

Right-of-Way Pest Control

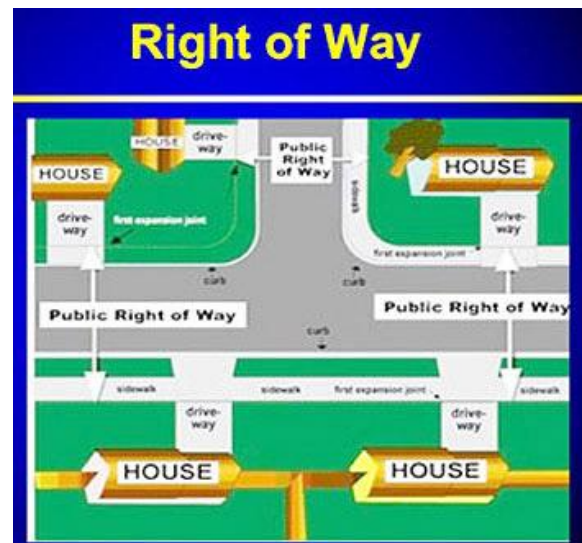
Rights-of-way are the areas involved in common transport. They are essential for the proper functioning of a modern society and include:

- federal, state, and county highways and roads
- public airports
- railroads
- electric utilities (substations, switching stations, transmission lines, and distribution lines)
- pipelines and pumping stations
- public surface drainageways
- public irrigation waterways
- banks of public bargeways and areas around locks and dams
- other public paths or trails outside of established recreational areas.



Rights-of-way occur in every type of terrain, soil, climate, vegetation complex, and land-use area. Vegetation management on rights-of-way is desirable and necessary for both aesthetic and practical reasons, including:

- safety due to improved visibility on transportation rights-of-way,
- reduced fire hazard by encouraging less fire-prone plants,
- soil erosion control,
- assured continuity of utility services,
- promotion of public health and comfort
- ornamental values enhanced by control of nuisance vegetation.



(Photo: www.slideshare.net)

Rights-of-way generally must be **kept free of large brush or trees**. That is, they must be **maintained at an early stage of plant community succession** so the vegetation must be continually managed. Maintaining land in this stage often favors the growth of persistent vines, such as kudzu, which can be as undesirable as large woody plants. The type of vegetation management necessary depends on the function of the right-of-way, as well as its topography, biology, and ecology.



(Photo: www.capecentralhigh.com)

Undesirable vegetation includes plants that:

- create a safety hazard or nuisance
- disturb the normal operation or functional activities of the right-of-way
- are considered “noxious”
- overcrowd desirable vegetation
- damage right-of-way structures, such as road surfaces, railroad ballast, utility wire poles or supports, and pipelines and pumping stations
- provide cover for undesirable wildlife
- are a pest to crops and cropland if allowed to spread.

Vegetation Management

Goals

The principal goal of vegetation management is to ensure the protection, operation, stability, continuance, and safety of the common transport involved.



Highway spraying (Photo: www.wmky.org)

Other goals of a well-planned vegetation management program may be to:

- naturalize the right-of-way using native plants where possible, to make it blend in with the surrounding landscape, and benefit the native ecosystem;
- reduce maintenance costs;
- reduce erosion or water quality problems;
- provide food or shelter for wildlife.

Planning Requirements

Successful right-of-way vegetation management requires good planning that incorporates well-developed goals and objectives into a rational, comprehensive, and practical program. This planning must include recognition of the environmental requirements of both desirable and undesirable plants and the use of methods that will accomplish the goals and objectives in an economical and environmentally sound manner. A properly planned and executed management program uses varied control techniques and strategies that are determined by economics, terrain, vegetation, and public relations. The program should have options for alternative management methods, such as cropping and grazing, as well as chemical weed and brush control.

Good planning and execution can result in:

- increased public acceptance of the right-of-way facility,
- fewer complaints about the right-of-way,
- reduced maintenance cost,
- decreased damage to facilities and structures,
- fewer operational interruptions,
- increased safety,
- improved public relations and less legal difficulty with public action groups and right-of-way neighbors,
- reduced erosion and water pollution,
- improved cost planning and control, and
- better utilization of equipment and reduced work load fluctuation.

