Category 906
RIGHTS-OF-WAY VEGETATION MANAGEMENT

UNIVERSITY OF WYOMING EXTENSION CATEGORY906

UNIVERSITY of WYOMING
EXTENSION

Preface

Wyoming Department of Agriculture Commercial Applicator Category 906 Rights-of-Way Vegetation Management covers basic information weed classification and biology, and management principles used for controlling vegetation along roadsides, railways, powerlines, ditchbanks, industrial sites (airports, industrial parks, large parking areas), and other rights-of-way. 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 Category 906 Rights-of-Way Vegetation Control.

In order to be fully licensed in Category 906, you will need to pass the the Wyoming CORE Manual exam (including materials covering the Wyoming state statutues chapters 21 and 28), and this manual exam. If you intentionaly apply pesticides beyond the boundaries of a ROW you may also need to pass the exam for Category 903A Agricultural Weeds. Testing is proctored by employees located the University of Wyoming County Extension Offices. Locations and telephone numbers of each office can be found in Appendix F of the Wyoming CORE Manual.

Rights-of-Way Vegetation Management will help you master the basic concepts of chemical vegetation management and learn the language on herbicide labels. This manual does not give recommendations on pesticide use; other reference and technical materials are available for specific pest problems.

An example label is located at the end of this manual. Read the example label prior to taking the exam as there are several questions on the exam referencing this label. This label will also be available to you during the exam. All commercial exams are closed book. The state passing score is 70% or better.

The appendix lists rights-of-way herbicides by their common names and some of their associated trade names. As with any printed material, these products may become eliminated from the market place prior to our ability to release the next revision. Before you use any herbicide, read the label and make sure that the 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 spcific sites such as ditchbanks versus industrial sites or asphalt.

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Acknowledgments

The contents of this manual are adapted from:

- Use of Chemicals to Manage Roadside Vegetation. 1991. H.A. Holt. Purdue University Cooperative Extension. Modules 1-9.
- Agricultural Weed Management Principles. 1999. C.M. Boerboom, C.A. Ramsay, and B. Parker. Washington State University, EM043.
- Right-of-way Pest Control. 1988. J. Doll, N. Neher, and R. Flashinski. University of Wisconsin.
- Herbicide-Resistant Weeds and Their Management. 2008. C. Mallory-Smith, A. Hulting, D. Thill, D. Morishita, and J. Krenz. Pacific Northwest Extension Publications, PNW437.
- Herbicide Mode of Action and Injury Symptoms. 1996. J.L. Gunsolus and W.S. Curran. North Central Regional Extension Publ. 377.
- PNW Weed Management Handbook. Oregon State University, Washington State University, and University of Idaho Extension, MISC0049.

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Find more pesticide eduation information at the University of WYoming Pesticide Safety and Education Program website http://uwyoextension.org/psep. You may order copies of this and other publications from UW Extension Communications and Technology at cespubs@uwyo.edu • 307-766-2115

Contents

Introduction

Rights-of-way are distinct areas involved in common transport and include:

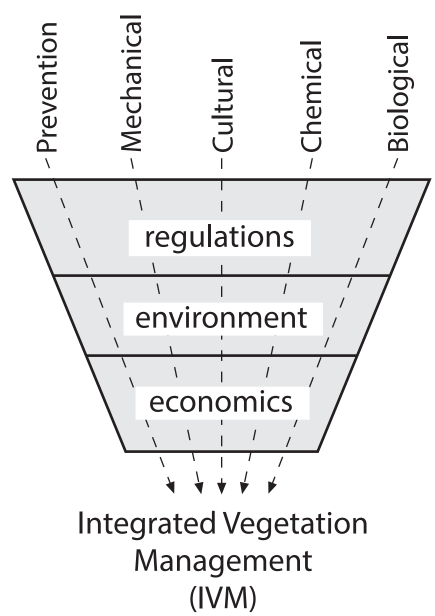
- Federal, state, and county highways and roads
- Electric utility lines (including transformer stations and substations)
- Roadside rest areas and parks
- Pipelines (including pumping stations)
- Equipment yards
- Public airports
- Railroads
- Public surface drainage ways
- Telephone and other communication networks
- Irrigation ditchbanks
- 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 by injuring us, our animals, or our environment. Some vegetation can cause safety and legal problems along our roadsides and railways by hiding signs, reducing distance visibility, and reducing areas where one can pull off the road safely. Undesirable vegetation also hinders water flow and drainage, enhances roadbed degradation, causes snowdrifts, creates a fire hazard, and increases soil erosion severity. Woody plants that grow too tall can interfere with our power supply and present shock hazards in substations and other high voltage areas. Several weeds are classified state noxious weeds and legally must be controlled. In rights-of-way management, preventing weed seed emergence is very important to achieve weed-free rights-of-way. Managers also implement corrective weed control measures to reduce the numbers of weeds already present.

Vegetation management prolongs the life of the roadway and enhances its aesthetic nature and safety 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 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 desired vegetation that you want on the site: bareground, 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 may not be wise on a particular site because of environmental concerns. Similarly, some mechanical practices may cause severe damage to certain sites. After considering all of these factors, design and implement the management plan.



The best management plans often use an integrated approach, employing more than one method for weed control. IVM (integrated vegetation management) 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 the 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 means of 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.

Basic Weed Science

Origins of Weeds

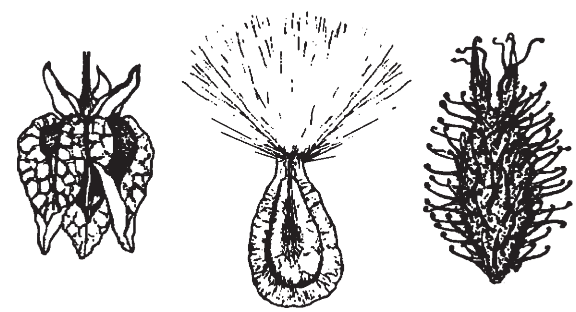
Weeds are classified as native or introduced according to their origin. Plant origin may determine weed management strategies.

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 human activities, animal movements, and water flow. For example, most of our problem weeds are plants that were inadvertently introduced through crop seed, hay, straw, and ship ballast water. Some of our problem weeds 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. Many areas often lack a weeds' natural predators or limiting factors, such as climate, to hold introduced plants in check. This lack of natural control allows adaptable weeds to flourish and spread.

Wind carries many seeds to new areas. Some weeds, such as dandelion, have a parachute-like 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, Russian thistle, and knapweeds are common examples.

Water from rain, irrigation, and surface runoff also transports 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.



Weed Seed Dissemination

How Weeds Spread

Weeds spread when seed or growing plant parts (roots, rhizomes, stems) are moved or carried into new territory. Some invading weed species have evolved special seed shapes or structures to aid their movement by wind, water, or animals. Also, many plants have vegetative parts that resprout new shoots and roots. 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. Contaminated 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.

Mammals, birds, and humans carry seeds on their bodies, dropping them into new areas. Plants have seed shapes (burs, hooks, barbs) that cling to feathers, hair, 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.

Weed Establishment and Persistence

Weeds rapidly become problems when introduced into 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.

Number of Seeds Produced Per Plant

Weed	Seeds per plant
Common mullein	223,200
Redroot pigweed	117,400
Shepherdspurse	38,500
Kochia	14,600
Wild sunflower	7,200
Canada thistle	680/stem
Wild oat	250

Source: Stevens, O.A. 1932. Amer. J. Bot. 19:784-794.

Weed seeds, depending on the species, can lie dormant in the soil for many decades. This long seed viability helps guarantee weed survival. Because weeds can produce high numbers of seed 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. You may easily recognize some of the more common weeds, but identifying new weed species is a difficult task requiring a working knowledge of plant anatomy and classification.

People and resources available to help you identify plants or weeds exist through the university and county extension systems and county noxious weed programs. Resources include plant identification keys, picture guides, pamphlets, and weed identification computer software.

One of the basic concepts to weed identification is differentiating among grass, broadleaf, or woody plants and understanding their life cycles. Proper identification will help you develop a successful management plan.

Major plant groups are designated according to structural characteristics. For instance, we generally divide weeds into three major groups: grasses, herbaceous broadleaves, and woody plants. This grouping excludes a few species, such as sedges (yellow nutsedge), ferns (bracken fern), horsetail, and scouring rush.

Grasses have only one leaf, which is narrow and upright. Leaf veins run paralled to leaf margins. Most grasses have fibrous root systems. The growing point for grass seedlings is located below the soil surface. As the plant grows and matures, the growing point gradually moves up to the soil surface. Much of roadside vegetation management is directed at establishing and maintaining healthy grass stands of desired species.

Two Major Plant Groups

Herbaceous broadleave plants have two seed leaves and die back to the ground each winter. Their leaves are usually 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 are often the target pest plants on road or rail rights-of-way since they frequently invade grass sites and bareground areas.

Woody plants form wood and do not die back during the winter. They include brush, shrubs, and trees. Woody plants are broadleaf plants with two seed leaves and a coarse root system. Woody plants have a place in the roadside landscape, but 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 cause snow drifts. Woody plants are the major problem in powerline 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. Some control methods are more effective during certain stages of the weed's life cycle. The effectiveness of a weed management plan often depends on targeting certain plant growth stages (seedling, vegetative, flower, maturity). Plants are classified by their life cycle: annuals, biennials, or perennials.

Annual plants complete their life cycle in less than 12 months. Normally annuals are the easiest weed type to control, though they are the most common in disturbed areas.

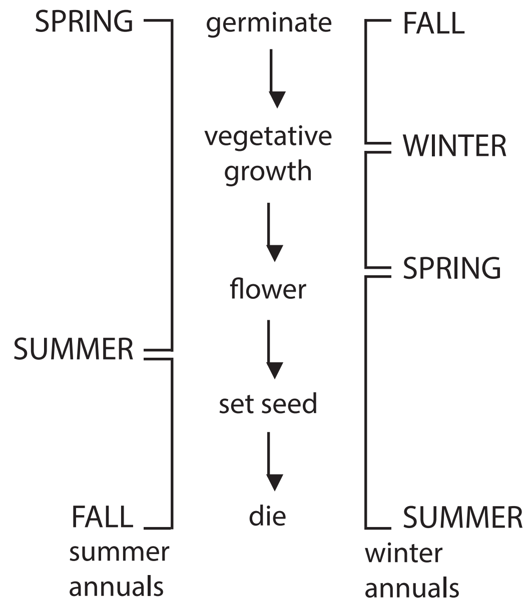
Examples of Common
Summer and Winter Annuals

Summer Annuals	Winter Annuals
Green & yellow foxtails	Tumble mustard
Pigweeds	Corn cockle
Puncturevine	Downy brome
Russian thistle	Shepherdspurse
Crabgrass	Henbit
Kochia	
Common lambsquarter	

Annuals are a continual problem because of an abundance of dormant seed, fast growth, and high seed production. They may actually 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.

