion to the nozzle flow rate. For example, if the nozzle with the lowest flow rate covers a 10-foot swath, then a nozzle with twice that flow rate should be set to cover a 20-foot swath.

Small off-center nozzles are effective devices for treating narrow strips under guardrails (generally about 3 feet wide). The nozzles are mounted about 15 inches above ground level on a fixed spray-bar and are spaced approximately 18 inches apart in line with the direction of travel. They are adjusted so the front nozzle throws a pattern angled forward in the direction

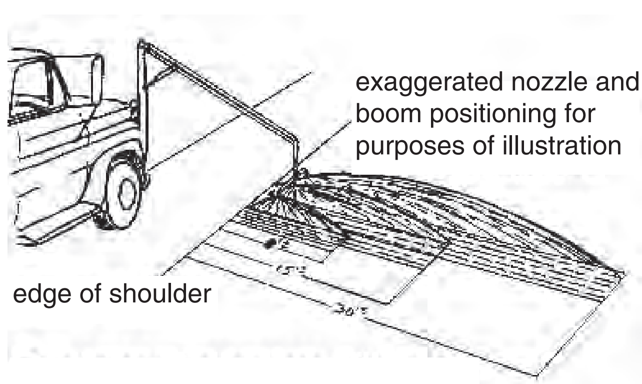


Figure 21.—Truck-mounted sprayer with boom set up to use off-center nozzles.

of travel, and the rear one throws a pattern angled back, as shown in Figure 22. This design eliminates "shadowing" behind posts. The desired pattern width is obtained by adjusting the nozzle angles.

Off-center nozzles also can be used to treat under guardrails without producing significant drift. This type of application uses a single hand-held or truck-mounted spray bar fitted with two nozzles as shown in Figure 23.

Flood flat-fan nozzles. Flood flat-fan nozzles produce a wide-angle pattern and function well when broadcasting herbicides; the flooding nozzle spacing should be 60 inches or less. Optimum operating pressures are 10 to 25 psi.

Pressure changes on flood flat-fan nozzles affect the angle and width of the spray pattern more than with regular flat-fan nozzles. The width of the spray pattern increases as the pressure increases. Although the discharge can be directed horizontally backward for a uniform pattern or downward for minimum drift potential, the best compromise position is backward at 45 degrees with the soil surface.

Spray patterns should overlap 100 percent for uniform distribution. Therefore, the area sprayed by one nozzle should be twice the nozzle spacing. Flood nozzles with improved spray pattern and drift reduction capability are available.

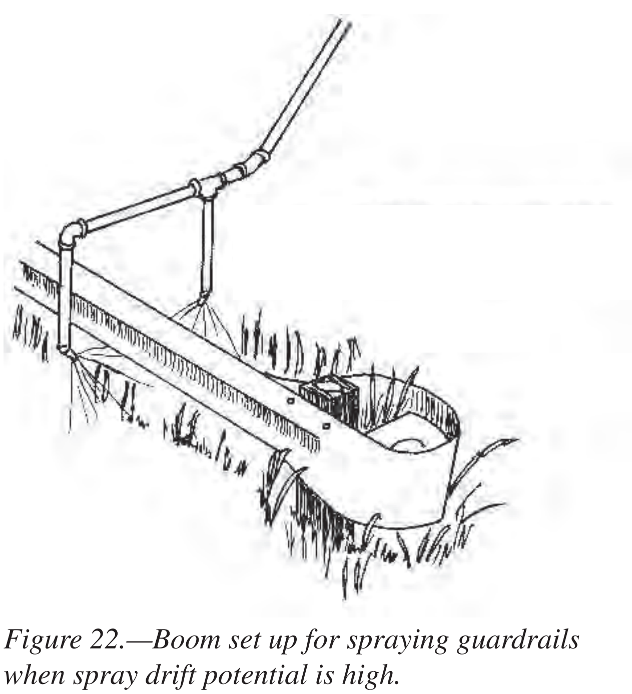


Figure 22.—Boom set up for spraying guardrails when spray drift potential is high.

Hollow-cone nozzles

At pressures of 40 to 100 psi, hollow-cone nozzles produce many small droplets that penetrate plant canopies and cover both sides of the leaves more effectively than fan nozzles. They also can be used to spray the foliage of individual brush plants. Adjustable-tip nozzles are commonly used on backpack sprayers in rights-of-way. They allow the operator to change the spray from a solid stream to a fine mist and are operated at relatively low pressures.

Full-cone nozzles

Full-cone nozzles are suitable for foliar sprays in many rights-of-way sites. They give excellent coverage and few fine particles.

Directa-spray and Wobbler nozzles

Directa-spray, Radi-arc, and Wobbler nozzles produce very coarse spray droplets. The spray solution is discharged through a rotating (Directa-spray and Radi-arc) or oscillating (Wobbler) unit as a stream. When the stream hits the air, it is broken into large droplets. These nozzles usually are used to apply 2,4-DP and related products to brush.

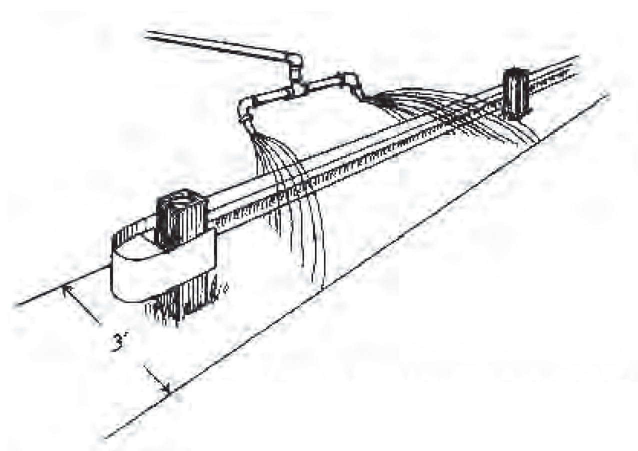


Figure 23.—Boom set up for spraying guardrails using off-center nozzles.

Operation and maintenance of sprayers

Proper operation and maintenance of spray equipment are essential for safe and effective pest control and significantly reduce repair costs and prolong the life of the sprayer.

Before spraying

At the beginning of each spraying season, thoroughly rinse the sprayer with clean water. All nozzles should be of the same type, size, and fan angle. If using nozzle strainers with check valves, make sure they are working properly; they prevent dripping when flow to the nozzle drops below a certain pressure. When broadcast spraying with fan-type nozzles, align nozzles at a slight angle with respect to the boom. **Do not align nozzles parallel with the boom.** Doing so will cause the outer edges of adjacent spray patterns to collide with each other and concentrate the spray mixture midway between nozzles.

Check the spraying system for leaks. Measure the distance between the nozzle tip and target and adjust the boom accordingly. Nozzle height is very important in broadcast application because it affects uniformity of the spray pattern.

Keep the tank level during filling so that the quantity in the tank is correctly indicated. After filling, the sprayer must be calibrated (see below).

During spraying

Frequently check the pressure gauge and tachometer while spraying, making sure that the sprayer is operating at the same pressure and speed as when it was calibrated. Speeds should be low enough that sprayer booms do not bounce or sway excessively. Periodically check hoses and fittings for leaks and nozzles for unusual patterns.

If you must make emergency repairs or adjustments in the field, wear adequate protective clothing, particularly rubber gloves. Use an old toothbrush, a nozzle-cleaning brush, or compressed air to unclog nozzles. Never use a metal wire to unclog a nozzle because it may distort the nozzle opening and change the spray pattern.

After spraying

Always flush the spray system with water after each use. Clean the inside and outside of the sprayer thoroughly before switching to another pesticide and before doing any maintenance or repair work. Remember that all equipment and equipment parts exposed to a pesticide normally have some residue, including sprayer pumps, tanks, hoses, and boom ends. Pesticide residue on application equipment can cause serious pesticide poisoning, particularly by absorption through the skin.

Use the following procedure as a guide for cleaning spray equipment. Clean equipment on a wash pad and apply rinsate to labeled sites as previously described.

1. Flush the sprayer tank, lines, and booms thoroughly with clean water and apply the pesticide-contaminated rinsate to labeled sites.
2. Fill the sprayer to capacity with water, adding 1 cup of trisodium phosphate or household ammonia for each 10 gallons of water. If neither is available, use a strong detergent or soap. Hormone-type herbicides (e.g., 2,4-D, dicamba) can be removed only with ammonia.
3. Wash the tank and pump parts thoroughly by running the sprayer for about 5 minutes with the flow to the nozzles turned off.
4. If possible, let the cleaning solution stand in the sprayer overnight. (Note: household ammonia will corrode aluminum sprayer parts.)
5. Discharge the liquid from the tank, spraying some through the nozzles.
6. Drain the sprayer completely and remove nozzles, screens, and strainers.
7. Scrub all accessible parts with a stiff bristle brush.
8. Rinse the sprayer thoroughly with clean water and reassemble.

Storage of sprayers

Before storing the sprayer at the end of the season:

1. Clean the sprayer thoroughly.
2. Refill the tank with clean water.
3. Add l to 5 gallons of lightweight emulsifiable oil (depending on the size of the tank).
4. Flush the entire system with the oil/water mixture. As the mixture is pumped from the sprayer, the oil will leave a protective coating on the inside of the tank, pump, and plumbing.
5. Remove and clean all nozzles and screens and place them in diesel fuel or kerosene to prevent corrosion. Cover the nozzle openings in the sprayer boom with tape to prevent dirt from entering.

As an added precaution to protect pumps, you may pour 1 tablespoon of radiator rust-inhibitor antifreeze into the pump inlet. Turn the pump several revolutions to coat the internal surfaces.

Review questions (answers on next page)

1. How are basal applications made, and when can basal treatments be applied?
2. What type of application equipment causes the herbicide mixture to flow through the spray system under pressure and to be released through a nozzle onto the target area?
3. At what pressure do vehicle-mounted sprayers typically run?
4. What type of sprayer is well suited for treating individual brush plants and for basal and cut-surface applications?
5. What type of material should be used for hoses on spray equipment?
6. What type of nozzle patterns work best for rights-of-way weed control?

Answers to review questions

1. Basal applications can be made year-round to the lower 18 inches of the stems and exposed roots (thoroughly wet) to most species of actively growing or dormant plants.
2. Hydraulic sprayers.
3. Low pressure (15 to 100 psi).
4. Backpack sprayers.
5. Synthetic rubber or plastic hoses that have a burst strength greater than peak operating pressures and that resist oil and solvents that are in pesticides.
6. Regular flat-fan, flood, and cone nozzles are preferred for rights-of-way weed control.