Characteristics of Rights-of-Way

Rights-of-way are composed of a series of narrow strips of land that are used for different types of common transport. They range from highly manicured highway rights-of-way to low maintenance rights-of-way for electric or gas lines in forested areas. Each has different requirements for vegetation control.

Electric utility rights-of-way vary in width from 30 feet to 200 feet and have been set aside for the erection of poles and guys, towers, and electrical conductors necessary to carry electricity from the generator to the customer. Electric companies usually acquire rights-of-way from property owners through an easement that grants the utility company the right to install and maintain the facilities necessary to transmit and distribute electricity. The utility company does not normally purchase the land for the rights-of-way; rather, it simply acquires permission or easement from the property owners to install the needed facilities. In many instances,

one or more types of rights-of-way are combined. For example, a highway right-of-way is often built next to a utility right-of-way.

Terrain and Vegetation

The terrain over which these rights-of-way pass vary from cropland or pasture to rugged, mountainous terrain. Rights-of-way also pass over streams, rivers, lakes, ponds, and roads. A variety of vegetation grows along most rights-of-way. The level of vegetation management necessary depends on the type of right-of-way and the sections within it.

Levels of Vegetation Management



Railroad right-of-way (Photo: www.ca.uky.edu)

Highways and railroads need complete vegetation control in the roadbed. The shoulder of the road or rail line is usually kept free of vegetation to allow drainage. The rest of the right-of-way may consist of grass or low-growing shrubs. The type of vegetation allowed to grow will be limited to plants that do not interfere with the movement of vehicles or the vision of their drivers.



Electric utility right-of-way (Photo: www.jobs.tva.com)

Electrical transmission lines through forested areas may have:

- a central path or road for inspection and/or maintenance crews,
- an area of low-growing shrubs or grasses under the wires,
- an area kept cleared of large trees 25 to 75 feet on either side of the centerline (greater clearance required for extremely high voltage), and
- an edge of easement or an area off easement having dangerous trees removed as necessary (depending on easement description).

Electrical distribution lines are often virtually surrounded by vegetation but continual efforts are made to clear vegetation to eliminate power outages. Sometimes mature trees that pose a dangerous threat to electrical facilities must be completely removed.



Gas line right-of-way (Photo: www.geology.com)

Gas pipeline rights-of-way are somewhat different because the soil is disturbed when the pipe is laid. Generally, the area is bare until grass or other vegetation re-invades. Pipeline rights-of-way are usually kept mowed so grasses and low-growing broadleaf plants are the predominant vegetation.

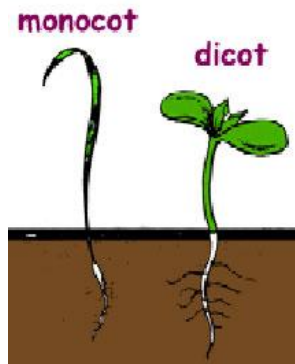
Biology and Ecology of Weeds

Weeds are unwanted plants or ones that are growing out of place. They range from low-growing grasses to large trees. The **biology** of a weed includes its establishment, growth, and reproduction, as well as the influence of environment. The **ecology** of a weed includes the effects of climate, physiology, and biological factors on the plant.

Classification

There are many ways to classify weeds. For control purposes, they can be divided into two major groups: **grasses** and **broadleaves**. Broadleaf weeds are divided into herbaceous and woody plants.

Monocot - Dicot seedlings (www.extension.illinois.edu)



Grasses (monocots) have only one leaf as they emerge from the soil. Their leaves are two-ranked and typically upright, narrow with parallel veins. Grass stems are round and hollow. The root system of a grass is fibrous with the growing point located at or below the soil surface (surrounded by several layers of leaves). Perennial grasses can produce new shoots from growing points located on rhizomes (belowground) and/or stolons (aboveground).

Broadleaf plants (dicots) have two leaves (cotyledons) as they emerge from the soil. The leaves are generally broad with net-like veins. Broadleaves typically have a taproot surrounded by a relative coarse root system. Actively growing broadleaf plants have exposed growing points at the end of each stem and in each leaf axil.

Perennial broadleaves may have growing points on roots and stems above and below the surface of the soil.

(Photo: www.extension.illinois.edu)

Woody plants live longer than 2 years and have a thick, tough stem or trunk covered with cork. Examples include trees, shrubs, and woody vines.