<u>Summer annual</u> 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.

<u>Winter annual</u> 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 one full year. The seeds lie dormant in the soil during the summer months.



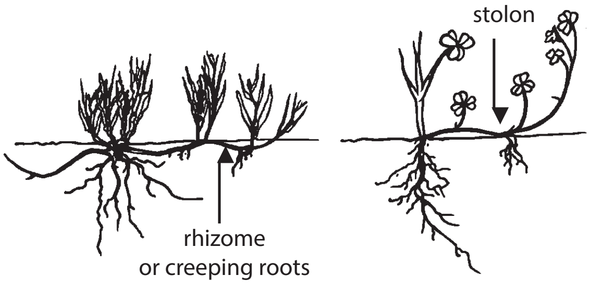
Life Cycle of Annuals

Biennial plants complete their life cycle within two years. In the first year, the plant forms basal leaves (rosette) and a tap root. 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 two calendar years and during two seasons, but they complete their life cycle in less than 12 months. Biennial weeds usually are easier to kill in their first year, but their rosette stage is easily overlooked.

Examples of Common Biennials
Musk Thistle
Scotch Thistle
Common mullein
Houdstonge
Bull thistle
Poison hemlock

Perennials live more than two years, and some may live almost indefinitely, resprouting from vegetative plant parts. Because of these persistent, resprouting roots, rhizomes, stolons, tubers, and plant fragments, perennials are difficult to control. To avoid these problem weeds, do not let perennial seedlings become established. Most reproduce by seed and many spread vegetatively as well. Perennials are classified according to how they spread: simple or creeping.



Vegetative Propagation
by Creeping Perennials

Simple perennials propagate and spread primarily by seed. They can also resprout from buds on the tap root. The roots are usually 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 propagation: creeping roots, creeping aboveground horizontal stems (stolons), or creeping belowground horizontal stems (rhizomes). They can also reproduce by seed. Canada thistle and field bindweed propagate new vegetative shoots from creeping roots. Bentgrass and ground ivy propagate new plants from stolons. Quackgrass and Johnsongrass sprout new growth from rhizomes. Yellow nutsedge also produces rhizomes, but the rhizomes end with underground tubers that sprout new plants.

Examples of Common Perennials

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

Once an area is infested, creeping perennials and woody plants are probably the most difficult to control. Control might require repeated mowing or cutting, herbicide application(s), or combinations of these management options.

Vegetation Management Strategies

Integrated Control

Integrated Vegetation Management (IVM) either stresses the control of undesirable vegetation or enhances the environment for desirable plants. Seldom will 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 proper identification. This enables you to learn about the weed's biology. Once you understand the weed's strengths and weakness, 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 rights-of-way to record desired and undesired plant species. Inventory highways, utility lines, and ditchbanks. Some rights-of-way may require up to three separate 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 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 the rate of vegetation growth (especially brush), effectiveness of your management practices, 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 indicate wet, poorly drained areas that often have standing water. St. John's wort and diffuse knapweed reflect sandy, well-drained soils. Foxtail barley or Halogeton along the pavement may indicate high salt levels. These and other responses to the environment can be useful in implementing a management program. For example, use of highly soluble soil residual herbicides around guard rails when diffuse knapweed is present may endanger both surface and groundwater sources if the soil is very sandy and water table is shallow. Reseed sites heavily infested with annual or biennial weeds to establish the dominance of perennial species once again. Select grasses and other plants that are adapted to the rainfall area where they will be grown; rainfall varies from 8 to 20 inches per year in Wyoming.

Thresholds are levels of infestation at which control practices are justified. These vary greatly in managing rights-of-way depending on the weed species present, land use, and 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 sign posts, while another may be willing to allow vegetation to grow to perhaps 2 feet before implementing control measures.

Evaluate your results after using any vegetation management practice. Know the objectives of the control program when evaluating the results. Carefully inspect the area. Note the type of vegetation that was controlled and the soil type. If an herbicide application was made, record weather conditions during and after the application. In some cases, suppression of treated vegetation is sufficient; in others, selective or total vegetation control is the goal. Allow plenty of time because some evaluations take a while, especially long-term residual herbicide 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 obtained 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 problems 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 in the site's environmental conditions. 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 with weed control, irrigation, and fertilization.

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.

- 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 seed certified free of noxious weed seeds to prevent contaminating a new planting or when overseeding an established stand.
- Inspect straw, hay, and other mulching material to assure that it does not contain highly undesirable weeds or seeds. Use certified weed-free straw.

Mechanical Control

Mechanical techniques are the oldest methods of vegetation control. These include hand-pulling, blading, grubbing, mowing, burning, flooding, mulching, and tillage.

Hand-operated tools include power weeders, string trimmers, chain saws, brushhooks, machetes, hoes, shovels, and hand-held burners. All of this equipment cuts and most is sharp. Protection for eyes, ears, legs, and feet is required when using these tools. In addition to hazards associated with manual equipment, operators are exposed to road traffic on highway rights-of-way.

Hand pulling is commonly used for small areas and where obstacles prohibit other methods. It is comparatively labor-intensive and very expensive. Some cut plants may resprout, requiring further attention.

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 operations. Brush cutting is usually done with machines that are heavier versions of grass mowers.

Cutting and mowing remove 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 the safety of nearby motorists since mowers throw rocks and other debris. Sod scalping can cause 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.

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 under favorable conditions can destroy some seed on plants and in surface litter.

Cultural Control

Vegetation management in rights-of-way can be based on ecological principles that encourage the growth and de-

> If you want to use burning in your management plan, check with local authorities or Fire Protection District. Burning may be subject to local rules.

velopment of desirable vegetation. Often we can maintain the competitive advantage of our desired species over undesired weeds by using adapted species, overseeding, fertilizing, liming (if required), and mulching.

Overseeding can fill in the stand with new plants. Fertilization encourages desirable plant cover, which in turn prevents the growth of weeds and woody plants. Liming soils changes the pH, can reduce the ability of some weeds to use the site, and favors selected desirable plants. Mulches exclude light and are particularly useful in landscape plantings.

The most effective weed control method is using plant materials to prevent weeds from establishing via competition and/or allelopathy. 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. 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, and 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 are sometimes used as competitors. They make the site attractive and prevent or slow weed invasions. However, it is important that the wildflower mix does not contain weed seeds.

Biological Control

Biological control uses living organisms (insects, animals, or pathogens) to control undesirable vegetation. Examples using insects include the Mecinus beetle to control dalmation toadflax and the Urophora wasp to control Canada thistle. Currently, the use of disease organisms to control weeds is very limited.

Biological controls always lag behind the development of the weed population. They are also very specific, and most require a long period of time for establishment and little vegetation disturbance. The inability to adequately control a variety of weeds in a timely manner on rights-of-way limits their effectiveness as a management tool. Because noxious weeds need immediate attention, biological controls are usually regional programs, of which the rights-of-way are an incidental beneficiary.

Chemical Control

Chemical methods include herbicides and plant growth regulators. 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 desirable plants on or off the rights-of-way can be injured.

Chemical control methods are usually less expensive and present less hazard to the operators and public than mechanical methods. Chemical methods can reduce the number of mowings and the need for brush cutting.

Herbicide Activity and Selectivity

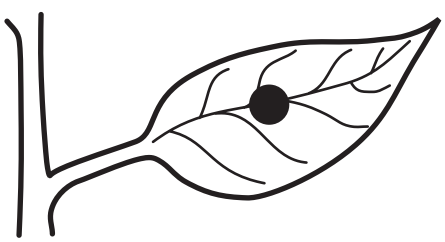
To select the best herbicide for a particular weed you must understand how herbicides:

- Enter and move in plants
- Kill or control plants
- Can be used to kill only the targeted weeds, not the desirable vegetation (selective control)

Uptake and Movement: Contact versus Translocated

Herbicides need to be absorbed by the plant and are either applied: 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 differs among plant species and herbicides. This is why some herbicides work better on certain species, while having little affect on others. Herbicides only need to kill the shoots of annual or biennial broadleaf weeds, but must move to the roots to control perennials.

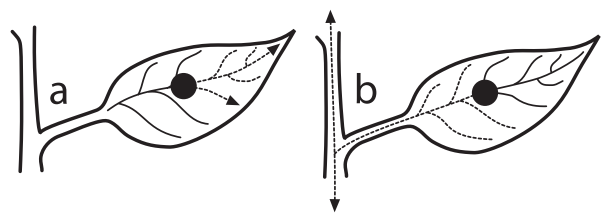
Contact herbicides are applied directly to plant foliage and only kill plant parts they directly contact. They do not move (translocate) throughout a plant. Activity is often very quick, with visible damage occurring in a few hours. You must get even herbicide distribution over the entire weed. Only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



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, paraquat, and glufosinate are examples of contact herbicides.

Translocated (systemic) herbicides are absorbed through the foliage, stem, shoots, or roots and move throughout plants. 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 is often seen first in developing tissues.



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

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. Uniform application is not as critical since the herbicide moves within the weed. Most herbicides are translocated herbicides. Some examples are glyphosate, 2,4-D, MCPA, picloram, diuron, clopyralid, and dicamba.

Selective versus Nonselective Activity

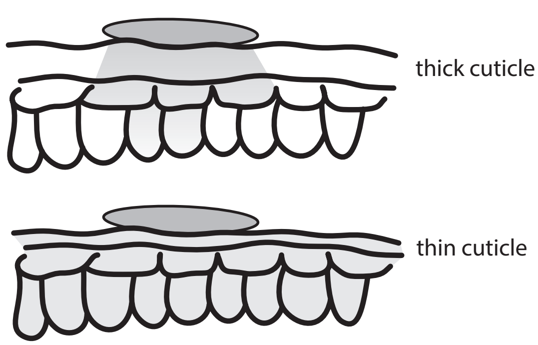
The selectivity of an herbicide refers to whether a plant is susceptible (injured or killed) or tolerant (not injured). An advantage of chemical vegetation control is that some herbicides control weeds while doing little or no damage to the desirable vegetation. These selective herbicides are commonly used in rights-of-way management. For example, use broadleaf herbicides to maintain a dense grass stand. Nonselective herbicides kill or control almost all plants, weeds as well as desirable vegetation. These are used for bareground 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, rate of application, as well as how and when applied, and under what environmental conditions. Even closely related plants may respond differently to applications of the same herbicide. Selectivity may be lost when applying herbicides to desirable plants under stress or 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. Plants with upright leaves, extremely hairy leaves, or hard-to-wet leaves (waxy leaves) are less likely to retain sprays. These differences may 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," pp. 12–13). 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.