7 Calibration, Mixing, and Calculations

Calibration

The effectiveness of any herbicide depends on the proper application and placement of the chemical. The purpose of calibration is to ensure that application equipment uniformly applies the labeled rate of product over a given area. Too little herbicide results in poor weed control and a waste of money. Too much herbicide may result in damage to desirable vegetation, pollution, environmental and human health problems, and a waste of money. Herbicide delivery rate can change with equipment wear, gauge error, nozzle wear, wheel slippage, and speedometer error.

Application equipment suppliers often provide charts and tables to help you determine equipment setup and approximate desired delivery rates; however, such sources of information only estimate delivery rates. Charts and tables cannot account for equipment wear and variations in gauges, speedometers, and plumbing. You must calibrate equipment to obtain more reliable determinations of equipment delivery rates.

Calibration is simply determining the equipment delivery rate, or the amount of material delivered (applied), over a known area.

You must make several decisions before every herbicide application.

- Determine and possibly adjust the equipment delivery rate (calibration).
- Determine how much product (granules or liquid) is necessary for the job (the label).
- Determine the appropriate amount of carrier for the amount of product to be used.

The product label, calibration, and your calculations answer these questions.

Depending on the type of equipment, calibration may require a bucket marked in gallons, a scale, a stopwatch, tools such as a wrench or screwdriver, a container marked in ounces for nozzle output, a tape measure, and flags or stakes for marking distances. A pocket calculator helps reduce mathematical errors. Unless your equipment is new, it probably has some pesticide residue in and on the various parts; therefore, wear rubber gloves.

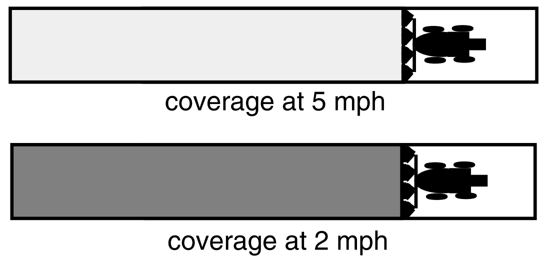


Figure 24.—Effect of travel speed on delivery rate.

Granular applicator calibration

Calibrating granular application equipment requires you to measure the amount of granules spread over a known area. Calibrate using the herbicide granule to be applied or a similar blank, because each granule type flows differently. Recalibrate each time you switch the type or rate of granular herbicide.

Variables that determine granular applicator output

Two variables affect the amount of granules applied per unit area: the size of the gate opening and the ground speed of the applicator.

The rate that granules flow out of the applicator depends on the size of the gate opening. A larger opening allows more granules to flow (a higher delivery rate). Changing the size of the gate opening significantly increases or decreases the delivery rate.

The speed at which the granular applicator travels also affects total output per unit area (Figure 24). When travel speed increases, less material is applied per unit area, and when speed is reduced, more material is applied (except with wheel-driven applicators). Test speed over terrain similar to the application site (soft ground, hard ground).

Adjust the gate opening or travel speed to fine-tune your application equipment. When small changes to the delivery rate are necessary, adjust travel speed. It may take many adjustments before the applicator is calibrated correctly.

Conduct the calibration test over a measured area where the granules can be collected (e.g., tarped area or driveway) or use a collection device mounted on the applicator. The catch container must not interfere with the chemical delivery. Use the following steps to calibrate a granular applicator.

1. Measure a known area (e.g., measure swath width, multiply swath width by course length to find covered area).
2. Set up a collection device: an attachment or a tarp on the ground.
3. Apply at proper speed and gate setting.
4. Collect and weigh the amount of chemical "spread" over the measured area.
5. The delivery rate is the weight of material collected for the area covered.
6. Convert units to a pound-per-acre basis, or whatever basis the label states.
7. Adjust gate setting or speed to get desired output.

Example

Prior to planting a new landscape at a roadside rest stop, you choose to apply a granular formulation of a preemergence herbicide. The spreader covers a swath of 30 feet. At the set speed and gate openings, collect granules in a collection device while covering a 100-foot course. The collected material weighs 1.25 pounds (Figure 25). The label states an application rate of 20 pounds of product per acre. What is the equipment's delivery rate in *pounds per acre*?

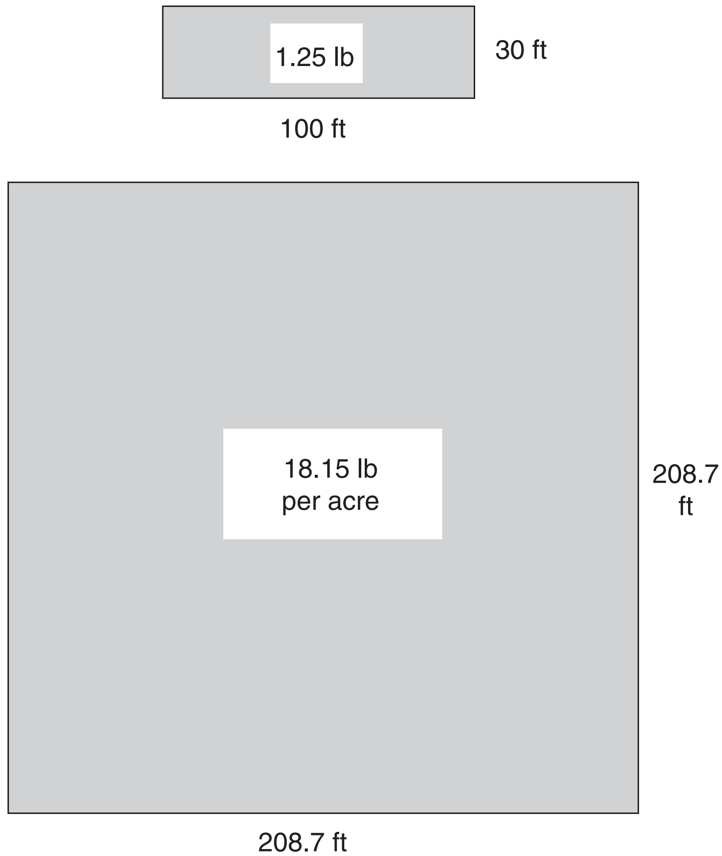


Figure 25.—Calibrating a granular spreader.

- Delivery rate is the amount applied per unit area, 1.25 lb per 3,000 sq ft.
- Convert 3,000 sq ft to an acre (43,560 sq ft = 1 acre). How many 3,000-sq-ft units are in 1 acre?

  43,560 sq ft per acre ÷ 3,000 sq ft
  = 14.52 units

- Multiply by the number of pounds of product per 3,000-sq-ft unit x 14.52 units

  14.52 units x 1.25 lb per unit
  = 18.15 lb per acre

The rate is less than desired and needs to be increased. To correct the problem, you may either reduce the speed or choose a different gate setting and recalibrate.

Sprayer calibration

Proper sprayer function is essential for accurate sprayer calibration; therefore, follow the procedures outlined below before calibrating the equipment.

- Be sure sprayer nozzle tips are uniform and appropriate for the spray application to be made. Consult the nozzle manufacturer's recommendations and the herbicide label.
- Thoroughly clean all nozzles, nozzle tips, and screens to ensure proper operation. Use a soft brush, not wire or any hard material. Add water to the spray tank and visually check nozzle output during sprayer operation. Discard and replace nozzle tips that produce distorted spray patterns.
- Check spray volume output of all nozzles and replace nozzle tips that differ by more than 10 percent from the average output of all nozzles, or replace all the nozzles if more than one is off.
- Check all pressure gauges. If a gauge is rusty or of questionable accuracy, replace it.

Table 17.—Effects of sprayer pressure on delivery rate (speed constant).

Sprayer pressure (psi)	Sprayer delivery rate (gal/acre)
10	10
40	20
160	40

Table 18.—Effects of sprayer speed on delivery rate (constant pressure).

Sprayer speed (mph)	Sprayer delivery rate (gal/acre)
1	40.0
2	20.0
3	13.3
4	10.0

Variables that determine sprayer output

Three variables affect the amount of spray solution applied over a given area: nozzle output, nozzle spacing or spray width, and ground speed of the sprayer.

Nozzle output varies with the pressure and the size of the nozzle tip (Table 17). Increasing the pressure or using a nozzle tip with a larger orifice (opening) increases the output.

Increasing pressure does not give a proportional increase in the output. For example, doubling the pressure does not double the flow rate; you must increase the pressure fourfold to double the flow rate. Therefore, adjust pressure for minor changes in spray delivery rate, not major ones. Operating pressure must be maintained within the recommended range for each nozzle type to obtain a uniform pattern and to minimize drift.

An easy way to make a large change in flow rate is to change the size of the nozzle tips. Depending on operating pressure, the speed of the sprayer, and the nozzle spacing, small changes in nozzle size can change per-acre sprayer output significantly. Nozzle manufacturers' catalogs give information to help you select the proper tip size.

For ground sprayers, delivery rate is inversely proportional to the speed of the sprayer; that is, as speed increases, the amount of spray applied per unit area decreases at an equal rate (Table 18). If spray pressure remains constant, doubling the sprayer's ground speed will reduce the amount of spray per area by one-half.

Sprayer calibration determines the amount of spray volume the equipment delivers per unit area. Most labels direct the user to apply a specific amount of herbicide per acre, but some label instructions include directions for an amount of herbicide to be applied per 1,000 square feet or some other area measure. Calibrate the sprayer and determine the delivery rate in the units used on the label (such as gallons per acre or per 1,000 square feet).

Boom sprayer calibration

The following calibration method is only one of many used for boom sprayers.

- **Test nozzles.** Make sure all nozzles have the same output and good spray patterns.
- **Determine travel speed.** Select a reasonable operating speed for the terrain, soil condition, and durability of the spray equipment. Record the tachometer or speedometer readings and the gear setting used to maintain the selected speed. Fill tank at least half full to simulate application conditions. Time how long it takes the spray equipment to travel a set distance (e.g., 200 ft) in similar site conditions. This accounts for wheel slippage. Time equipment in both directions and calculate the average time.

  Example: 34 seconds to travel 200 ft

- **Determine nozzle output per 200 feet.** Select and record the spray pressure at which the system will be operated. (Check label and nozzle recommendations for guidelines.) Adjust to the desired pressure while the pump is operating at normal speed and water is flowing through the nozzles. (Minimize off-target drift by operating at the lower end of a nozzle's pressure range.)

  Collect spray from nozzles (measured in ounces) at the pressure to be used for the time it took to cover 200 feet (34 seconds). The more nozzles from which you collect spray, the more accurate the calibration. Calculate the average output from the nozzles sampled.

  Example:

  16 oz + 14.5 oz + 15 oz + 14 oz + 14.5 oz = 74 oz

  74 oz ÷ 5 nozzles = 14.8 oz in 34 sec (or per 200 ft)

- **Measure nozzle spacing in inches.** Measure the distance between two nozzles, center to center.