Herbaceous plants do not have persistent woody aboveground stems so they die back to the ground each winter. They may be annuals, biennials, or perennials. New tissue of biennial and perennial plants emerges from the ground each spring to start the life cycle again.

Plant Life Cycles

Plant life cycles or growth habits determine the most effective methods to manage them effectively.

Annuals

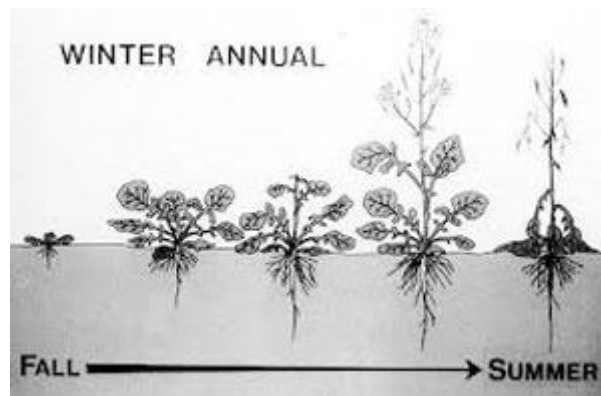
Annual plants develop from seeds, mature, produce seeds, and die in one growing season.



Chickweed (Photo: www.burke.ces.ncsu.edu) Henbit (Photo: www.pestid.msu.edu)

Summer annual plants germinate from seeds in the spring, grow through the summer, produce seeds, and die in the fall. Examples are crabgrass, foxtail, fall panicum, pigweed, and lambsquarters.

Winter annual plants germinate from seeds in the fall, overwinter, mature, produce seeds, and die in the spring or early summer. Examples are chickweed, henbit, cheat, and shepherd's purse.



Winter annual weed life cycle (Photo: www.uky.ca.edu)

Annual weeds frequently can be controlled with residual herbicides applied to the soil before the plants emerge. Foliar herbicides, either contact or translocated, are also effective in controlling annual weeds. Usually, the combination of a residual and a foliar herbicide provides the most dependable control.

Biennials

Biennial weeds complete their life cycle over a two-year period (two growing seasons). They frequently develop from seed and form a rosette (a low-growing cluster of leaves) during the first year. During the second growing season, the stems elongate, flowers and seeds develop, and the plant then dies. Biennial weeds include poison hemlock, Queen Anne's lace (wild carrot), common mullein, and musk or nodding thistle. Biennial weeds can usually be controlled using the same methods that are effective against annual weed but they are easier to control during the first year of growth.



Musk thistle - rosette stage (Photo: www.extension.umn.edu)

Perennials

Perennial plants live for 3 or more seasons and reproduce by seed and/or vegetative parts: bulbs, tubers, rhizomes, stolons, or roots. They are often more persistent than annuals or biennials. Control may require repeated applications of foliar translocated herbicides. Soil-applied herbicides may have to be applied at high rates to control perennial weeds. Johnsongrass, quackgrass, Canada thistle, brush, shrubs, and trees are perennial weeds.

Simple perennial weeds usually reproduce by seed but vegetative reproduction can occur if roots or crowns are cut by tillage implements. The cut pieces can send out feeding roots and stems to become new plants. Dandelion, curly dock, and plantain are examples of simple perennials.



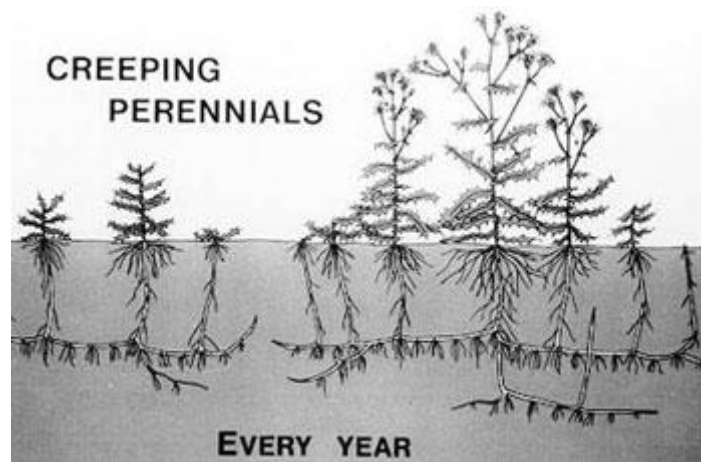
Curly dock - rosette stage (Photo: www.pestid.msu.edu)

Bulbous perennial weeds, such as wild garlic, reproduce by bulbs and bulblets, as well as by seeds. Both aerial bulblets and seeds may be produced in the flower heads. In addition, secondary bulbs may develop belowground.