Cuticle thickness affects herbicide penetration.

Chemical and Application Factors. Several factors affect herbicide selectivity:

- How much herbicide is applied
- The particular formulation used
- Where it is applied
- When it 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 and provides nonselective residual control at higher rates.

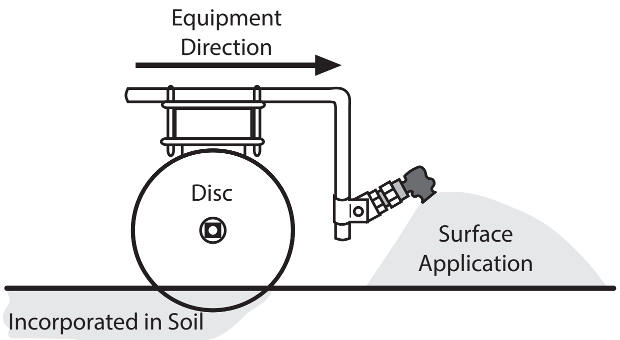
DOSE EFFECT EXAMPLE

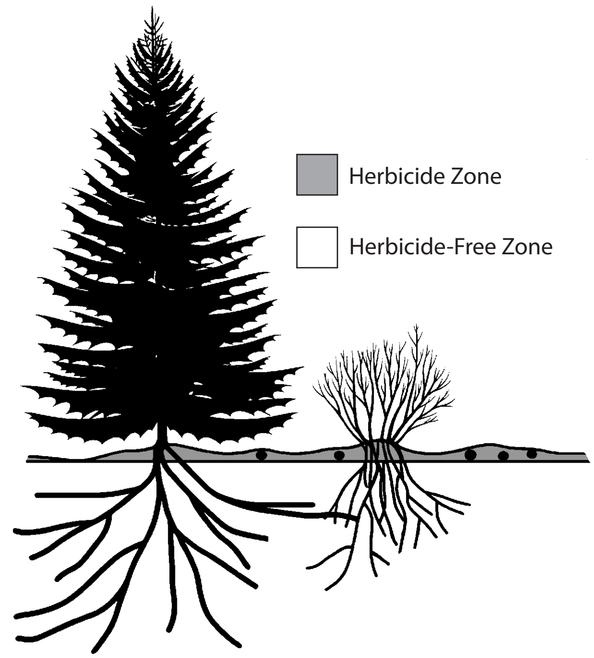
plants controlled	herbicide rate
annual broadleaf weeds	0.5 pint per acre
simple perennials	1 pint per acre
creeping perennials	1 quart per acre

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 growth stage, which 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. Preplant treatments are generally applied





to the soil and incorporated into the soil to prevent weed emergence. Depending on the herbicide, 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. Apply the herbicide after the weeds are up. This is usually a foliar application.

<u>Placement.</u> 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. Leaching may move the herbicide into the root zone of desirable plants and cause injury.

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 herbicide off desirable plant leaves.

WIPER TREATMENTS apply contact or translocated herbicides selectively to weeds. Wicks made of rope, rollers covered with carpet or other material, or absorbent pads (composed of 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.

Modes of Herbicide Action

Understanding how herbicides control weeds is useful in selecting and applying the proper herbicide. It also may be useful in recognizing herbicide injury in plants. There are seven major modes of action. Trade names are mentioned to help with recognition. (Associated common names are listed in the appendix.)

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

Growth Regulators

Chemical Family	Examples
Phenoxy acetic acids	2,4-D, MCPA
Benzoic acids	Banvel, Vanquish
Pyridine	Milestone, Transline, Tordon, Garlon

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 include stunting, yellowing (chlorosis), and purpling of leaves.

Amino Acid Synthesis Inhibitors

Chemical Family	Examples
Imidazolinones	Stalker, Arsenal
Amino acid derivatives	Roundup, Touchdown, Accord

Lipid inhibitors prevent the production of fatty acids that make cell membranes, which are 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 inhibition activity are usually cessation of growth, yellowing (chlorosis), or browning of leaves.

Lipid Inhibitors

Chemical Family	Examples
Cyclohexanediones	Select, Poast
Aryloxyphenoxypropionates	Fusilade

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.

Seedling Growth Inhibitors

Chemical Family	Examples
Dinitroanilines	Pendulum, Barricade, Surflan
Nitriles	Casoron

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 along the leaf margins and tips of older leaves first. Nitrile and benzothiadiazole herbicides do not translocate and must be applied postemergence for contact action. Symptoms include yellowing (chlorosis) and death (necrosis) of leaf tissue.

Photosynthesis Inhibitors

Chemical Family	Examples
Triazines	Princep, Pramitol
Ureas	Spike, Lorox, Karmex
Uracils	Hyvar
Nitriles	Buctril
Benzothiadiazole	Basagran

Cell membrane disrupters destroy plant tissue by rupturing plant cell membranes. These are contact herbicides having little or no mobility in the plant and 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.

Cell Membrane Disrupters

Chemical Family	Examples
Bipyridyliums	Reglone, Diquat, Gramoxone
Sulfentrazone	Portfolio
Carfentrazone	Aim, Quick Silver

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, plants turn white following treatment.

Pigment Inhibitors

Chemical Family	Examples
Pyridazinones	Solicam

Herbicide Groups

Herbicides are grouped based on their primary site of action. Currently there are 17 groups of herbicides. Herbicide labels provide information about what group a particular product belongs to. It is important to pay attention to the group classification in resistant management. To avoid selecting for herbicide-resistant weeds, do not use herbicides from the same group more than once in a three year period. Rather, rotate to a different group every year.

The table below provides a list of the herbicide groups with a few examples of their related common and trade names. For more information, look at the PNW Weed Management Handbook, MISC0049 (http://weeds.ippc.orst.edu/pnw/weeds).

Group number and site of action		Examples of common or trade names
Group 1	Acetyl CoA carboxylase (ACCase) inhibitors	Select Max, Poast, Achieve, Hoelon, Puma, Acclaim, Fusilade DX
Group 2	Acetolactate synthase (ALS) inhibitors	Raptor, Arsenal, Escort, Oust, Chopper, Telar
Group 3	Microtubule assembly inhibitors	Balan, Suflan, Pendulum, Treflan, Kerb
Group 4	Synthetic auxins	2, 4-D, MCPP, dicamba, Stinger, Garlon
Group 5	Photosystem II inhibitors	atrazine, simazine, bromacil, Basagran
Group 6	Photosystem II inhibitors (same site as groups 5 and 7 but different binding behavior)	Buctril, Bromox
Group 7	Photosystem II inhibitors (same site as groups 5 and 6 but different binding behavior)	diuron, linuron
Group 8	Lipid synthesis inhibitors but not ACCase inhibitors	Sutan, Ro-Neet, Eradicane
Group 9	EPSP synthase inhibitors	glyphosate, Roundup
Group 10	Glutamine synthase inhibitors	glufosinate, Rely, Liberty
Group 14	Inhibitors of protoporphyrinogen oxidase	Ocyfluofen, SureGuard, Aim, ET, Spartan
Group 15	Inhibitors of very long chain fatty acid synthesis	Harness, alachlor, Dual Magnum, Stalwart
Group 16	Unknown	Nortron
Group 20	Inhibitors of cell wall synthesis Site A	dichlobenil, Casoron
Group 22	Photosystem I electron diverters	diquat, paraquat, Gramoxone
Group 26	Unknown	Pelargonic acid, Avenge, Scythe
Group 28	Inhibitors of 4-hydroxy-phenyl-pyruvated-dioxygenase (4-HPPD)	Huskie, Callisto, Impact

Example:

Galeston Chemical

GROUP	6	27	HERBICIDE

BROMOX HERBICIDE

FOR CONTROL OF CERTAIN BROADLEAF WEEDS IN RIGHTS OF WAYS

ACTIVE INGREDIENT:

Bromoxynil Heptanoate........ 25%

INERT INGREDIENTS 75%

TOTAL 100%

*Protected by US Patent No. 6,420,317
Contains petroleum distillate

E.P.A. Reg. No. 333-3333

KEEP OUT OF REACH OF CHILDREN

Factors Influencing Herbicide Performance

Two major factors influence an herbicide's performance or efficacy. 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 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 environmental influences that affect herbicide performance.

Soil Factors. The following are different properties of soils and how they interact with different 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.

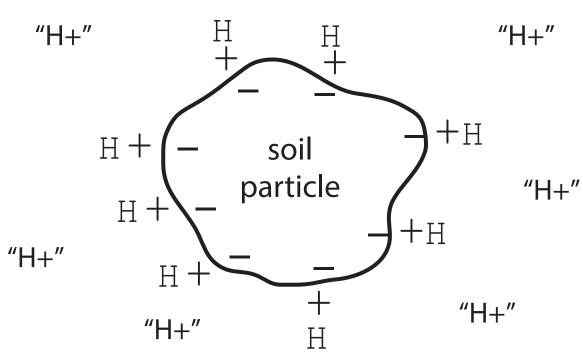
In this case, adsorption is the attraction or adhesion of herbicide molecules to the soil particle surface, a process similar to the attraction of iron filings to a magnet or lint to a nylon surface.

Herbicide molecules adsorbed to the soil are inactive. Roots can only absorb 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 are not usually bound to the soil at the same time. Some may be bound, while others are dissolved in soil water. The bound molecules can be released into the water 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 do not usually have any 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.