  Example: 20 inches

- **Calculate the delivery rate in gallons per acre (GPA).** Using the following formula, insert the average nozzle output over a 200-foot course and the nozzle spacing in inches. (20.5 is a mathematical constant accounting for changes in volume and area measurements on a 200-foot course for these problems only.)

$$\frac{\text{oz per nozzle (collected per 200 ft)} \times 20.5}{\text{nozzle spacing (inches)}} = \text{GPA}$$

$$\frac{14.8 \text{ oz} \times 20.5}{20 \text{ inches}} = 15.2 \text{ GPA}$$

Sprayer calibration example

A sprayer is set up with five nozzles at 20-inch spacings, an 8-foot boom swath, and 40 psi. Set the course at 200 feet. It takes the equipment 34 seconds to travel 200 feet in second gear at 1,700 rpm. The five nozzles delivered 18.5, 19, 18.5, 19.5, and 19.5 ounces, respectively, in 34 seconds.

- Find average nozzle output (200 ft):

  18.5 + 19 + 18.5 +19.5 + 19.5 = 95
  95 ÷ 5 = 19 oz

- Measure nozzle spacing:

  20 inches

- Use this formula to calculate gallons per acre:

$$\frac{\text{oz per nozzle (collected per 200 ft)} \times 20.5}{\text{nozzle spacing (inches)}} = \text{GPA}$$

$$\frac{19 \text{ oz} \times 20.5}{20 \text{ inches}} = 19.5 \text{ GPA}$$

Sprayer calibration results are valid only for the speed, nozzles, pressure, and spray width (nozzle spacing) used during the calibration process. Significant changes in any of these factors will require another calibration check. Calibrate your sprayer more than once per season, even if you do not change the system.

Another method of calibration is to spray an acre. Measure how much water it takes to cover 1 acre to determine the gallon-per-acre output for the sprayer.

For example, a sprayer has an 8-foot swath. To cover 1 acre, the sprayer needs to travel 5,445 feet (43,560 sq ft ÷ 8 ft = 5,445 ft). After spraying the 5,445-foot course, it took 32 gallons to exactly refill the spray tank to the level prior to spraying the acre. This means the sprayer is delivering 32 gallons per acre. Always measure the water accurately. Check all nozzles for uniform output with this method.

Compressed air sprayer calibration

Most compressed air sprayers are small, hand-operated units carried by the operator; consequently, application factors such as speed, spray width, and pressure depend on who is spraying.

The following is just one of several methods used to calibrate hand-pressurized sprayers.

- Measure and mark a square area 18.5 feet x 18.5 feet, preferably on a surface that will easily show the spray pattern width (e.g., a paved parking lot).
- Starting with an empty liquid spray tank and using a container graduated in ounces, add 2 quarts (64 ounces) of water to the spray tank.
- Pressurize the sprayer and spray the area within the marked square. Maintain uniform operator walking speed, nozzle height, and tank pressurization.
- Depressurize the spray tank by opening the filler cap; drain the spray wand back into the tank by holding the spray wand above the tank and opening the spray valve on the wand.
- Using a container marked in ounces, determine the number of ounces remaining in the sprayer.
- Calculate the number of ounces sprayed by subtracting the number of ounces left in the sprayer from the 64 ounces originally added to the spray tank.

The number of ounces sprayed on the defined area is equal to the gallon-per-acre delivery of that sprayer. For example, if the number of ounces used to cover the marked area (342.25 square feet or $^1/_{128}$ of an acre) is 36 ounces, then the sprayer is delivering about 36 gallons per acre.

Again, this rate applies only to the operator who calibrated the sprayer.

Percentage solutions

In some applications, herbicides are mixed as a percent of the volume in the tank, and the mixture is sprayed-to-wet. Spraying-to-wet means thoroughly covering all foliage and stems. This type of mixing and application often is done with handguns and backpack sprayers. This method also is used with wiping applicators. Some surfactants are added as a percent volume.

Changing sprayer delivery rate

It is easy to adjust sprayer delivery rates. If your sprayer is delivering less than or more than enough spray to each acre, you can change the rate by using one of these methods (Table 19).

- **Change the nozzle orifice.** The larger the hole in the nozzle tip, the more spray is delivered. This usually is the preferred method when making substantial changes in sprayer output.
- **Change the speed of the sprayer.** Slower speed means more spray is delivered over the area; faster speed means less spray is delivered over the area. Doubling the ground speed of the sprayer reduces the sprayer delivery rate by one-half, except for wheel-driven sprayers.
- **Change the pump pressure.** Lower pressure means less spray is delivered; with higher pressure, more spray is delivered. To double output, you must increase the pressure fourfold. Remember that spray pressure affects both nozzle patterns and drift.

Table 19.—Equipment adjustments to alter delivery rates.

	To *increase* GPA	**To *decrease* GPA**
Nozzles	larger	smaller
Sprayer speed	slower	faster
Pressure	increase	decrease

Injection sprayer calibration

The calibration of injection sprayers is done in a few steps. The entry of the calibration numbers into the computer console can be somewhat complex. Calibrate or correct the speed sensor on each unit until the console is measuring the actual distance traveled. A measured distance of 1,000 to 4,000 feet is suggested. Drive over this distance at the normal operating speed. The ratio of the actual distance to the recorded distance is the correction factor to enter in the console.

In a similar fashion, compare the actual output from each pump with the indicated output. The amount caught from each pump should be as much as practical; 2 gallons is suggested. The larger the volume, the less the effect of measurement errors. Check the sprayer periodically to adjust for wear. Follow the manufacturer's operating manual carefully.

Mixing and calculations

Calculating the correct amount of product needed and proper mixing are essential for safe, effective, legal applications. Directions for mixing are given on the herbicide label; calculations generally are necessary. Mixing and calculations vary depending on the type of herbicide used.

Label rates may vary depending on site conditions. Read the label carefully to select the proper rate of application.

To determine the amount of product needed for the application, know the total area to be treated and read the label carefully for the proper rate. The unit of application used varies among labels and written recommendations. Most labels give the application rate in the amount of *product* per acre. Many recommendations state the application rate in amount of *active ingredient* (ai) or *acid equivalent* (ae) per acre. Always convert rates to the amount of product when calculating how much herbicide you need.

The formulas in the box below ("Product conversions") will help you calculate the amount of product and active ingredient equivalents for dry and liquid formulations.

Following are some examples of these calculations. Determine how much product is needed to cover 16 acres for each of the different rates.

- 6 pounds dry product per acre:

  6 lb product per A x 16 A = 96 lb product

- 1 pound ai per acre of a 75 percent wettable powder (first convert ai to product):

  1 lb ai per A ÷ 0.75 lb ai per lb product
  = 1.33 lb product per A

  1.33 lb product per A x 16 A
  = 21.3 lb product

- 1 pint liquid product per acre:

  1 pt per A x 16 A = 16 pt or 2 gal

- 1 pound ai per acre of a 4-pound-ai-per-gallon emulsifiable concentrate (first convert ai to product):

  1 lb ai per A ÷ 4 lb ai per gal
  = 0.25 gal product per A

  0.25 gal per A x 16 A = 4 gal product

Often, spray mixes for small, hand-held sprayers are based on a percentage of product within the spray mix. These are commonly volume-to-volume ratios, but can be a weight-to-volume ratio.

Product conversions

Dry formulations

Convert commercial product and ai in formulation:

- amount product x % ai = *amount ai*
- amount ai ÷ % ai = *amount product*

Liquid formulations

Convert commercial product and ai in formulation:

- gal product x lb ai per gal = *lb ai*
- lb ai ÷ lb ai per gal = *gal product*

Example

The label indicates you need a 2 percent concentration of an herbicide (not active ingredient). You have a 3-gallon backpack sprayer. How much herbicide do you need to fill the sprayer?

3 gal x 128 oz per gal = 384 oz of spray will be made up

0.02 x 384 oz = 7.68 oz of herbicide needed to make up 3 gal of a 2% solution

Often, mixing two or more chemicals together in the tank saves time and money, increases the number of weeds controlled, and delays weed resistance. Many manufacturers recommend tankmixing their products with specific other products. Fertilizers also are commonly added with some herbicides. It is **legal** to tankmix chemicals if all products are labeled for the application site, but **not if the label prohibits** mixing specific pesticides. Prior to tankmixing products, read the label and make sure tankmixing is not prohibited.

Some products may be incompatible. Incompatibility results in gelatin or crystals forming in the tank mix or loss of herbicide activity. In some cases, tank mixes may increase injury to desirable plants. When labels include tank mix recommendations, the manufacturer has conducted compatibility and performance tests.

Conduct a jar test for physical compatibility if the label does not specifically recommend the combination. Many labels give directions for compatibility tests. If not, mix the products with their carrier in a small jar at proper concentrations. Watch for changes and feel for heat, which indicates a reaction. If products do not mix properly, compatibility agents might solve the problem. Repeat the jar test with the compatibility agent. If everything looks fine, test the tank mix on a small portion of the site to make sure the combination is effective and safe to the desirable vegetation **before** mixing hundreds of dollars worth of solution.

Tankmix herbicides in the following sequence to lessen incompatibility problems, unless otherwise directed by the label. First, partially fill the tank with carrier. Add buffers if necessary. Next, add dry or flowable formulations and get them into suspension by agitation before adding emulsifiable concentrates. Next, add those products that form true solutions with the carrier and then add adjuvants. Finally, add the remaining carrier to bring the spray mix to the full volume required for the job.

Many herbicide products recommend adding adjuvants to the tank mix to increase product effectiveness. **Surfactants** are a class of adjuvants that includes spreaders and stickers that change the surface tension of the spray solution. When the surface tension of the spray solution is reduced, spray droplets are more likely to remain on leaves without bouncing or rolling off. They also spread over a greater area on the leaves. Some herbicides need penetrants to aid herbicide uptake through waxy leaves and stems. Weeds densely covered with hairs may require a spreader so the droplets pass through the hairs to reach the leaf.

Buffers are adjuvants that adjust the pH of the spray solution. They usually reduce the pH, either to avoid hydrolysis of certain pesticides in alkaline water or to improve uptake through the plant cuticle. Other adjuvants include thickeners, defoaming agents, and compatibility agents. Read the label directions for recommendations and rates.

The following calibration and mixing problems will help you become familiar with the calculations often used in herbicide applications.

Calibration calculations

Problem 1. A sprayer travels 4.5 mph, keeping pressure at 40 psi. The boom has nine nozzles spaced 20 inches apart, a 15-foot swath. A calibration course is set at 200 feet, which is covered in an average of 30 seconds. From each of three nozzles, 24 ounces is the average volume collected over the course. What is the sprayer delivery rate in gallons per acre?