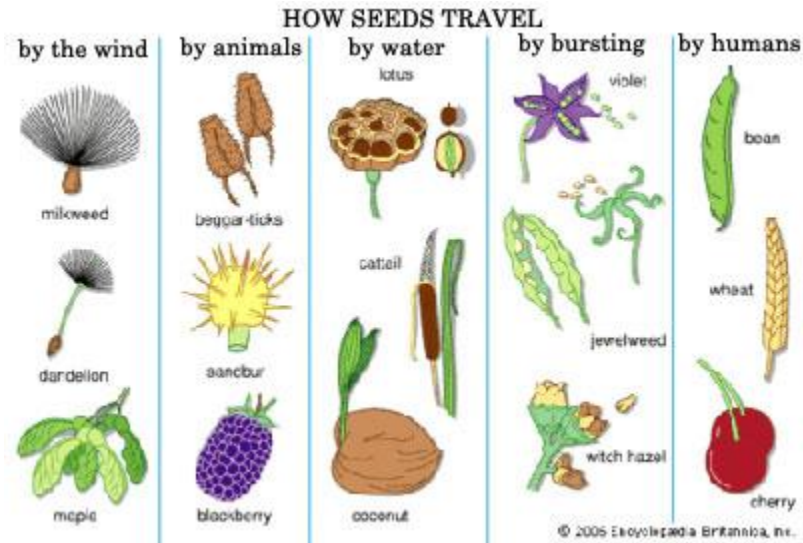
Wild garlic bulbs (Photo: newstimes.augusta.com)

Creeping perennials spread by growth of stems (stolons) along the soil surface, by stems (rhizomes) beneath the soil, by roots, or by seeds. Mouse-ear chickweed, knotgrass, and pennywort spread by creeping stems. Quackgrass, Johnsongrass, and hedge bindweed spread by rhizomes. Sow thistle and red sorrel spread by creeping roots.



Creeping perennials (Photo: www.ca.uky.edu)

Dissemination and Persistence



Seed dispersal by wind, animals, water, bursting, humans (weed-science-classes.wikispaces.com)

Plants spread through the dispersal of their sexual (seed) and asexual (rhizomes, stolons, tubers, roots, and bulbs) reproductive parts. Annuals and most biennials spread by seeds, which can be carried by wind, water, animals, machinery, and crop seed. The persistence of annual and biennial weeds mainly depends upon their ability to re-infest the soil with their seed.

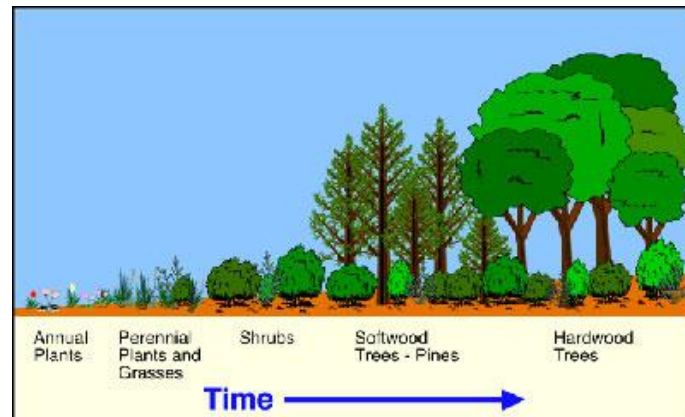


The introduction or infestation of perennials into an uninfested area depends on seed. Therefore, **controlling seed production** can prevent further spread of many species. However, many perennials also spread by asexual methods. Their spread is slow compared to most annuals, especially in uncultivated land that may occur in rights-of-way. Trees and shrubs have large root systems, and often the roots and stumps can sprout when the top is removed. Some species, such as black locust and beech, can readily produce root suckers or sprouts even when the top is not cut.