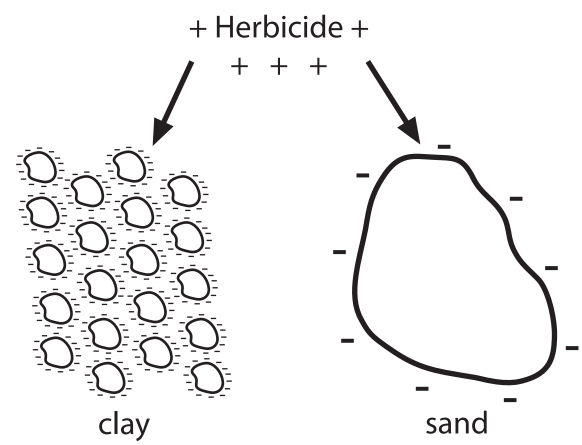
Soil texture. Texture refers to the particle size of different soils. Different soil types have different capacities to bind herbicides.

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 are generally used on sandy soils.

Silt is intermediate in surface area per given volume of soil. It has more adsorptive sites than sand but many



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



Clay has more total surface area, thus more adsorption sites compared with sand.

times fewer than clay and organic matter. Medium application rates will often be 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. Higher use rates will be 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.

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. Some herbicides readily leach through sandy soils, diluting the herbicide. Leaching can result in injury to deep-rooted plants and poor weed control. 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 is usually 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 the 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 to be available for plant uptake. 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 will soon be available. 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, 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 a 50˚F to 100˚F temperature range. The more actively a plant is growing, the easier it will be to control with herbicides.

Always read the label to see if you must monitor temperature before applying a particular herbicide. Such statements are usually 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 two or three days." High and low temperatures place stress on desirable plants that can adversely affect plant growth and the ability to tolerate the 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 during high temperatures, because volatility increases as temperature rises.

Precipitation. Rainfall occurring soon after a foliar-applied herbicide treatment may wash the chemical off and reduce control. Herbicide labels indicate the rain-free period required to prevent this. Rain moves soil-applied herbicides into the soil solution, but excess rain can leach herbicide 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.

Water-stressed weeds are less susceptible to foliar-applied herbicides than nonstressed weeds. This may be due to a thicker wax layer on the leaves or a slow-down in plant metabolism. Remember: 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 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, you will find thicker wax layers and cuticles, and faster evaporation rates.

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 onto 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 different types of weed control strategies. If chemical control does not occur during the optimum growth stage, consider changing the control method or increasing the herbicide rate (but not over the labeled rate). In general, plants are most susceptible to postemergence herbicides:

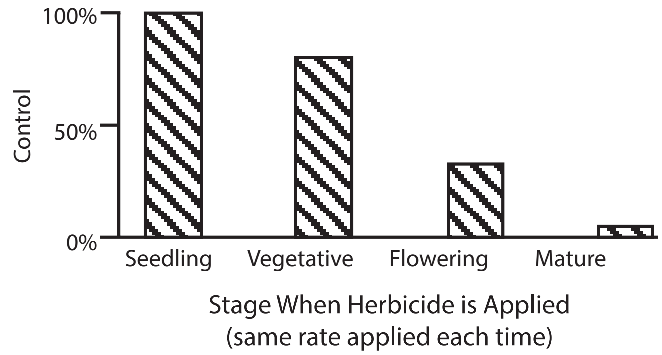
1. As seedlings when rapid growth takes place
2. In perennials once past the seedling stage, when a period of rapid growth has ended and food reserves in the roots are temporarily depleted or exhausted

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

Annual Plants

Vegetative. 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.

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.



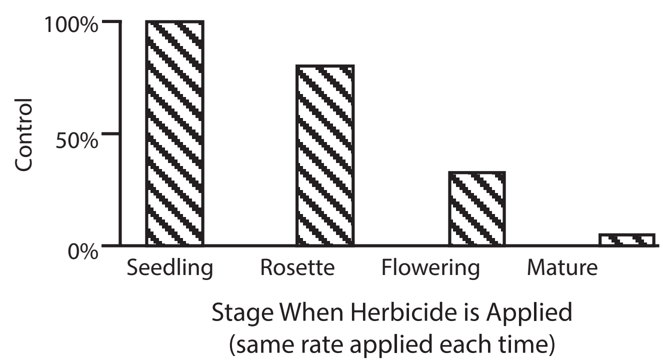
Herbicide Control of Annual Weeds

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

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

Biennial Plants

Biennials take two 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. Control of the rosette stage is second best. Control decreases as plants mature.



Herbicide Control of Biennial Weeds

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 a general rule of thumb for controlling perennial weeds. Exceptions depend on the specific weed and herbicide. For many perennial weeds, the herbicide label states the best application timing.

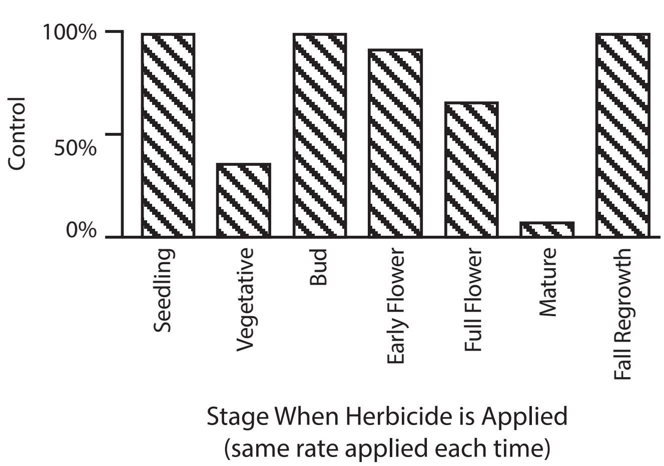
Perennials, like annuals and biennials, are easiest to control during the seedling stage. However, successful control of established perennial plants requires translocation of herbicide into the perennial plant's underground system (roots, rhizomes, tubers). Two key facts help you understand perennial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

1. 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.
2. Foliar-applied translocated herbicides move with the flow of plant sugars. Therefore, apply herbicides when the flow of sugars is downward into the roots, usually during summer and fall regrowth.

Vegetative. Chemical control is generally 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 recommendations.

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 months and send up new shoots the following spring.



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, which depends on the product you are using and the target weeds. For best control of established perennials, plan herbicide applications according to the yearly growth cycle of the specific species and 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.

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 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. Control is easier at different growth stages, depending 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 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. A July application is best for glyphosate on red alder. In general, best woody plant control occurs when the majority of the sap flow is not moving up the tree. Check label directions or PNW Weed Management Handbook, MISC0049, for recommendations.

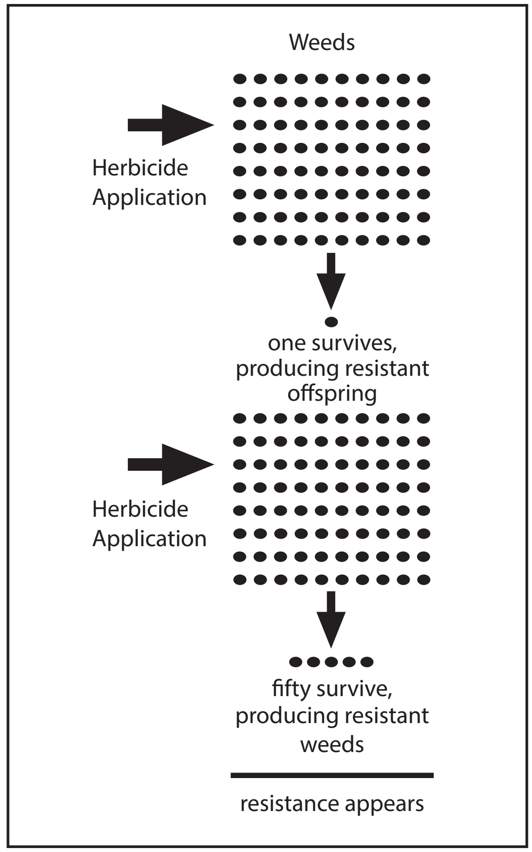
Spraying or painting the surface of a cut stump with an herbicide immediately after cutting an unwanted tree prevents the stump and roots from sprouting. For effective control, the herbicide must be placed where the tree sap flows (cambium), which is conductive tissue located near the outside rings of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

Herbicide Tolerance and Resistance

Herbicide tolerance is similar to herbicide resistance in a general sense, but the terms are distinct when used to describe specific plants and herbicides. Any plant that historically has not been affected by an herbicide is technically tolerant. For example, grasses are inherently tolerant to 2,4-D, whereas many broadleaf weeds are susceptible.

Herbicide resistance is similar to tolerance in that it describes weeds that survive herbicide application. However, resistant weeds have an evolved ability to withstand an herbicide after repeated applications. Often the resistant weed species is also resistant to other herbicides in the same herbicide family (i.e., herbicides that inhibit the same plant process). Herbicide-resistant weeds are an increasingly important problem.

Herbicide Tolerance: when a plant has historically survived a particular herbicide action
Herbicide Susceptibility: when a plant is killed by herbicide action
Herbicide Resistance: when a plant has an evolved mechanism to survive a particular herbicide action



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 other herbicides. 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 a weed population. The number of resistant individuals may be very few, perhaps only one among a million plants of that weed species.

An effective herbicide may control 999,999 plants out of a million, but that one survivor produces resistant seeds. These resistant seeds germinate and their plants produce more resistant seeds. The susceptible population of weeds is controlled by the herbicide in following seasons, but the resistant weed population continues to expand. To make matters worse, in most cases, resistant weeds can survive high rates of certain herbicides and resistance is genetically dominant (i.e., if a resistant plant and a sensitive plant cross, the offspring is resistant). Fortunately, it is usually possible to find an herbicide with a mode of action to which resistant weeds are susceptible.

The following resistance management strategies are effective for minimizing the development of herbicide-resistant weeds:

- Use other methods of weed control along with herbicides. This may 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 treat weeds effectively, do not always use herbicides with similiar modes of action. Weeds that develop resistance to sulfometuron methyl (Oust) are often resistant to imazapyr (Arsenal, Chopper, Contain), metsulfuron methyl (Escort), and chlorsulfuron (Telar) because they are in the same group (Group 2) and site of action.
- Do not 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. Higher rates 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, but in small areas, this may be extremely cheap in the long-term. If a new herbicide provides 99% control the first year, the remaining 1% probably escaped, but they might be genetically resistant. Eliminate them while they are still few in number.
- Use herbicide combinations. Herbicide combinations generally are used to increase the number of weed species controlled. 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. For example, sulfonylurea herbicides are regularly tank mixed with other herbicides with different modes of action (growth regulators, amino acid synthesis inhibitors).