The method using the formula:

$$\frac{\text{oz per nozzle (collected per 200 ft) x 20.5}}{\text{nozzle spacing (inches)}} = \text{GPA}$$

$$\frac{\text{24 oz x 20.5}}{\text{20 inches}} = \text{24.6 GPA}$$

A method using math:

- Determine area covered:

  swath width x course length = area

  15 ft x 200 ft = 3,000 sq ft

- Determine spray output of entire boom in *gallons:*

  24 oz per nozzle x 9 nozzles = 216 oz

  216 oz ÷ 128 oz per gal = 1.68 gal

- Determine how many 3,000-sq-ft units are in 1 acre:

  43,560 sq ft per A ÷ 3,000 sq ft = 14.5 units

- Multiply number of units by gallons of spray applied per unit:

  14.5 units x 1.68 gal = 24.4 GPA

Problem 2. A spray gun operates at 40 psi. A spray truck travels 200 feet in 23 seconds. The spray gun covers a 10-foot swath. In 1 minute, the gun delivers 3.1 gallons of spray. What is the sprayer delivery rate in gallons per acre?

A method using math:

- Determine total area covered per minute:

  200 ft ÷ 23 sec = 8.696 ft per sec

  8.696 ft per sec x 60 sec per min = 521.7 ft per min

  10-ft swath x 521.7-ft length = 5,217 sq ft

- Determine how many 5,217-sq-ft units are in 1 acre:

  43,560 sq ft per A ÷ 5,217 sq ft = 8.35 units

- Multiply number of units by spray delivered in 1 minute:

  8.35 units x 3.1 gal = 25.9 GPA

Mixing calculations

Problem 1. A boom sprayer has a 15-foot boom and travels 6 mph. The auxiliary pump is set at 30 psi. The spray tank holds 50 gallons. Equipment is calibrated to deliver 12.9 GPA. Two miles of ditch bank need a broadcast treatment. The label-recommended rate is 24 ounces of product per acre. How much product is needed?

- How many acres will be treated?

  2 miles x 5,280 ft per mile = 10,560 ft

  10,560 ft x 15-ft swath = 158,400 sq ft

  158,400 sq ft ÷ 43,560 sq ft per A = 3.6 A

- How much total spray solution is needed?

  3.6 A x 12.9 GPA = 46.4 gal of spray

- How many *pints* of product should be added for the tank batch?

  3.6 A x 24 oz per A = 86.4 oz product

  86.4 oz ÷ 16 oz per pt = 5.4 pt

Problem 2. You have a 300-gallon tank spray system calibrated to deliver 16 gallons per acre. The spray gun nozzle covers a total of 5 feet. You need to treat 40 miles of road shoulder. The application rate is 2 ounces of product per acre. How much product is needed?

- How many total acres need to be treated?

  40 miles x 5,280 ft per mile = 211,200 ft

  211,200 ft x 5-ft swath = 1,056,000 sq ft

  1,056,000 sq ft ÷ 43,560 sq ft per A = 24.2 A

- How much spray solution is needed to treat the area?

  24.2 A x 16 GPA = 388 gal

- How many acres will each of the tank loads cover (assuming two loads at 194 gallons)?

  tank size ÷ GPA = acres covered

  194 gal ÷ 16 GPA = 12.1 A

- How many *ounces* of product will be added to each tank?

  12.1 A x 2 oz per A = 24.2 oz

Problem 3. To treat the same 40 miles of road shoulder with the same setup as in Problem 2, determine the amount of product necessary for a recommended rate of 1.5 pounds active ingredient per acre for a 2-lb-ai-per-gal emulsifiable concentrate.

- How much product is needed per acre to equal the 1.5-lb-ai-per-A rate?

  1.5 lb ai ÷ 2 lb ai per gal = 0.75 gal product

- How much product should be added to make up 388 gallons of spray if applied at 1.5 lb ai per A (0.75 gal per A)?

  388 gal spray ÷ 16 GPA = 24.2 A

  24.2 A x 0.75 gal per A = 18.2 gal product

Problem 4. How much product is needed to make up a 5 percent product concentration solution for a total of 10 gallons of spray using an emulsifiable concentration?

10 gal x 0.05 = 0.5 gal product

How to read a pesticide label

Every pesticide product is required to have a complete label with detailed instructions on how to use the product correctly, efficiently, safely, and legally. The label also contains instructions for medical personnel in the event of an accidental exposure or illness. Read the label before buying a pesticide and before each use. The label is there for a reason. Follow it to protect yourself and others, and to maximize pest control benefits while minimizing risk.

Pesticide manufacturers are legally bound to include certain information on pesticide labels. Take time to familiarize yourself with the parts of the label so that you know where to find specific information when you need it. The main sections of a pesticide label are:

- **Common name and brand name.** Several manufacturers produce pesticides with the same common name, but with different brand names. Therefore, it is important to be familiar with the common name of a pesticide. The herbicide with the common name glyphosate, for example, is sold with dozens of brand names in the Pacific Northwest. The common name of a pesticide is similar to the scientific name of a plant. Plants often have regionalized common names that differ and create confusion, but their scientific name is used worldwide.
- **Active ingredients.** This section is similar to the "ingredients" list on a food product. The active ingredient in a pesticide is the component that controls the target pest. The active ingredient is listed either as the common name or as the chemical name. The label will give the percentage of product that is active ingredient and the percentage of product that is inert ingredient (the portion of the product that is inactive toward the target pest). The label is required to list the percentage of inert ingredients, but not to list the makeup of the inert ingredients.
- **EPA registration number.** This number indicates that the Environmental Protection Agency (EPA) has registered the pesticide product. Not all pesticides with an EPA registration number are registered in each state.
- **Signal words.** The signal word is a general indication of the potential hazard level from the pesticide to humans and animals. There are four categories of signal words, summarized in Table 20.
- **Precautionary statements.** These statements, sometimes listed under "Hazards to Humans and Domestic Animals," provide guidance in protecting humans and animals from pesticide exposure.
- **First aid or statement of practical treatment.** If inhalation, swallowing, or eye exposure could be harmful, the label must include emergency first aid instructions. First aid is not a substitute for medical treatment; always seek medical advice after any exposure, and have the label available for medical personnel.
- **Environmental hazard statement.** These statements include information on how to prevent environmental contamination with the pesticide.

- **Reentry statements.** Some pesticide labels indicate how much time must pass after application before a person can reenter a treated area without appropriate protective clothing.
- **Directions for use.** This section tells you how to use the pesticide, rates for effective pest control, and application types and timings.
- **Storage and disposal.** This section describes how to safely store and dispose of the product.

Table 20.—Signal words: relative toxicity, minimum personal protective equipment (PPE), and work clothing requirements.

Signal word	DANGER (I)	WARNING (II)	CAUTION (III)	CAUTION (IV)
Relative toxicity	High toxicity	Moderate toxicity	Slight toxicity	Very slight toxicity
Protection from dermal toxicity or skin irritation potential	Coveralls worn over long-sleeved shirt and long pants	Coveralls worn over long-sleeved shirt and long pants	Long-sleeved shirt and long pants	Long-sleeved shirt and long pants
	Socks	Socks	Socks	Socks
	Chemical-resistant footwear	Chemical-resistant footwear	Shoes	Shoes
	Chemical-resistant gloves	Chemical-resistant gloves	Chemical-resistant gloves	No minimum*
Protection from inhalation toxicity	Respiratory protection device	Respiratory protection device	No minimum*	No minimum*
Protection from eye irritation potential	Protective eyewear	Protective eyewear	No minimum*	No minimum*

* EPA may require PPE on a product-specific basis. Consult label prior to use.

Review questions (answers on back of page)

1. What are three things that must be determined before every application in order to deliver the proper amount of herbicide to the target area?
2. What happens to the delivery rate of a pesticide as the rate of travel of the application equipment increases?
3. What is a good precaution to take before tankmixing products?
4. Name the three signal words that might be found on a pesticide label.
5. The ingredients that kill the pest are called ___________ ingredients.

Answers to review questions

1. Determine and possibly adjust the equipment delivery rate (calibration), determine how much product is necessary for the job, and determine the amount of carrier for the amount of product to be used.
2. The delivery rate decreases.
3. Read the label for precautions and prohibitions, then perform a jar compatibility test.
4. Caution, warning, danger.
5. Active.

8 Rights-of-Way Vegetation Management and the Public

Of the areas where pesticides are commonly used, rights-of-way vegetation management involves the greatest interaction and visibility with the public. Pesticides are applied on many miles of rights-of-way that border private and public property. Occasionally, there may be a difference in perception of the need for vegetation management in rights-of-way and of appropriate management strategies. Public concerns or questions often include:

- "Brownout" areas alongside lawns, gardens, and other private lands
- Potential nontarget pesticide exposure to desirable plants, humans, pets, and farm animals
- Potential environmental hazards to water sources, wildlife, and threatened plants and animals

The public perception of vegetation management with pesticides in rights-of-way often can be improved by taking a few simple steps.

- **Educate yourself as a supervisor or applicator.** Misperception often is a result of lack of knowledge. Consider yourself an objective educator in addition to a pest management practitioner. Communication between vegetation managers and the public should be based on current and objective information on the target pests and available control methods. Direct communication often takes place between applicators and concerned citizens; therefore, pest management education is necessary at all levels of vegetation management.
- **Improve operational practices and avoid carelessness.** In this case, the saying "one bad apple spoils the bunch" holds true. Public perception often is based on the rare "negative" incidents, such as pesticide spills, environmental exposure, or nontarget plant damage. Follow the label, use common sense, and avoid unnecessary risks. Maintain equipment and appear professionally prepared for the job.
- **Choose your contractors and applicators carefully.** Keep in mind that these people are representatives of your company or agency and often are the most visible to the public.
- **Be open and professional with the public.** Lack of communication or knowledge can be perceived as hiding something and can lead to formal complaints or investigations.
- **Be prepared to answer questions.** Applicators should have pesticide product information—including the label, Material Safety Data Sheet (MSDS), and appropriate literature—available at the time of application. If you cannot answer a question immediately, get the name, address, and phone number of the person making the inquiry and respond in a timely manner. Be sure to check with your supervisor concerning specific agency or company policy on public relations.

Practice Test

The first 15 questions are based on pesticide label interpretations. Read the ARCHER Herbicide label (pages 85–88) prior to answering these questions. Read the questions carefully and select the **best** answer for each question. Answers are found on page 84.

1. What is the trade name of ARCHER Herbicide?
   a. ARCHER Herbicide
   b. 2,4-D
   c. triclopyr
   d. 2,4-D + triclopyr

2. What is the minimum acceptable personal protective clothing when applying ARCHER Herbicide to a fencerow?
   a. long-sleeved shirt, long pants, PVC gloves
   b. long-sleeved shirt, long pants, cotton gloves, full face shield
   c. long-sleeved shirt, long pants, nitrile gloves, safety glasses
   d. long-sleeved shirt, long pants, PVC gloves, respirator

3. The ARCHER label directs the user to treat the cambium layer on a cut stump. What is the cambium layer?
   a. bark
   b. conductive tissue, just inside the bark
   c. root collar, just above the ground
   d. heartwood, in the center of the stump

4. ARCHER Herbicide is a:
   a. preemergence herbicide
   b. postemergence herbicide
   c. preplant herbicide
   d. preemergence, incorporated herbicide

5. Tansy ragwort is best controlled by ARCHER in which stage?
   a. rosette b. early flowering
   c. bolt d. late flowering

6. Control of willow with ARCHER is affected by:
   a. temperature b. soil microorganisms
   c. soil pH d. air stability

7. Thin-line basal applications of ARCHER Herbicide:
   a. are prohibited
   b. direct concentrated herbicide solution to a pencil-thin line around the stem
   c. greatly increase the spray volume of herbicide required to treat an area
   d. require a minimum of a 1 percent solution

8. What is the minimum amount of ARCHER Herbicide needed to broadcast treat 2 acres of densely growing sumac?
   a. 0.5 gallon b. 4 ounces
   c. 3 gallons d. 8 gallons

9. ARCHER Herbicide is a translocated herbicide.
   a. true b. false

10. A foliar application of ARCHER to control multiflora rose is best in:
    a. early spring b. late fall
    c. summer d. winter

11. Is a reapplication of ARCHER Herbicide to woody plants grown in sandy soils a serious groundwater concern?
    a. yes b. no

12. Which of the following could you tankmix with ARCHER Herbicide?
    a. 2,4-D herbicide b. liquid fertilizer
    c. surfactant d. all of the above

13. Long-term control of mouseear chickweed with ARCHER Herbicide requires:
    a. stopping only seed production
    b. killing all the green vegetation
    c. inhibiting photosynthesis
    d. killing the roots to prevent resprouting

14. At what rate will ARCHER Herbicide provide long-term residual control of germinating broadleaf seedlings?
    a. 1 quart/acre b. 2 quarts/acre
    c. 3 quarts/acre d. no residual control

15. How much triclopyr is in a 2.5 gallon container of ARCHER Herbicide?
    a. 0.13 pound b. 0.4 pound
    c. 2.5 pounds d. 5 pounds

The following questions relate to general weed management principles. Read the questions carefully and select the **best** answer for each question.

---

16. Weeds compete with landscape plants and turf for which of the following:
    a. organic matter, light, and carotenes
    b. proteins, water, chlorophyll
    c. nutrients, light, and water
    d. all of the above

17. Annual weed seeds survive for:
    a. less than 1 calendar year
    b. 1 to 5 years
    c. more than 5 years
    d. any of the above

18. Which of the following is a key characteristic of grasses?
    a. woody tissue b. netlike veins in leaves
    c. fine, branching roots d. biennial life cycle

19. Which of the following are common ways weedy species invade our rights-of-way?
    a. they move with contaminated vehicles
    b. they move with rivers and streams to new places
    c. they move with livestock to new places
    d. all of the above

20. Perennial weeds are the most persistent and difficult to control because:
    a. they live for more than 2 years and may live almost indefinitely
    b. most perennials reproduce vegetatively as well as by seed
    c. effective control usually requires destruction of underground plant parts
    d. all of the above

21. Destroying the top growth of perennial weeds on a **one-time** basis normally will kill the plant if:
    a. conducted in the seedling stage
    b. conducted before root tubers are formed
    c. conducted just prior to flowering
    d. conducted during the spring growth flush

22. Diquat is a nonselective contact herbicide. Which of the following weeds does it control?
    a. mustards b. common lambsquarters
    c. annual bluegrass d. all of the above

23. Which of the following is a structural reason some plants are tolerant of herbicides?
    a. wax layer on leaves
    b. chitin layer on leaves and stems
    c. exoskeleton
    d. spiracles under leaves

24. Which of the following is **not** a chemical or application factor that affects susceptibility of one group of plants to certain herbicides?
    a. addition of adjuvants
    b. application rate
    c. product formulation
    d. leaf angle or size

25. Growth regulators or phenoxy compounds have caused major problems due to movement to nontarget plants. Which of the following fall into that group?
    a. Escort, Telar, Oust
    b. Banvel, MCPA, Transline
    c. Arsenal, Plateau
    d. Velpar, Spike

26. Some soil-applied herbicides require higher rates of application because of:
    a. photodegradation
    b. chemical degradation
    c. soil adsorption
    d. leaching

27. The risk of weed resistance can be reduced by:
    a. rotating herbicide mode of action
    b. repeated application of the same herbicide
    c. rotating herbicides with the same mode of action
    d. using lower rates of the same herbicide year after year

28. What nozzle would you avoid using with emulsifiable concentrate formulations?
    a. stainless steel
    b. ceramic
    c. nylon
    d. aluminum

29. Calibrate the following backpack sprayer. The calibration area is 20 feet by 25 feet. You use 60 ounces of spray to cover the calibration area. What is the sprayer output per 1,000 square feet?
    a. 60 oz per 1,000 sq ft
    b. 120 oz per 1,000 sq ft
    c. 20.4 gal per acre
    d. 40.8 gal per acre

30. The label application rate is 1 quart product per acre. You need to treat 30,000 square feet with this product. How much product do you need?
    a. 22 ounces
    b. 11 pints
    c. 1.5 ounces
    d. 2.75 pints

31. Herbicide vapor drift occurs most commonly when:
    a. air temperature is high
    b. air temperature is low
    c. relative humidity is low
    d. air temperature is high and relative humidity is low

32. Which is the most common symptom of damage by growth regulator herbicides?
    a. "burning" of plant leaves
    b. stubby root tips
    c. yellowing or chlorosis between leaf veins
    d. cupping of leaves and twisting of stems

33. The development of herbicide-resistant weeds can be prevented or delayed by:
    a. integrating weed control methods, such as mechanical, chemical, and cultural control
    b. repeated use of the same herbicide mode of action to ensure a complete weed kill
    c. increasing the herbicide rate when weed control is poor
    d. allowing a few weeds to produce seed each year after herbicide application

34. Surface water can be protected from herbicide contamination by:
    a. choosing herbicides and formulations carefully
    b. avoiding sprays right next to the water's edge
    c. triple-rinsing used spray containers prior to disposal
    d. all of the above

Practice test answers

1. a	8. c	15. c	22. d	29. b
2. c	9. a	16. c	23. a	30. a
3. b	10. c	17. d	24. d	31. d
4. b	11. b	18. c	25. b	32. d
5. a	12. d	19. d	26. c	33. a
6. a	13. d	20. d	27. a	34. d
7. b	14. d	21. a	28. c	

To determine score based on 100%, multiply the number of your correct answers by 2.94.
State pesticide exams require 70% to pass.

THIS IS A FICTITIOUS LABEL FOR EDUCATIONAL PURPOSES ONLY!

ARCHER Herbicide

For the control of most kinds of unwanted trees and brush, as well as annual and perennial broadleaf weeds on rangeland, permanent grass pastures, Conservation Reserve Program (CRP) acres, fence rows, nonirrigation ditchbanks, roadsides, other noncrop areas, and industrial sites

Active Ingredient(s):

2,4 dichlorophenoxyacetic acid 34.4%
triclopyr: 3.5.6 trichloro-2 pyndinyloxyacetic
acid butoxyethyl ester 16.5%
Inert Ingredients 49.1%
Total 100.0%
Contains Petroleum Distillates
Acid Equivalents:
2,4-D acid - 34.4% - 2 lb/gal • triclopyr 11.9% - 1 lb/gal)

EPA Reg. No 321123 EPA Estab. No. 5-455569

Precautionary Statements

Hazards to Humans and Domestic Animals
Keep Out of Reach of Children

CAUTION PRECAUCION

Precaución al usuario: Si usted no lee inglés, no use este producto hasta que la etiqueta le haya sido explicada ampliamente.

Harmful If Swallowed, Inhaled, Or Absorbed Through Skin • Causes Eye Irritation • Prolonged Or Frequently Repeated Skin Contact May Cause Allergic Skin Reactions In Some Individuals

Avoid contact with skin, eyes, or clothing. Avoid breathing vapor. Wash thoroughly with soap and water after handling and before eating or smoking. When handling this product wear suitable eye protection and chemical resistant gloves. Remove and wash contaminated clothing before reuse.

First Aid
In case of contact: Flush skin or eyes with plenty of water. Get medical attention if irritation persists.
If swallowed: Do not induce vomiting. Call a physician or poison control center.

Environmental Hazards
This product is toxic to fish. Drift or runoff may adversely affect fish and nontarget plants. Do not apply directly to water, to areas where surface water is present, or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment washwaters.

Mixing and Loading: Most cases of groundwater contamination involving phenoxy herbicides such as 2,4-D have been associated with mixing/loading and disposal sites. Caution should be exercised when handling 2,4-D pesticides at such sites to prevent contamination of groundwater supplies. Use of closed systems for mixing or transferring this pesticide will reduce the probability of spills. Placement of the mixing/loading equipment on an impervious pad to contain spills will help prevent groundwater contamination.

Physical or Chemical Hazards
Combustible - Do not use or store near heat or open flame. Do not cut or weld container.

Directions for Use

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. Read all Directions for Use carefully before applying.

This product may not be applied to forage that is to be cut and sold for commercial purposes.

General Information
ARCHER herbicide is recommended for control of most species of unwanted woody plants, as well as annual and perennial broadleaf weeds growing on rangeland, permanent grass pastures, CRP, fence rows, nonirrigation ditchbanks, roadsides, other noncrop areas, and industrial sites.

Apply this product only as specified on this label.

Be sure that use of this product conforms to all applicable regulations.

Chemigation: Do not apply this product through any type of irrigation system.

Foliar sprays should be applied during warm weather when brush and weeds are actively growing. Application under drought conditions may provide less than desirable results. Use low spray pressures to minimize spray drift. **Apply ARCHER in a manner to avoid contacting nearby susceptible crops or other desirable plants and to avoid contaminating water intended for irrigation or domestic use. Read and follow all use precautions given on this label.**

Do not use on bentgrass. Do not use on newly seeded grasses until grass has established a good root system and is tillering.

Do not reseed pastures within a minimum of three weeks after treatment.

Do not spray pastures containing desirable broadleaf forbs, especially legumes such as clover, unless injury or loss of such plants can be tolerated. However, the stand and growth of established grasses usually is improved, particularly when rainfall is adequate and grazing is deferred.

Do not apply ARCHER directly to, or otherwise permit it to come into direct contact with cotton, grapes, tobacco, vegetable crops, citrus, flowers, fruit or ornamental trees, or other desirable broadleaf plants and do not permit spray mists containing it to drift onto them.