Use these procedures before resistance becomes evident. Once resistance develops, large numbers of resistant seed have already entered the soil. Eliminating the resistant type one year will not solve the problem. Once you notice an herbicide-resistant weed problem, you will likely have the problem forever. You can also get assistance from your local Extension educator, herbicide supplier, or Weed and Pest District office.

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 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.

Spray 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. Spray particles smaller than 150 microns (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 (droplet classification)
- 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 gaseous form), producing fumes off the plant or soil surfaces that may cause damage. For volatile herbicides, the potential increases as temperature increases. Since stone and asphalt surfaces become much hotter than the surrounding air temperature, these sites have a higher volatility potential than plant foliage. Use of high-volatile ester formulations of 2,4-D are particularly vulnerable to volitilization and drift.

Herbicide Formulations and Hazards

Phenoxy (2,4-D, MCPA) and other growth regulator (dicamba picloram, triclopyr) herbicides are commonly used in rights-of-way vegetation management. You must consider many factors to obtain satisfactory control with them, such as weed species, herbicide formulation, 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 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 may potentially drift.

Several nonphenoxy herbicides also cause problems if they drift off-target. Sulfonylurea compounds (Oust, Telar, Escort), glyphosate, 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. Make sure you follow label directions and heed the precautionary statements regarding application.

Surface Water Protection

Everyone needs to be sensitive to the risk of water contamination. Use extra caution when applying herbicides next to open water. Runoff from treated sites can carry herbicide into waterways with the herbicide dissolved or suspended in water or adsorbed onto soil particles.

When treating next to surface water, consider using an herbicide registered for both sites. Do not spray over water or allow chemical to drift into 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 chemicals into the water source.

Runoff of chemicals is usually 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.

When filling a spray tank from an open water source, 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 when emptying them and dispose of or recycle the containers properly and according to label instructions. Never reuse a pesticide product container.

Groundwater Protection

We must prevent herbicides from leaching into groundwater to protect our water supply and future uses of the herbicide. 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, type 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 that have a known potential to leach through the soil profile have a groundwater advisory statement in the "Environmental Hazard" section of the product label. Read the precautionary statement. 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 can be injured or killed from applicators using spray equipment contaminated with herbicides from previous applications. To minimize contamination problems, consider dedicating one sprayer only for a particular use (bare ground) and another sprayer for another use (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 herbicide label. Do not allow herbicides formulated for suspensions 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 and cleaning difficult.

Soil-residual Herbicides

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 gives 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.

Soil-residual herbicides are selected and applied to achieve herbicide activity over a period of time (weeks, months, or even years). They are effective against germinating weed seeds and seedlings. These chemicals are absorbed by roots and shoots. Soil-residual herbicides vary in their solubility in water and many remain close to the soil surface.

Depending on soil type, rate of application, and herbicide, soil-residual herbicides can control weeds from several weeks to several years. 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 in the past were called "soil sterilants," but this term is misleading since they did not sterilize the soil. They do not kill fungi, bacteria, and other microorganisms as some soil fumigants do. A better term is "bareground treatments," since residual herbicides only kill plant life. At lower application rates, some of these compounds provide selective weed control. At higher application rates, they are generally nonselective. Examples of soil residual herbicides include diuron, tebuthiuron, and bromacil.

Observe the following precautions when using bareground or residual herbicides:

- Do not apply where the root systems of desirable trees or shrubbery now exist or may extend later. Desirable plant roots may grow in the zone under or near the roadway. Applicator inattention to root zones is a primary cause of damage to desirable plants.
- 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 also occur because the soil is bare.
- Prevent humans, animals, and equipment from moving soil from treated areas.

Soil Persistence

The length of time that an herbicide remains active determines the length of time you can expect weed control. Residual activity also is important because of potential injury to subsequent plantings. Several factors affect herbicide persistence in the soil.

Photodegradation. Sunlight can break down some herbicides such as napropamide and dinitroaniline compounds. 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.

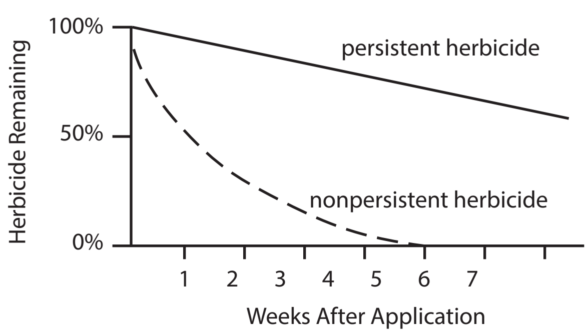
Microbial Degradation. When soil microorganisms such as bacteria and fungi use herbicides as part of their food supply, they decompose or break down the chemicals.

Some herbicides are degraded rapidly (easily used by microorganisms), whereas 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.

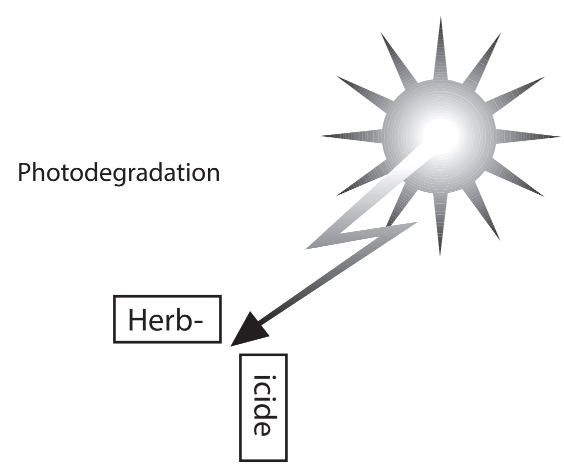
Chemical Degradation. Some herbicides break down in the soil through natural chemical reactions. Chemical degradation generally involves reactions such as oxidation, reduction, and hydrolysis and occurs most readily in warm, moist soil. Soil pH often influences the rate of chemical degradation.

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 section "Environmental Influences on Herbicide Availability," pp. 15–17.) 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 the soil-applied herbicide ineffective.



Residual Activity Comparison
of Two Herbicides



- 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 for both new or established plantings.

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.

Leaching. Herbicides may move or leach through the soil profile with water. Leaching is usually less if the soil dries out after the initial amount of moisture is used to move the chemical to the desired depth. Several factors influence leaching:
- Initial soil moisture content,
- Amount of water passing through the soil,
- Herbicide adsorption on soil particles and organic matter, and
- Solubility of the herbicide in water.

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

Volatilization. A compound is volatile when 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 means to reduce herbicide loss.

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

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

Applying Herbicides Safely and Accurately

Successful weed management relies on integrating the best weed control strategies. When management includes herbicides, select the product 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 uniformly deliver the herbicide to the target area, 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 calculations lead to either 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 or 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.

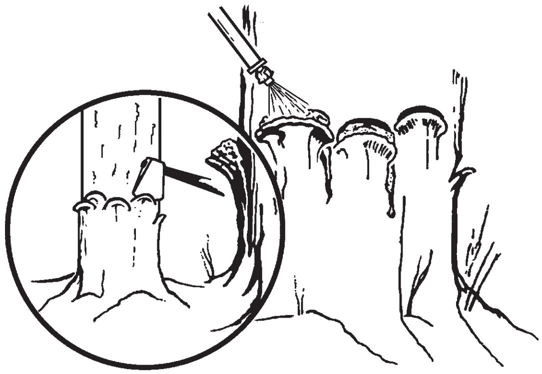
Methods of Application

The application 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 of an herbicide application is to bring the chemical into contact with the targeted weed(s).

Below are the most common ways of applying herbicides (some weed situations may require more than one method):

- <u>Preplant incorporation</u> 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 is then available to kill germinating weed seeds.
- <u>Preemergence application</u> puts herbicide directly in or on the soil before weeds or desirable vegetation emerge. It may also be a foliar application to weeds, prior to emergence of desirable vegetation.
- <u>Postemergence application</u> 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.
- <u>Broadcast treatment</u> or blanket application is a uniform treatment of an entire area. It can be made preplant, preemergence, or postemergence.
- <u>Spot treatments</u> are applied to a localized or restricted area, usually to control a small weed infestation requiring special attention.
- <u>Band treatment</u> 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 is often used with mechanical controls.
- <u>Directed sprays</u> keep herbicides off desirable vegetation. Such sprays are usually directed at or just above the ground line, treating only the lower part of the plant stem or trunk, or treating vegetation at the base of a tree.
- <u>Basal sprays</u> 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 (legumes, grapes).
- <u>Thin line</u> treatments are a modified basal-stem application of undiluted herbicide concentration 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 bark with downward ax cuts around the base of a tree. Spray the herbicide into the cambium area (growing wood area inside bark) immediately after making the cuts.



Frill Treatment

- Tree injection tools speed frill or notch treatment.
- Soil treatments can control woody plants. They require rainfall to move them 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 one 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 difficult to apply.

Notice that many of the herbicide treatments also utilize mechanical, cultural, and other control methods. The most effective weed management programs use more than a single control method. The product application method will be defined in the product label. All methods are not appropriate for all products.

Application Equipment

Application equipment choice depends on site working conditions, pesticide formulation, type of area to be treated, and possible problems. While large power-driven equipment may be desirable for some jobs, other jobs are done best by small portable or hand-held equipment. Different application equipment is needed for applying dry pesticide formulations and the pesticides in a liquid carrier (water, oil, liquid fertilizer).

Equipment for Dry Applications

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 pesticide, 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.

Equipment for Liquid Applications

Most herbicides are applied as liquids with sprayers. Sprayers vary from hand-operated units to machines with 100-foot booms. Some apply dilute herbicide mixtures, while others apply concentrates. Some apply spray through single nozzles, while others use multiple nozzles linked by sections of pipe or tubing to form a boom or spray head. The principal types of application equipment used for weed control are discussed below. Variations or combinations of this equipment also exist.

Hydraulic (liquid) sprayers make spot or broadcast treatments. The sprayer may have one or several nozzles on a boom or in a cluster. The nozzles may be permanently mounted or handheld. Hydraulic sprayers are usually powered and can be towed, self-propelled, or mounted on other equipment, including aircraft. However, for small jobs, a hand-carried compressed-air or backpack sprayer often is most effective.

A hydraulic (liquid) sprayer uses water, liquid fertilizer, oil, or a mixture of these to carry the herbicide. The herbicide is combined with enough carrier to obtain the desired application rate at a specified pressure and travel speed. The spray solution then is forced through the spraying system under pressure by either a pump or

Invert oil sprayers apply herbicide concentrate in a thick, oil-based mixture to reduce drift. Invert emulsions (invert oils) are most often applied through a hydraulic sprayer as a foliar spray.