Grazing and Haying Restrictions
Grazing or harvesting green forage:

1) Lactating dairy animals–Two gallons/acre or less: Do not graze or harvest green forage from treated area for 14 days after treatment. Greater than 2 gallons to 4 gallons/acre: Do not graze or harvest green forage until the next growing season.

2) Other livestock–Two gallons/acre or less: No grazing restrictions. Greater than 2 gallons to 4 gallons/acre: Do not graze or harvest green forage from treated area for 14 days after treatment. Note: If less than 25% of a grazed area is treated, there is no grazing restriction.

Haying (harvesting of dried forage):

1) Lactating dairy animals–Do not harvest hay until the next growing season.
2) Other livestock–Two gallons/acre or less: Do not harvest hay for 7 days after treatment. Greater than 2 gallons to 4 gallons/acre: Do not harvest hay for 14 days after treatment.

Avoid injurious spray drift. Applications should be made only when hazards from spray drift are at a minimum. Very small quantities of spray, which may not be visible, may seriously injure susceptible plants. Do not spray when wind is blowing toward susceptible crops or ornamental plants near enough to be injured. Spray drift can be reduced by adding a spray thickening agent such as Nalco-Trol or its equivalent to the spray mixture. If a spray thickening agent is used, follow all use recommendations and precautions on the product label.

With ground broadcast equipment, drift can be reduced by keeping the spray boom as low as possible; by applying no less than 20 gallons of spray per acre; by keeping the operating spray pressures at the lower end of the manufacturer's recommended pressures for the specific nozzle type used (low-pressure nozzles are available from spray equipment manufacturers); and by spraying when the wind velocity is low (follow state regulations). Avoid calm conditions, which may be conducive to air inversions. In handgun applications, select the minimum spray pressure that will provide adequate plant coverage. The use of a mistblower is not recommended.

With aerial applications, use a drift control system. Keep spray pressures low enough to provide coarse spray droplets. Spray boom should be no longer than ¾ of the rotor length. Do not use a thickening agent with the Microfoil or the Thru-Valve booms, or other systems that cannot accommodate thick sprays. Spray only when the wind velocity is low (follow state regulations). Avoid calm conditions, which may be conducive to air inversions.

Under conditions that are conducive to evaporation (high temperatures and low humidity), vapors from this product may injure susceptible crops growing nearby. Excessive amounts of this herbicide in the soil may temporarily inhibit seed germination and plant growth.

Mixing Directions

ARCHER in water forms an emulsion (not a solution), and separation may occur unless the spray mixture is agitated continuously.

Water Spray: Fill the spray tank about half full with clean water. Then add the ARCHER and complete filling the tank with agitation running. Mix thoroughly and continue moderate agitation while spraying.

Sprayer Size (gals)	Amount of Archer Required for Spray Solution 1%	1.5%	4%
1	1⅓ fl oz	2 fl oz	5⅓ fl oz
3	4 fl oz	6 fl oz	1 pt
5	6⅔ fl oz	10 fl oz	1⅓ pt
50	2 qt	3 qt	2 gal
100	1 gal	1½ gal	4 gal

Approved Uses

Woody Plant Control

Note: For rangeland and pastures, the maximum application rate is 4 quarts per acre per application.

Easy-To-Control Species: 1.5 gal/acre broadcast application or 1 to 1.5% solutions for high-volume foliar applications.

alder	elderberry	Scotch broom
ash	hawthorn	sumac
birch	multiflora rose	white oak
blackberry	poison ivy	wild grape
Ceanothus sp.	poison oak	willow

Harder-To-Control Species: High-volume applications, 1.5% solutions, and conventional basal or dormant stem applications are recommended. A broadcast rate of 2 to 4 gal/acre will increase the degree of control of these species. See grazing restrictions when rates of application greater than 1.5 gal/acre are used.

elm (except winged elm)	Russian olive
honeylocust (suppression)	salmonberry (suppression)
pine (suppression)	trumpetcreeper (suppression)

High-volume Foliar Applications Through Handguns: Using a power or hand-pressured spray-gun, apply a foliar wetting spray containing 1 to 1.5 gallons of this product in sufficient water to make 100 gallons of total spray mix. See mixing chart under Mixing Directions for preparing small amounts of this 1 to 1.5% spray mix.

Spray to give thorough coverage of the foliage, wetting all leaves and green stems to the drip point. Depending on the plant size and foliage density, the total amount of required spray is usually 100 to 200 gallons per sprayed acre.

For best results, applications should be made when woody plants are actively growing. This is most likely to occur for a period after full leaf in the spring to early summer when moisture and temperature are favorable. For multiflora rose control, the best time for treatment may be expected during the early- to mid-flowering stage.

The required spray volume will increase substantially if the brush exceeds 5 feet in height. Brush over 8 feet tall is difficult to treat efficiently. Large brush or trees may be controlled better by basal or mechanical methods.

Foliar Broadcast Sprays (Ground Equipment and Helicopter): Apply 1.5 to 4 gallons of this product in enough water to deliver 10 to 30 gallons total spray per acre. Use a boom type or other broadcast spray equipment that provides uniform spray coverage over the top of the foliage and make applications when plants are growing well. The favorable period for treatment is most likely to occur after full leaf in the spring and continue into early summer, depending on soil moisture and other conditions. Follow-up treatment with foliar high-volume or basal type treatments may be needed, especially if treating under less favorable conditions.

Aerial Application (Helicopter Only): Use drift control additive as recommended by the manufacturer of the drift control system.

Dormant Stem Applications: To control susceptible woody species such as multiflora rose and blackberry, mix 1 to 4 gallons of this product in diesel oil, No.1 or No. 2 fuel oil, or kerosene to make 100 gallons of spray. Apply to thoroughly wet upper and lower stems including the root collar and any ground sprouts. Treat at any time when the brush is dormant and the bark is dry. Best results have been obtained with late-winter to early-spring applications. Do not treat when snow or water prevent spraying to the groundline. For the most susceptible woody species such as blackberries, substitute other diluents or oils only in accordance to manufacturer's recommendations. Apply mixture to thoroughly wet upper and lower stems as described above. The more tolerant species may require total oil carrier for better control. Brush over 8 feet in height is difficult to treat efficiently. Basal or mechanical methods may be better suited for control of large trees.

Conventional Basal Bark and Stump Applications: For control of susceptible woody plants and to prevent or control regrowth from cut stumps, mix 4 gallons of this product in diesel oil, No. 1 or No. 2 fuel oil, or kerosene to make 100 gallons of spray mixture. Spray the basal parts of brush or trees to a height of 15 to 20 inches from the ground. Thoroughly wet all the basal bark area including crown buds and ground sprouts. Spray runoff should visibly wet the ground at the base of the stems or trunks. Basal and cut stump applications can be made at any time of the year except when snow or water prevent spraying to the groundline. Best results have been obtained with winter to early-spring applications. Basal treatments are less effective on trees with diameters larger than 6 to 8 inches. For better regrowth control, cut the larger trees and treat the stumps. Treat stumps the same as the trunks and also treat the freshly cut surface. The cambium layer just inside the bark is the most important area of the cut surface to treat.

Thin-line Basal Applications: For the control of small multiflora rose, apply a horizontal thin line of undiluted herbicide across all the stems at a height where the stems are less than ½ inch in diameter and have thinner bark to penetrate. For bushes with large numbers of stems (more than 3 or 4), coverage may be difficult. Basal bark or dormant stem applications may be more effective. Treat when the bark is dry and rain is not forecast. Best time for multiflora rose control using this application method is during early spring to early summer, when the plants are just about breaking dormancy to actively growing. Apply approximately 20 ml undiluted product per bush. Wherever a stem larger than ½ inch in diameter is treated, it should be completely ringed with herbicide to obtain best results. Additional herbicide is likely to be needed for adequate coverage of these larger stems in a bush or clump.

Old stems with thickened bark require more herbicide than young stems with thin bark. Where regrowth is treated, better root kill may result if resprouts are treated after they are 1 year old and the bark has lost its green color, but before sprouts reach 1 inch in diameter.

General Weed Control (See Table)

Broadcast Treatment (Ground Equipment and Helicopter): Use up to 1.5 gallons of ARCHER per acre in enough water to deliver 10 to 30 gallons of total spray per acre. Apply when weeds are actively growing. Best time for treatment of biennial and winter annual weeds is when the plants are in the rosette stage. Treat when plants are actively growing. Retreatment of hard-to-control weeds such as field bindweed, goldenrod, horsenettle, kudzu, milkweed, perennial sowthistle, leafy spurge, and Canada thistle may be necessary. See recommendations regarding the use of drift control additives as listed in the "General Use Precautions" section under "Avoid injurious spray drift."

General Weed Control

High-Volume Foliar Treatment or Spot Treatment			
1% Solution	1% Solution	1 to 1.5% Solution	1.5% Solution
Foliar Broadcast Applications			
1 qt/acre	2 qt/acre	2 – 4 qt/acre	4 qt/acre
blueweed (B)	bedstraw, annual (A)	chickweed, mouseear (P)	bindweed, field (P) (TG)
buttercup, annual (A)	burdock (B)	dock, curly (P)	carrot, wild (B)
horseweed, marestail (A)	clover, white sweet (B)	ivy, ground (P)	goldenrod (P) (TG)
lambsquarters, common (A)	clover, bur (A)	kochia (A)	horsenettle (P)
mustard, wild (A)	cocklebur (A)	oxalis (P)	marshelder (A)
ragweed, common (A)	dogbane, hemp (P) (TG)	pennycress, field (WA)	milkweed (P), suppression
spurge, thyme-leaf (A)	lettuce, wild (A, WA)	pigweed, redroot (A)	pepperweed, perennial (P)
	mustard, tansy (WA)	plantain (P)	pokeweed (P)
	radish, wild (A)	purslane, annual (A)	sowthistle, perennial (P)
	ragwort, tansy (B)	sowthistle, annual (A)	spurge, leafy (P) (TG)
		sunflower (A)	thistle, bull (B)
		thistle, Russian (A)	thistle, Canada (P) (TG)
		vetch (P)	thistle, musk (nodding) (B)

(A) Annual (B) Biennial (WA) Winter Annual (P) Perennial
(TG) Top growth control only. Repeat treatment may be necessary.
Note: Best time for treatment of biennial and winter annuals is when plants are in the rosette stage.

Spot Treatment: To control broadleaf weeds in small areas with a hand sprayer, use 4 to 6 fl oz of ARCHER in 3 gallons of water and spray to thoroughly wet all foliage.
Use in Liquid Nitrogen Fertilizer: ARCHER may be combined with liquid nitrogen fertilizer suitable for foliar application to accomplish weeding and feeding of grass pastures in one operation. Use ARCHER in accordance with recommendations for grass pastures as given on this label. Test for mixing compatibility using desired procedure and spray mix proportions in clear glass jar before mixing in spray tank. A compatibility aid such as Unite or Compex may be needed. Premixing ARCHER with 1 to 4 parts water may help in difficult situations.