Miscellaneous Equipment

Tree injectors precisely and directly inject herbicide into the trunks of larger brush or trees.

Wiper-type roller or rope-wick applicators apply herbicides at a set height, usually targeting weeds taller than the desirable plants.

Injection spraying systems precisely meter and inject herbicide concentrate into the water line just before the water reaches the spray outlet (boom, head). This eliminates the need to premix a tank solution. It also allows a variety of herbicides to be injected into the water line, depending on the weed species present.

Sprayer Components

Sprayer tanks must allow easy use, cleanup, and maintenance. They must be made of material that resists corrosion from various formulations. Suitable tank materials include polyethylene (do not use with ammonium phosphate solutions and complete-analysis fertilizers; ultraviolet light causes polyethylene to break down), fiberglass (may be affected by some solvents), and stainless steel. Some pesticides corrode aluminum, galvanized, and steel tanks.

Tanks should:

- Have large openings for easy filling and cleaning
- Allow straining during filling
- Allow for mechanical or hydraulic agitation
- Have a large drain
- Have a gauge to show the liquid level (protect gauges to prevent breakage)
- Have a cutoff valve for storing liquid pesticide temporarily while other parts are being serviced
- Have outlets sized to the pump capacity

Pumps must be large enough to supply the volume needed for the nozzles and to the hydraulic agitator (if necessary), and to maintain the desired pressure. The pump parts should resist corrosion and abrasion from materials such as wettable powders. Select gaskets, plunger caps, and impellers resistant to swelling and chemical breakdown caused by some liquid pesticides. Consult your dealer for available options.

Never operate a sprayer pump at speeds or pressures above those recommended by the manufacturer. Pumps can be damaged if they run dry or have a restricted inlet or outlet. Pumps depend on the spray liquid for lubrication and removal of friction heat.

Common pesticide sprayer pumps are roller, centrifugal, piston, and diaphragm. Each has unique characteristics for a particular use.

Agitators uniformly mix the components of spray mixtures and, for some formulations, keep the material in suspension. If agitation is inadequate, the actual pesticide application rate may vary as the tank empties. The two common types of agitators are hydraulic and mechanical.

Strainers filter spray mixture, protect the working parts of the spraying system, and prevent clogged nozzle tips. 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 (50 vs 100) indicates a fine screen. Place strainers on the filler opening, on the suction or supply line to the pump, between the pressure relief valve and the boom, and on the nozzle body. Clean strainers after each use. Replace damaged or deteriorated strainers.

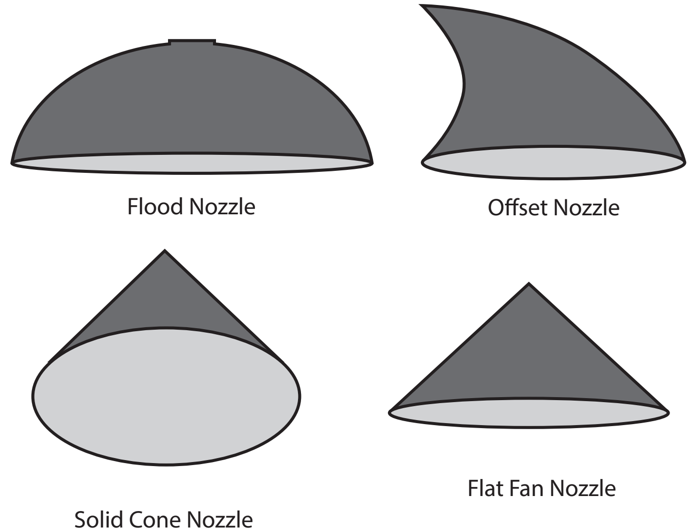
Hoses need to be weather-resistant, made of synthetic rubber or plastic, have a burst strength greater than peak operating pressures, and resist oil and solvents present in pesticides and adjuvants. Keep hoses from kinking or being rubbed. Rinse them often, inside and out, to prolong hose life. Store them out of the sun. Replace hoses at the first sign of surface deterioration. Frequently inspect all hoses and fittings and make sure hose fittings are free of leaks.

Pressure gauges monitor your spraying system. They must be accurate and have the range needed for your work. For example, a 0–100 psi gauge with 2-lb gradations is adequate for most sprayers. Check frequently for accuracy. If the gauge does not zero properly, replace it.

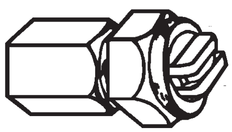
Nozzle tips break liquid into droplets, distribute spray in a predetermined pattern, and control the application rate. Nozzle performance depends on:

- Nozzle design or type
- Size of the spray tip opening (orifice)
- Operating pressure
- Discharge angle
- Spacing between nozzles
- Distance between the nozzle and target

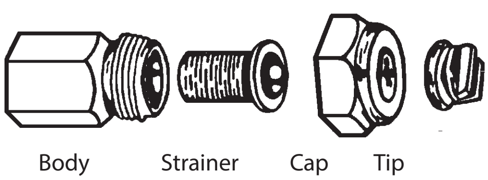
Nozzles have four major parts: body, strainer, cap (screen), and tip or orifice plate. They also may include a separate spinner plate. Successful spraying depends on correct nozzle selection, assembly, and maintenance.



Nozzle Types



Spray Nozzle



Parts of a Nozzle

The three basic nozzle patterns are solid stream, fan, and cone. Some special purpose nozzle tips or devices produce solid cone, flood, and wide angle fan or off-centered patterns. Check with the nozzle manufacturer's literature for the best nozzle for your job. Certain nozzle types may be better suited for contact herbicides because of different droplet sizes and resulting coverage.

Tungsten carbide nozzle tips and ceramic nozzles are most resistant to abrasion and corrosion but are the most expensive. Stainless steel tips resist corrosion and abrasion, especially if they are hardened stainless steel; they are moderately priced. Brass tips are less expensive than stainless steel and resist corrosion (except from fertilizers), but not abrasion. Nylon tips wear out like brass, will not corrode, but may swell when exposed to some organic solvents. Aluminum tips wear quickly, are inexpensive, and resist some corrosive materials.

Pressure regulators control the pressure, and indirectly, the quantity of spray material delivered by nozzles. They protect pump seals, hoses, and other sprayer parts from damage due to excessive pressure.

Cutoff control valves need to be located between the pressure regulator and nozzles to provide positive quick-acting on-off action. Have cutoff valves that stop all flow or flow in any section of the spraying system within easy reach of the applicator.

Spray monitors detect system errors or failure. Nozzle monitors sense the flow at each nozzle, emitting a warning buzzer or flasher with any changes. System monitors sense the operating conditions of the total spraying system, providing information such as travel speed, pressure, line flow, application rates, acres, and gallons to empty. If something goes wrong, an alarm sounds.

<u>Operating and Maintaining Sprayers</u>

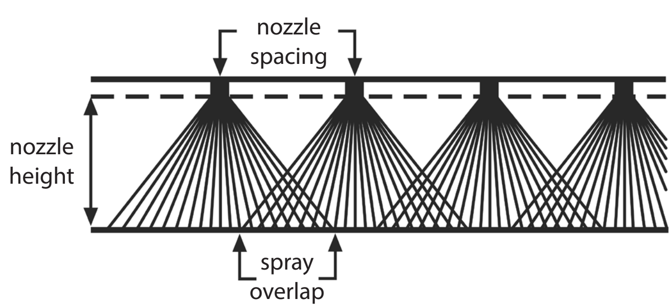
Properly operate and maintain spray equipment for safe and effective herbicide application. This significantly reduces repair costs, prolongs sprayer life, and ensures consistent weed control while minimizing chemical costs.

Before Spraying – Thoroughly rinse the sprayer with clean water. Check gauges and tank. Make sure nozzles are the appropriate type for the job and droplet size meets label requirements. If using nozzles with check valves, make sure they prevent dripping when flow to the nozzle drops below a certain pressure. Check the spraying system for leaks and output pattern.

Precalibration Check

- √ Clean system
- √ Strainers in appropriate locations
- √ Agitator works properly
- √ Nozzles are appropriate type and size
- √ Nozzle output within 10% of rating
- √ Proper nozzle alignment
- √ Correct boom height and nozzle spacing
- √ Accurate pressure gauge
- √ Speed of travel check
- √ Accurate tank volume markings

If using a boom type sprayer, make sure each nozzle output does not differ by 10% more or less the average. If it does, check screens, nozzles, hoses, etc. before changing that nozzle. If more than one nozzle varies by 10%, replace all the nozzles, because this strongly indicates excessive wear of the entire system. Also check the nozzle height, measuring the distance between the nozzle tip and target and adjust the boom accordingly. Boom height is very important in broadcast applications because it affects uniformity of the spray pattern. Check the nozzle manufacturer's recommendations for nozzle spacing, pattern overlap, alignment, and boom height above the target.



Boom Setup

Make sure the tank is level during filling so that the gauge shows the amount in the tank correctly. Know the true volume levels of your equipment. Factory sight gauges and volume markers often are incorrect, resulting in miscalibration or misapplication.

During Spraying – Frequently check the pressure gauge and speedometer or tachometer while spraying, making sure that the sprayer is operating at the same pressure and speed used when it was calibrated. Use reasonable speeds so that sprayer booms do not bounce or sway excessively. Periodically check hoses and fittings for leaks. Check nozzles for unusual patterns. If emergency repairs or adjustments are necessary, always use required personal protective equipment (PPE) as defined in the product label. Use an old toothbrush to unclog nozzles. Never use metal wire to unclog a nozzle because it may distort the nozzle opening and change the spray pattern and output.

After Spraying – Always flush the spray system, inside and out, with water after each use to prevent chemical buildup. Make the initial rinse of the inside of the tank at the application site. Apply the rinsate onto the site to reduce the buildup of wastes at the cleanup area. You will need extra water on site (saddle tank or truck).

Clean the inside and outside of the sprayer thoroughly before switching to another pesticide and before doing any maintenance or repair work. All equipment and equipment parts exposed to a pesticide normally have some residue, including sprayer pumps, tanks, hoses, and booms. Wear PPE as listed in the label and prevent skin contact with these residues.

Many herbicide labels describe specific instructions for cleaning sprayers because some tank cleaners work better with herbicides. If labels do not list specific cleaning directions, use the following guidelines:

- Flush the sprayer tank, lines, and booms thoroughly with clean water and apply the pesticide-contaminated rinsate to labeled sites or use rinsate in subsequent spray batches.
- Fill the sprayer to capacity with water, adding one cup of trisodium phosphate or household ammonia for each 10 gallons of water. If neither is available, use a strong detergent or soap. Only ammonia will remove hormone-type (2,4-D) or sulfonylurea (Oust) herbicides.
- Wash the tank and pump parts thoroughly by running the sprayer for about 5 minutes with the spray boom off.
- If possible, let the cleaning solution stand in the sprayer overnight. (Household ammonia will corrode aluminum sprayer parts.)
- Discharge the liquid from the tank, spraying some through the nozzles.
- Drain the sprayer completely and remove nozzles, screens, and strainers.
- Scrub all accessible parts with a stiff bristle brush.
- Rinse the sprayer (inside and outside) thoroughly with clean water and reassemble.

Storage of Sprayers – Clean the sprayer thoroughly before storing for a long period of time. Then add 1 to 5 gallons of lightweight emulsifiable oil (depending on the size of the tank) to an equal volume of clean water and 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.

Remove, clean, and place all nozzles and screens in a dry place to prevent corrosion. Cover the nozzle openings in the sprayer boom with tape to keep dirt out. When storing for the winter, drain water from pumps, or it may freeze and crack the pump (if not stored in a heated building). As an added precaution to protect pumps, you may pour one tablespoon of radiator rust-inhibitor antifreeze into the pump inlet. Turn the pump several revolutions to coat the internal surfaces.

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. Applying too little herbicide results in poor weed control. Application of too much may result in damage to desirable vegetation, pollution, and environmental and human health problems. 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, charts and tables cannot account for equipment wear and variations in gauges, speedometers, and plumbing. You must calibrate equipment to obtain a 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.

Before every herbicide application you must:

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

This information is provided by reading the product label, calibrating the equipment, and performing calculations.

To properly calibrate the equipment, you may need a bucket marked in gallons, a scale, a stopwatch, tools, a container marked in ounces for nozzle output, a tape measure, and flags or stakes for marking distances. Unless your equipment is new, it probably has some pesticide residue in and on the various equipment components; therefore, wear a pair of rubber gloves. In addition, a pocket calculator helps reduce mathematical errors.

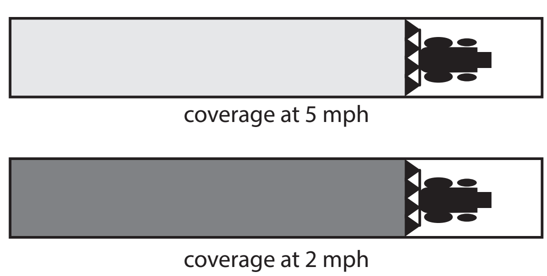
Granular Applicator Calibration

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 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 out and therefore have 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. Test speed over similar terrain conditions to the application site (soft ground, hard ground). 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). When small changes to the delivery rate are necessary, adjust travel speed.



Effects of Travel Speed On Delivery Rate

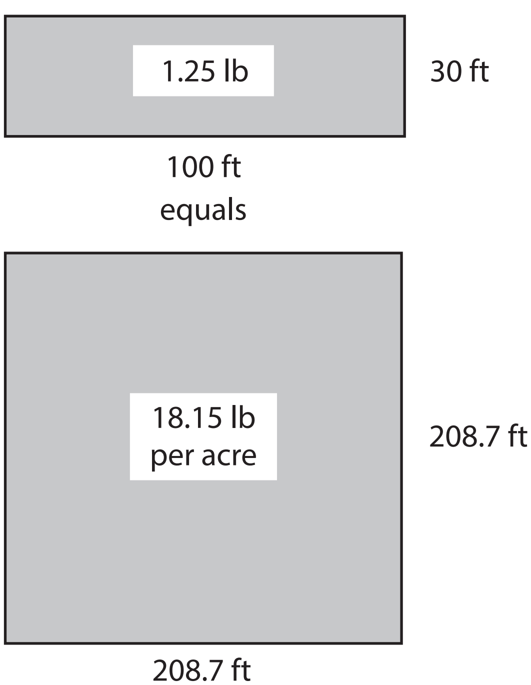
Adjust the gate opening or travel speed to fine-tune your application equipment. It may take many adjustments before the applicator is calibrated correctly.

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

1. Measure a known area (e.g., 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 the gate setting or speed for desired output.

Example

Prior to planting a new landscape at a roadside park, 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. The label states an application rate of 20 pounds of product per acre.



What is the equipment's delivery rate in pounds per acre?

- Delivery rate is the amount applied per unit area, 1.25 lb per 3,000 sq ft (100 ft x 30 ft).
- Convert 3,000 sq ft to an acre (43,560 sq ft = 1 acre). How many 3,000 sq ft units are in one acre?

  43,560 sq ft/A ÷ 3,000 sq ft = 14.52 units

  Multiply by the number of pounds of product per 3,000 sq ft unit.

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

- The rate is less than desired and needs to be increased.

<u>Sprayer Calibration</u>

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 application. Also check nozzle size, type, and pressure for delivery of proper droplet classification. Consult nozzle manufacturer's recommendations and the herbicide label.
- Thoroughly clean all nozzles, nozzle tips, and screens with 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 the spray volume output of all nozzles. Replace nozzle tips that differ by more than 10% of the average output of all nozzles. If more than one is off, replace all the nozzles.
- Check all pressure gauges. If a gauge is rusty or of questionable accuracy, replace it.

Variables that Determine Sprayer Output – Three variables affect the amount of spray solution applied per area: nozzle output, nozzle spacing or spray width, and groundspeed of the sprayer.

Nozzle output varies with the pressure and size of the nozzle tip. While increasing the pressure or using a nozzle tip with a larger orifice (opening) increases the output, it is not proportional. 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 minimize drift and deliver the correct drop size in a uniform pattern.

Effects of Sprayer Pressure on Delivery Rate (speed constant)

Sprayer Pressure (psi)	Sprayer Delivery Rate (gal/A)
10	10
40	20
160	40

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 significantly change sprayer output per acre. Nozzle manufacturers' catalogs give information for selection of 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. If spray pressure remains constant, doubling the sprayer's groundspeed will reduce the amount of spray per area by one-half.

Effects of Sprayer Speed on Delivery Rate (constant pressure)

Sprayer Speed (mph)	Sprayer Delivery Rate (gal/A)
1	40.0
2	20.0
3	13.3
4	10.0

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 sq ft).

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 desired pressure while pump is operating at normal speed and water is actually flowing through the nozzles. (Minimize off-target drift by operating at the lower end of a nozzle's pressure range.)

  With the sprayer at a constant pressure, collect spray from nozzles (in ounces) for the 34 seconds it took to cover 200 feet. The more nozzles you collect from, 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 ÷ 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). Use the following formula by average nozzle output over a 200 ft course and the nozzle spacing in inches, with 20.5 as a mathematical constant accounting for changes in volume and area measurements.

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

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

Sprayer Calibration Example

A sprayer is set up with 5 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. Two nozzles delivered 18.5 ounces and 19.5 ounces each in 17 seconds.

- Find the average nozzle output (200 ft):
  19.5 + 18.5 = 38
  38 x 2 = 76 oz in 34 seconds
  76 ÷ 2 = 38 oz per nozzle
- Measure nozzle spacing:
  20 inches
- Use this formula to calculate gallons per acre:

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

$$\frac{38 \text{ oz} \times 20.5}{20 \text{ inches}} = 39 \text{ GPA}$$

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 one 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 one acre, which is the gallon per acre output for the sprayer.

For example, a sprayer has an 8-foot swath. To cover one 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 and check all nozzles for uniform output.

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 (known as the 1in 128th calibration method) is just one of several possible methods used to calibrate hand-pressurized sprayers:

1. 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 (example: a paved parking lot).
2. Add about 2 quarts of water to a clean empty spray tank.
3. Pressurize the sprayer and spray the area within the marked square. Record the amount of time to fully cover the area. Maintain uniform operator walking speed, nozzle height, and tank pressurization. Repeat step 3, two additional times and determine the average time.
4. Refill the tank if necessary.
5. Using a container marked in ounces, point the spray nozzle into the container, pull the trigger for the same amount of time as determined in step 3.
6. 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 sq ft or 1/128 of an acre) was 36 ounces, then the sprayer is actually delivering about 36 gallons per acre.
7. Again, this 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. Mixing percent solutions is also done for 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:

- <u>Change the nozzle orifice</u>. The larger the hole in the nozzle tip, the more spray is delivered. This is usually the preferred method when making substantial changes in sprayer output.
- <u>Change the speed of the sprayer</u>. Slower speed means more spray is delivered over the area; faster speed

Equipment Adjustments Alter Delivery Rates

	to <u>Increase</u> GPA	to <u>Decrease</u> GPA
Nozzles	larger	smaller
Sprayer Speed	slower	faster
Pressure	increase	decrease

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 spray pressure affects both nozzle patterns and drift.

Injection Sprayer Calibration. The calibration of injection sprayers is done in a few steps. The entry of the calibration numbers into the computer console may be somewhat involved. 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; two 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 operations 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. 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 actual amount of product needed for the application, know the total area to be treated and read the label carefully for the proper rate. The units of application rate vary among labels and written recommendations. Most labels give the application rate in the amount of product per acre, but 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.

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/gal = lb ai
- lb ai ÷ lb ai/gal = gal product

These formulas will help you calculate the amount of product and active ingredient equivalents for dry and liquid formulations.

Following are some examples of these variations. 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/A x 16 A = 96 lb product
- 1 pound ai per acre of a 75% wettable powder (need to convert ai to amount of product)
  1 lb ai/A ÷ 0.75 lb ai/lb product = 1.33 lb product/A
  1.33 lb product/A x 16 A = 21.3 lb product
- 1 pint liquid product per acre
  1 pt/A x 16 A = 16 pints or 2 gal
- 1 pound ai per acre of a 4 pound ai per gallon emulsifiable concentrate (need to convert ai to amount of product)
  1 lb ai/A ÷ 4 lb ai/gal = 0.25 gal product/A
  0.25 gal/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.

Example
The label indicates you need a 2% concentration of an herbicide (not active ingredient). You have a 3 gallon backpack sprayer. How much herbicide do you need?

3 gal x 128 oz/gal = 384 oz of spray will be made up
2% = 0.02
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 a tank saves time and money, increases the number of weeds controlled, and delays weed resistance. 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.