Storage and Disposal
Do not contaminate water, food, or feed by storage or disposal.
Storage: Store above 10°F or agitate before use.
Pesticide Disposal: Pesticide wastes are toxic. Improper disposal of excess pesticide, spray mixture, or rinsate is a violation of Federal law and may contaminate groundwater. If these wastes cannot be disposed of by user according to label instructions, contact your State Pesticide or Environmental Control Agency, or the Hazardous Waste representative at the nearest EPA Regional Office for guidance.
Plastic Container Disposal: Do not reuse container. Triple rinse (or equivalent). Puncture and dispose of in a sanitary landfill, or by incineration, or if allowed by state and local authorities by burning. If burned, stay out of smoke. Consult federal, state, or local disposal authorities for approved alternative procedures.
Metal Container Disposal: Do not reuse container. Triple rinse (or equivalent). Puncture and dispose of in a sanitary landfill, or by other procedures approved by state and local authorities. Consult federal, state, or local disposal authorities for approved alternative procedures.

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Glossary

Absorption. The act of taking in and incorporating.

Acid equivalent (ae). The amount of herbicide in a formulation, when measured in its acid form, that is principally responsible for the herbicidal effects and is shown in the active ingredient statement on the herbicide label.

Active ingredient (ai). The chemical(s) in a formulated product that is (are) principally responsible for the herbicidal effects and is (are) shown as active ingredient(s) on herbicide labels.

Adjuvant. Any substance in an herbicide formulation or added to the spray solution that enhances the herbicide's effectiveness.

Adsorption. Adherence of a substance to a surface.

Agitate. To keep a mixture stirred up.

Alkaline. Containing sodium and potassium carbonate salts. (Calcareous: containing excess calcium, usually in the form of the compound calcium carbonate.)

Allelopathy. Suppression of plant growth by a toxin released from a nearby plant.

Annual. A plant that completes its life cycle from seed within 1 year.

Aquatic plant. A plant, including algae, that grows in water or water-saturated soil. There are three types: submergent plants grow beneath the surface; emergent plants have roots below the surface and the leaves and stems above the water; and floating plants.

Axil. The area between the upper side of a leaf or stem and the supporting stem or branch.

Band or row application. An application to a continuous restricted area, such as in or along a crop row, rather than over the entire field.

Band treatment. An application to a strip extending from a few inches up to a few feet on each side of an obstacle.

Basal treatment. A treatment applied to the stems of woody plants at and just above the ground.

Biennial. A plant that completes its life cycle in 2 years. The first year the seed germinates, and the plant produces leaves and roots and stores food. The second year it flowers and produces fruits and seeds.

Biological control. Controlling a pest with existing or introduced natural enemies.

Broadcast application. A uniform application over an entire area.

Broadleaf plants. Botanically classified as dicotyledons. Plants have two cotyledon leaves in the seedling stage; true leaves usually are broad and have reticulate (netlike) veins.

Brush control. Control of woody plants.

Cambium. Area just beneath the bark of woody plants; contains the conductive tissues (xylem and phloem).

Carrier or diluent. A gas, liquid, or solid substance used to dilute, propel, or suspend an herbicide during its application.

Chlorosis. An abnormal condition in plants in which the green parts lose their color or turn yellow.

Compatible. Herbicides that can be mixed in a spray tank for application together in the same carrier without reducing the activity of either herbicide.

Concentration. The amount of active ingredient or acid equivalent of an herbicide in a given quantity of the formulation; expressed as percent or lb ai/gal.

Contact herbicide. An herbicide that is phytotoxic or kills by contact with plant tissue rather than as a result of translocation.

Contaminate. To alter or render a material unfit by allowing a pesticide to come into contact with it.

Control. In general, reduction of a weed problem to the extent that it does not cause economic damage. According to the noxious weed law, the prevention of seed production.

Cut-surface application. Treatment applied to frills or girdles made through the bark into the wood of a tree.

Defoliant. A substance or mixture of substances used primarily to cause the leaves or foliage to drop from a plant.

Degradation. The process by which a chemical is decomposed or broken down into nontoxic compounds or elements.

Desiccant. Any substance or mixture of substances used to accelerate the drying of plant tissue.

Dicotyledon (dicot). A plant that has two seed leaves or cotyledons; broadleaf plant.

Directed application. Precise application to a specific area or plant part such as to a row or bed or to the lower leaves and stems of plants.

Dose (rate). The terms are the same; however, rate is preferred. Refers to the amount of active ingredient applied to a unit area regardless of percentage of chemical in the carrier.

Drift. The movement of airborne particles or vapors away from the intended target area.

Dry flowable (DF). Formulation made of finely ground herbicide particles compressed into granules that can be suspended readily in water for application.

Efficacy. How well an herbicide application works to control the target plants.

Emergence. The act of germinating seedlings breaking through the soil surface.

Emulsifiable concentrate (EC). A concentrated herbicide formulation containing organic solvents and emulsifiers to facilitate mixing with water.

Epinasty. More rapid growth on the upper surface of a plant part (especially leaves), causing the plant part to bend downward.

Eradication. The elimination of all live plant parts and seeds of a weed from a site.

Flowable (F). Formulation made of finely ground herbicide particles that are suspended in a liquid, which then is diluted with water for application.

Foliar application. Directing a pesticide to plant leaves or foliage.

Formulation. A mixture containing the active ingredient of an herbicide and other additives required for easy mixing and application.

GPA. Gallons per acre.

GPM. Gallons per minute.

Granule or granular (G). A dry formulation of herbicide in which the active ingredient is impregnated on small particles of carrier such as clay or ground corncobs. Applied in the dry form.

Grass. Botanically, any plant of the Poaceae family. Grasses are characterized by narrow leaves with parallel veins; by leaves composed of blade, sheath, and ligule; by jointed stems and fibrous roots; and by inconspicuous flowers usually arranged in spikelets.

Hazard. The potential for injury or detrimental effects to result if a substance is not used properly.

Herbaceous plant. A vascular plant that does not develop persistent aboveground woody tissue.

Herbicide. A chemical used to kill plants or severely interrupt their normal growth processes.

Hormone. A naturally occurring substance in plants that controls growth or other physiological processes. Also refers to synthetic chemicals that regulate or affect growth activity.

Incorporate into soil. To mix an herbicide into the soil, generally by mechanical means.

Inert ingredient. That part of a formulation without toxic or killing properties, sometimes called the carrier.

Inhibit. To hold in check or stop.

Integrated control. Decision-based approaches for pest control using pesticides when necessary and at appropriate rates.

Lateral movement. Chemical movement in a plant or in the soil to the side, or horizontal movement in the roots or soil layer.

Leaching. The downward movement of a substance in solution through the soil.
Mode of action. How an herbicide works to kill a plant or to prevent or stop plant growth.
Monocotyledon (monocot). A seed plant having a single cotyledon or seed leaf; includes grasses, sedges, and lilies.
Necrosis. Death of tissue.
Nonselective herbicide. A chemical that generally is toxic to plants without regard to species.
Noxious weed. A weed specified by law as being especially undesirable, troublesome, and difficult to control.
Penetrant. An adjuvant that helps a liquid enter a leaf.
Perennial. A plant that lives for more than 2 years.
Pesticide. Any substance or mixture of substances that controls or kills insects, rodents, weeds, fungi, and other pests.
Phloem. Vascular system in plants that transports sugars.
Photosynthesis. Plant process that converts carbon dioxide and water into sugar, using energy from sunlight.
Phytotoxic. Injurious or toxic to plants.
Postemergence. After emergence of the specified weed or planted crop.
Postharvest. After crops have been harvested.
Preemergence. Prior to the emergence of the specified weed or planted crop.
Preemergence incorporated. An herbicide that is applied after seeding and is incorporated into the soil above the crop seed.
Preplant application. Applied to the soil or weeds before seeding or transplanting.
Preplant incorporated. An herbicide that is applied and tilled into the soil before seeding or transplanting.
psi. Pounds per square inch.
Rate. The amount of product, active ingredient, or acid equivalent applied per unit area.
Registered. Approved for use in Oregon by the Environmental Protection Agency and Oregon Department of Agriculture.
Residual. To have continued killing effect over a period of time.
Resistant. Acquired trait that allows a plant to survive herbicide treatment that typically controls that species. Survival is not due to stress conditions or application rate, timing, or method.
Rhizome. Underground rootlike stem that produces roots and leafy shoots.
Rosette. Basal or early leaves of a plant, before bolting.
Rush. Monocotyledonous, grasslike plant common in marshy or wet areas. Rushes have cylindrical stems that often are hollow and grow in dense clumps.
Sedge. Grasslike plant with triangular stems and spiked inflorescence.
Seedling stage. Early stage of plant growth, within a few days to a few weeks after seed germination and emergence.
Selective herbicide. A chemical that is toxic to some plant species and not to others (may be a function of rate, mode of application, or plant physiology).
Soil application. Applied primarily to the soil surface rather than to vegetation.
Soil injection. Placement of an herbicide beneath the soil surface with minimal mixing or stirring of the soil using an injection blade, shank, knife, or tine.
Soil persistence. The length of time that an herbicide remains effective in the soil.
Soil-residual. An herbicide that prevents the growth of plants when present in the soil. Soil-residual effects may be short- or long-term.
Soil sterilant. See Soil residual.
Solubility. The extent to which an herbicide will dissolve in a given amount of liquid.
Solvent. A liquid such as water or oil used to dissolve other material such as herbicides.
Spot treatment. Application to a localized area.
Spray drift. The movement of airborne spray particles from the intended area of application.
Spreading agent. A substance to improve wetting, spreading, or the adhesive properties of a spray.
Stolon. Aboveground runners or slender stems that develop roots, shoots, and new plants at tips or nodes.

Stunting. Retarded growth and development.

Suppression. Reduction of a weed population, but not elimination.

Surface tension. Surface molecular forces that cause a drop of liquid to ball up rather than spread as a film.

Surfactant. A material that favors or improves the emulsifying, dispersing, spreading, wetting, or other surface-modifying properties of liquids.

Susceptible. A plant that is injured or killed because it is unable to tolerate herbicide treatment.

Suspension. Liquid containing dispersed, finely divided particles.

Synergism. Complementary action of different chemicals such that the total effect is greater than the sum of the independent effects.

Systemic. A compound that moves freely within a plant; application to one area results in movement to all plant areas.

Tolerant. A plant species that normally survives herbicide treatment without injury.

Translocated herbicide. An herbicide that moves within a plant. Translocated herbicides may be either phloem-mobile or xylem-mobile. The term most frequently refers to herbicides that are moved in the phloem.

Translocation. Transfer of sugars or other materials such as 2,4-D from one part to another in plants (see Systemic).

Vapor drift. The movement of chemical vapors from the area of application.

Volatile. A compound that evaporates or vaporizes (changes from liquid to a gas) at ordinary temperatures when exposed to air.

Weed. A plant growing where it is not desired. Any plant that is a nuisance, hazard, or causes injury to humans, animals, or crops.

Wettable powder (WP). A finely ground, dry herbicide formulation that can be suspended readily in water.

Wetting agent. An adjuvant that reduces interfacial tensions and causes spray solutions or suspensions to make better contact with treated surfaces.

Xylem. Vascular system in plants that transports water and nutrients.

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Gangstad, E.O. (ed.). 1982. *Weed Control Methods for Rights-of-way Management.* CRC Press, Inc. 362 pp.

Mallory-Smith, C., D. Thill, and D. Morishita. 2002 (revised). *Herbicide-resistant Weeds and Their Management* (PNW 437). University of Idaho.*

Roberts, H.A. (ed.). 1982. *Weed Control Handbook: Principles.* Issued by the British Crop Protection Council. Blackwell Scientific Publications. 533 pp.

For specific information on herbicide use in particular cropping, noncropland, and range management systems, consult:

PNW Weed Management Handbook (revised annually). Oregon State University, Washington State University, and University of Idaho.*

For specific information on weed identification in the Pacific Northwest consult:

Colquhoun, J. 2003. *Pacific Northwest's Least Wanted List: Invasive Weed Identification and Management* (EC 1563). Oregon State University.*

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Whitson, T.D. (ed.). 2001 (revised). *Weeds of the West.* Western Society of Weed Science. University of Wyoming. 644 pp.*

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*Available from the Oregon State University Extension Service at:

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Appendix. Oregon's Noxious Weeds, 2007

(Reference material only, not covered on exam)

Oregon Department of Agriculture
Noxious Weed Control Program

Oregon Department of Agriculture
Noxious Weed Classification System

This policy is available online at oregon.gov/ODA/

Noxious Weed Control Rating System

Noxious weeds, for the purpose of this system, shall be designated "A" or "B" and may be given the additional designation of "T" according to the ODA Noxious Weed Rating System.

- **"A" designated weed**—a weed of known economic importance which occurs in the state in small enough infestations to make eradication/containment possible; or is not known to occur, but its presence in neighboring states make future occurrence in Oregon seem imminent (Table A1, page 95). Recommended Action: Infestations are subject to intensive control when and where found.

- **"B" designated weed**—a weed of economic importance which is regionally abundant, but which may have limited distribution in some counties (Table A2, pages 96–97). Where implementation of a fully integrated statewide management plan is not feasible, biological control shall be the main control approach ("B" weeds targeted for biological control are identified with an asterisk). Recommended Action: Limited to intensive control at the state or county level as determined on a case-by-case basis.

- **"T" designated weed**—a priority noxious weed designated by the Oregon State Weed Board as a target on which the Oregon Department of Agriculture will develop and implement a statewide management plan. "T" designated noxious weeds are species selected from either the "A" or "B" list (Table A3, page 98).

Table A1. "A"-designated weeds as determined by the Oregon Department of Agriculture.

Common name	Scientific name
African rue	*Peganum harmala*
Camelthorn	*Alhagi pseudalhagi*
Coltsfoot	*Tussilago farfara*
Cordgrass	
Common	*Spartina anglica*
Dense-flowered	*Spartina densiflora*
Saltmeadow	*Spartina patens*
Smooth	*Spartina alterniflora*
European water chestnut	*Trapa natans*
Giant hogweed	*Heracleum mantegazzianum*
Goatgrass	
Barbed	*Aegilops triuncialis*
Ovate	*Aegilops ovata*
Hawkweeds	
King-devil	*Hieracium piloselloides*
Meadow	*Hieracium pratense*
Mouse-ear	*Hieracium pilosella*
Orange	*Hieracium aurantiacum*
Yellow	*Hieracium floribundum*
Hydrilla	*Hydrilla verticillata*
Kudzu	*Pueraria lobata*
Matgrass	*Nardus stricta*
Paterson's curse	*Echium plantagineum*
Purple nutsedge	*Cyperus rotundus*
Silverleaf nightshade	*Solanum elaeagnifolium*
Skeletonleaf bursage	*Ambrosia tomentosa*
Squarrose knapweed	*Centaurea virgata*
Starthistle	
Iberian	*Centaurea iberica*
Purple	*Centaurea calcitrapa*
Syrian bean-caper	*Zygophyllum fabago*
Texas blueweed	*Helianthus ciliaris*
Thistle	
Plumeless	*Carduus acanthoides*
Smooth distaff	*Carthamus baeticus*
Woolly distaff	*Carthamus lanatus*
Yellow floating heart	*Nymphoides peltata*

Table A2. "B"-designated weeds as determined by the Oregon Department of Agriculture (* indicates targeted for biological control).

Common name	Scientific name
Austrian peaweed (Swainsonpea)	*Sphaerophysa salsula*
Bearded creeper (common crupina)	*Crupina vulgaris*
Biddy-biddy	*Acaena novae-zelandiae*
Broom	
*French	*Genista monspessulana*
Portuguese	*Cytisus striatus*
*Scotch	*Cytisus scoparius*
Spanish	*Spartium junceum*
Buffalobur	*Solanum rostratum*
Butterfly bush	*Buddleja davidii (B. variabilis)*
Common bugloss	*Anchusa officinalis*
Creeping yellow cress	*Rorippa sylvestris*
Cutleaf teasel	*Dipsacus laciniatus*
Dodder	*Cuscuta* spp.
Dyers woad	*Isatis tinctoria*
English ivy	*Hedera helix (H. hibernica)*
Eurasian watermilfoil	*Myriophyllum spicatum*
False brome	*Brachypodium sylvaticum*
*Field bindweed	*Convolvulus arvensis*
Garlic mustard	*Alliaria petiolata*
Giant horsetail	*Equisetum telmateia*
*Gorse	*Ulex europaeus*
Halogeton	*Halogeton glomeratus*
Himalayan blackberry	*Rubus discolor (R. procerus* and *R. armeniacus)*
Houndstongue	*Cynoglossum officinale*
Johnsongrass	*Sorghum halepense*
Jointed goatgrass	*Aegilops cylindrica*
Jubata grass	*Cortaderia jubata*
Knapweeds	
*Diffuse	*Centaurea diffusa*
*Meadow	*Centaurea pratensis (C. jacea x C. nigra)*
*Russian	*Acroptilon repens*
*Spotted	*Centaurea maculosa (C. stoebe)*
Knotweeds	
Giant	*Polygonum sachalinense*
Himalayan	*Polygonum polystachyum*
Japanese (fleece flower)	*Polygonum cuspidatum (Fallopia japonica)*
Kochia	*Kochia scoparia*
*Mediterranean sage	*Salvia aethiopis*
Medusahead rye	*Taeniatherum caput-medusae*
Old man's beard	*Clematis vitalba*

continued on page 97

Table A2—continued. "B"-designated weeds as determined by the Oregon Department of Agriculture (* indicates targeted for biological control).

Common name	Scientific name
Parrots feather	*Myriophyllum aquaticum*
Perennial peavine	*Lathyrus latifolius*
Perennial pepperweed	*Lepidium latifolium*
Poison hemlock	*Conium maculatum*
Policeman's helmet	*Impatiens glandulifera*
*Puncturevine	*Tribulus terrestris*
*Purple loosestrife	*Lythrum salicaria*
Quackgrass	*Agropyron repens*
Ragweed	*Ambrosia artemisiifolia*
*Rush skeletonweed	*Chondrilla juncea*
*Saltcedar	*Tamarix ramosissima*
Small broomrape	*Orobanche minor*
South American waterweed (Elodea)	*Egeria (Elodea) densa*
Spikeweed	*Memizonia pungens*
Spiny cocklebur	*Xanthium spinosum*
Spurge	
*Leafy	*Euphorbia esula*
Myrtle	*Euphorbia myrsinites*
*St. Johnswort (Klamath weed)	*Hypericum perforatum*
Sulfur cinquefoil	*Potentilla recta*
*Tansy ragwort	*Senecio jacobaea*
Thistles	
*Bull	*Cirsium vulgare*
*Canada	*Cirsium arvense*
*Italian	*Carduus pycnocephalus*
*Milk	*Silybum marianum*
*Musk	*Carduus nutans*
Scotch	*Onopordum acanthium*
*Slender-flowered	*Carduus tenuiflorus*
Toadflax	
*Dalmatian	*Linaria dalmatica (L. genista)*
*Yellow	*Linaria vulgaris*
Velvetleaf	*Abutilon theophrasti*
Whitetop	
Hairy	*Lepidium pubescens*
Lens-podded	*Lepidium chalepensis*
Whitetop (hoary cress)	*Lepidium draba*
Yellow nutsedge	*Cyperus esculentus*
Yellow flag iris	*Iris pseudacorus*
*Yellow starthistle	*Centaurea solstitialis*

Table A3. "T" or target weeds designated by the Oregon Department of Agriculture.

The Oregon Department of Agriculture annually develops a target list of weed species that will be the focus of prevention and control by the Weed Control Program, sanctioned by the Oregon State Weed Board. Because of the economic threat to the state of Oregon, action against these weeds will receive priority.

Common name	Scientific name
Barbed goatgrass	*Aegilops triuncialis*
Common bugloss	*Anchusa officinalis*
Cordgrass	
Common	*Spartina anglica*
Dense-flowered	*Spartina densiflora*
Saltmeadow	*Spartina patens*
Smooth	*Spartina alterniflora*
Garlic mustard	*Alliaria petiolata*
Giant hogweed	*Heracleum mantegazzianum*
Gorse	*Ulex europaeus*
Hawkweeds	
Meadow	*Hieracium pratense*
Orange	*Hieracium aurantiacum*
Yellow	*Hieracium floribundum*
Knapweed	
Spotted	*Centaurea maculosa (C. stoebe)*
Squarrose	*Centaurea virgata*
Knotweeds	
Giant	*Polygonum sachalinense*
Himalayan	*Polygonum polystachyum*
Japanese (fleece flower)	*Polygonum cuspidatum (Fallopia japonica)*
Kudzu	*Pueraria lobata*
Leafy spurge	*Euphorbia esula*
Paterson's curse	*Echium plantagineum*
Portuguese broom	*Cytisus striatus*
Purple loosestrife	*Lythrum salicaria*
Rush skeletonweed	*Chondrilla juncea*
Starthistle	
Iberian	*Centaurea iberica*
Purple	*Centaurea calcitrapa*
Yellow	*Centaurea solstitialis*
Tansy ragwort	*Senecio jacobaea*
Woolly distaff thistle	*Carthamus lanatus*

For information on these or other noxious weeds, consult *Weeds of the West*, available through the Oregon State University Extension Service (see page 93).

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