You cannot tank mix if the combination of products exceeds the highest rate allowed by either herbicide label. For example, the highest labeled rate of Fusilade®DX is 1.5 pints/acre (equals 0.38 lb ai/A of fluazifop). That means tank mixing 1.5 pints/A Fusilade®DX (equals 0.38 lb ai/A of fluazifop) and 0.5 pints/A Horizon®2000 (equals 0.13 lb ai/A of fluazifop + 0.38 lb ai/A of fenox-aprop) is illegal because the combination exceeds the highest allowable rate of fluazifop, 0.38 lb ai/A. If both products were mixed at their highest allowable rate, the total amount of fluazifop would be 0.51 lb ai/A, which is greater than the legal limit.

Illegal Application of Fluazifop

1.5 pints/A Fusilade®DX	0.38 lb ai/A of fluazifop
0.5 pints/A Horizon®2000	+ 0.13 lb ai/A of fluazifop
total in tank mix	0.51 lb ai/A of fluazifop*

* This is over the legal limit of 0.38 lb ai/A.

Legal Application of Fluazifop

0.75 pints/A Fusilade®DX	0.19 lb ai/A of fluazifop
0.5 pints/A Horizon®2000	+ 0.13 lb ai/A of fluazifop
total in tank mix	0.32 lb ai/A of fluazifop*

* This is within the legal limit of 0.38 lb ai/A.

Herbicide mixtures are advantageous because they give better weed control. Many manufacturers recommend tank mixing their products with other specific products to increase the spectrum of weeds controlled and to reduce development of resistance weed populations.

Some products may be incompatible, resulting in gelatin or crystals forming in the tank mix or herbicides losing their activity. In some cases tank mixes may increase injury to desirable plants. Read the label for recommendations or concerns with tank mixing.

Prior to tank mixing products, read the label and make sure tank mixing is not prohibited. Conduct a jar test for physical compatibility. 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 may be able to 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 still effective and safe to the desirable vegetation before mixing hundreds of dollars' worth of solution.

When labels include tankmix recommendations, the manufacturer has already conducted the compatibility and performance tests.

Use the following sequence when tank mixing herbicices to reduce 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 the emulsifiable concentrates. Next, add those products that form true solutions with the carrier and finish with 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 include 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 to avoid hydrolysis of certain pesticides in alkaline water or to improve uptake through the plant cuticle. Other adjuvants include thickeners, defoaming agent, 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

1. A sprayer travels 4.5 mph, keeping pressure at 40 psi. The boom has 9 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?

A. The method using the formula

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

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

B. A method using straight math

step 1. Determine area covered:

area = swath width x course length

15 ft x 200 ft = 3,000 sq ft

step 2. Determine spray output of entire boom in gallons:

24 oz/nozzle x 9 nozzles = 216 oz

216 oz ÷ 128 oz/gal = 1.68 gal

step 3. Determine how many 3,000 sq ft units are in one acre:

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

Multiply number of units by gal spray applied per unit:

14.5 units x 1.68 gal = 24.4 GPA

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 one minute the gun delivers 3.1 gallons of spray. What is the sprayer delivery rate in gallons per acre?

A. A method using straight math

step 1. Determine total area covered per minute:

200 ft ÷ 23 sec = 8.696 ft per sec

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

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

step 2. Determine how many 5,217 sq ft units are in one acre:

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

multiply number of units by product

8.35 units x 3.1 gal = 25.9 GPA

Mixing Calculations

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

- How many acres will be treated?

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

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

  158,400 sq ft ÷ 43,560 sq ft/A = 3.6 acres

- How much total spray solution is needed?

  3.6 A x 12.9 gal/A = 46.4 gal of spray

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

  3.6 A x 24 oz/A = 86.4 oz of product

  86.4 oz ÷ 16 oz/pt = 5.4 pints

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 product per acre.

- How many total acres need to be treated?

  40 miles x 5,280 ft/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/A = 24.2 A

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

  24.2 A x 16 GPA = 388 gal

Convert commercial product and ai in formulation • gal product x lb ai/gal = lb ai • lb ai ÷ lb ai/gal = gal product

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

  acres = tank size ÷ GPA

  194 gal ÷ 16 GPA = 12.1 A

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

  12.1 A x 2 oz/A = 24.2 oz

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

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

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

- How much product should be added to make up 389 gallons of spray if applied at 1.5 lb ai/A (0.75 gal/A)?

  24.2 A x 0.75 gal/A = 18.2 gal of product

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

   10 gal x 0.05 = 0.5 gal product

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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

Precaucion al usuario: Si usted no lee Ingles no use este products hasta que la etiqueta le haya side 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 3/4 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 which are conducive to evaporation (high temperatures and 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	1 1/3 fl oz	2 fl oz	5 1/3 fl oz
3	4 fl oz	6 fl oz	1 pt
5	6 2/3 fl oz	10 fl oz	1 2/3 pt
50	2 qt	3 qt	2 gal
100	1 gal	1.5 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% solution, 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 1/2 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 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.

Thinline 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 1/2 inch in diameter and have thinner bark to penetrate. For bushes with large numbers of stems (over 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 over 1/2 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 one year old and the bark has lost its green color, but before sprouts reach one inch in diameter.

General Weed Control (See Table)

Broadcast Treatment (Ground Equipment and Helicopter): Use up to 1 1/2 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. Re-treatment 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."

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.

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) Bienniel (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.

General Weed Control
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 use 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. To take in and incorporate.

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

Active Ingredient (ai). The chemical(s) in a formulated product that is (are) principally responsible for 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.

Alkalinity. 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 12 months.

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. A treated 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 two years. The first year the seed germinates and the plant produces leaves, 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 are usually broad and have netlike or reticulate veins.

Brush Control. Control of woody plants.

Cambium. Area just within the bark of woody plants with conductive tissues (xylem and phloem).

Carrier or Diluent. A gas, liquid, or solid substance used to dilute, propel, or suspend a pesticide during its application.

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

Compatible. A satisfactory mix of two herbicides 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.

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

Control. Reduction of a weed problem to a point where it does not cause economic damage.

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 plants.

Directed Application. Precise application to a specific area or plant part such as to a row or bed or 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.

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. Rapid growth on the upper surface of a plant part (especially leaves), causing it 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 suspended in a liquid, that is then 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. They are applied in the dry form.

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

Hazard. The probability that injury or detrimental effects will result if a substance is not used properly.

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

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. It also refers to synthetic chemicals that regulate or affect growth activity.

Incorporate into Soil. Mixing an herbicide into 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. Sideways chemical movement in a plant or soil, or horizontal movement in roots or soil layers.

Leaching. The downward movement of a substance in solution through soil.

Monocotyledon (monocot). A seed plant having a single cotyledon (monocotyledon) or leaf; includes grasses, sedges, and lilies.

Necrosis. Dead tissue.

Nonselective Herbicide. A chemical that is generally toxic to plants without regard to species.

Noxious Weed. A weed specified by law as being especially undesirable, troublesome, and difficult to control.

Penetrant. Adjuvants that help a liquid enter a leaf.

Perennial. A plant that lives for more than two 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 converting carbon dioxide and water into sugar using energy from sunlight.

Phytotoxic. Injurious or toxic to plants.

Postemergence. After emergence of a specified weed or planted crop.

Postharvest. Application of a pesticide to soil or plants after crops have been harvested.

Preemergence. Prior to the emergence of a specified weed or planted crop.

Preemergence Incorporated. Applied after seeding and incorporated in soil above crop seed.

Preplant Application. Applied to soil or weeds before seeding or transplanting.

Preplant Incorporated. Applied and tilled into 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. Pesticides approved for use in Wyoming by the Environmental Protection Agency and Wyoming State Department of Agriculture.

Residual. To have continued killing effect over a period of time.

Resistant. A plant with an evolved mechanism that allows it to survive a previously effective herbicide treatment. Survival is not due to stress conditions or application.

Rhizome. Underground rootlike stem that produces roots and leafy shoots.

Rosette. Basal or early leaves of a plant, before bolting.

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 dosage, mode of application, or plant physiology).

Soil Application. Applied primarily to soil surfaces rather than vegetation.

Soil Injection. Placement of 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 an herbicide remains effective in 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.

Solubility. The amount of a substance that dissolves 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 an 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. Retarding effect on growth and development.

Suppression. Reduction of 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 naturally 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 tissue in plants that transports water.

Appendix

Cross-reference of Common and Trade Names

This list includes the names of many commonly used herbicides in Wyoming
This list does not include the trade names of package mixtures.

Common name	Trade name(s)
aminopyralid	Milestone
asulam	Asulox
atrazine	Atrazine, Aatrex
bentazon	Basagran
bromacil	Hyvar
bromoxynil	Buctril
carfentrazone	Quick Silver, Aim
chlorsulfuron	Telar
clethodim	Envoy, Select
clopyralid	Transline, Stinger
dicamba	Banvel, Vanquish, Clarity
dichlobenil	Casoron
diquat	Diquat, Knockout
diuron	Karmex, Diuron, Direx
fenoxaprop	Acclaim
fluazifop	Fusilade
flumioxazin	Payload
fluroxypyr	Starane, Vista
fosamine	Krenite
glyphosate	many
hexazinone	Velpar, Pronone
imazapyr	Arsenal, Stalker
linuron	Lorox
MCPA	several

Common name	Trade name(s)
MCPP	several
metolachlor	Pennant
metsulfuron methyl	Escort
MSMA	Bueno, Daconate
oryzalin	Surflan, Oryza
oxyfluorfen	Goal
paraquat	Gramoxone
pelargonic acid	Scythe
pendimethalin	Stomp, Pendulum, Prowl
picloram	Tordon
prodiamine	Endurance, Barricade
prometon	Pramitol
quinclorac	Drive, Eject
rimsulfuron	Matrix
sethoxydim	Vantage, Poast
simazine	Pramitol, Enforcer, Simazine
sodium chlorate	Total, Barespot
sulfentrazone	Crossing, Dismiss
sulfometuron methyl	Oust, Sulfomet
tebuthiuron	Spike
triclopyr	Garlon, Redeem, Pathfinder
trifluralin	Treflan, Biobarrier, Turfgo
2,4-D	many

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For specific information on weed identification in the Mountain West, consult:

*Whitson, Tom D., ed. 2006. Weeds of the West. 9th edition. Western Society of Weed Science. University of Wyoming. WYWSWS001. pp. 630.