(Photo: Black locust sprouts (coppice) (tpermaculture.com))

The length of time that weed seeds remain viable may depend on the species involved and the environmental conditions. In general, seeds that are viable but that do not germinate within a few days or months will remain in a **dormant or resting stage**. Dormancy may determine the time of year when weed seeds germinate. In some cases, germination may be delayed for years, guaranteeing a "seed bank" or source of viable seeds for years to come.

Stages of Vegetation Succession



Natural succession is toward a forest (www.physicalgeography.net)

Vegetation succession is the orderly development of different types of plants on land where the original plants have been removed. Annuals, such as ragweed and pigweed, appear first. Grasses, grass-like plants, and biennial or perennial herbaceous broadleaf plants come next. Shrubs and trees make up the final stage. The trend is for a right-of-way to develop into a forest.

The type of vegetation most suited for a particular right-of-way depends upon its function, as well as safety, wildlife, and soil conservation considerations. In general, annual plants and forests are undesirable right-of-way cover. The most suitable vegetation for most rights-of-ways is a community of certain grasses, grass-like plants, and perennial herbaceous broadleaves.

Vegetation Management Control Methods

The three methods of control used in right-of-way vegetation management are **biological, mechanical, and chemical**.

Biological Control



Weevil larvae feed on nodding thistle seed (Photo by L. Townsend)

Animals, birds, and competing plants are used in biological control of vegetation. This can be inexpensive if a stable right-of-way plant community is established. However, it requires a sound knowledge of the ecology of the area and the steps needed to keep a stable system. When rights-of-way cross pasture land, grazing usually

eliminates the need for vegetation control. In some cases, desirable vegetation is deliberately introduced onto the utility right-of-way. Maintenance and cultivation of these plants ensure the control of unwanted vegetation. Also, planting trees or shrubs that do not grow to line height can be used to help reduce control costs. This is true with Christmas tree farms or tree nurseries. The desirable vegetation is harvested or removed before it becomes a problem to the utility company. Landowners may also use rights-of-way to improve wildlife habitat or biodiversity.

Mechanical Control

Mechanical control is the oldest way of managing vegetation. It includes hand-pulling, hoeing, blading, mowing, cutting, pruning, carefully controlled burning, flooding, bulldozing, and cropping. Mechanical control methods usually require a lot of labor and can be very expensive. However, in some cases, mechanical controls may be the least expensive method of vegetation management. Areas that are being cropped, or residential and industrial areas maintained by the landowners, are often kept in superb condition at no cost to the right-of-way company. Unfortunately, many of these areas cannot be managed with less expensive methods, so mechanical controls are necessary.

Mowing is a common way to maintain pipeline and highway rights-of-way. Hay production is used in some states but is not practical in Kentucky. Mowing crews maintain roadsides on almost all of our highways and secondary roads.



(Photo: www.kdkz18.com)

Cutting or pruning by arborists is often the only acceptable management method for trees and brush that invade utility rights-of-way. Trees that grow around electrical and telephone wires are often considered to have ornamental value and must be selectively pruned. Special care must be taken to use Natural Target Pruning techniques to avoid extensive damage to trees. In Kentucky, utility arborists, who are also Certified Arborists, know appropriate pruning methods. Proper timing can improve the effectiveness of cutting or pruning.

Research has shown that when trees or shrubs are cut directly after full leaf out, they do not sprout as vigorously as they do when cut during late summer or winter. Large mechanical brush cutters are used to eliminate brush and small trees. Chainsaws, brush hooks, hand saws, and axes are needed when working in areas where large mechanized brush cutters cannot be used.



(www.georgiapower.com)

Tree topping along utility rights-of-way is not appropriate.



(Photo: cleatordesigns.wordpress.com)

Burning can be a cheap and effective way to manage vegetation but it is not practical in Kentucky because of legal and environmental complications.

Flooding is used effectively to control vegetation along the edges of canals and navigable rivers or lakes. The Corps of Engineers uses this method to maintain vegetation and to reduce mosquito breeding along the shorelines of the waterways it administers.

Mechanical control methods are very expensive so most rights-of-way operators would rather use less costly control methods, if possible. For instance, hand clearing of utility rights-of-way can cost 4 times more per acre than chemical control of the same vegetation. Also, hand cutting of some hillsides may be more dangerous to workers.

Chemical Control

Terrain often makes mechanical control methods impractical. For example, chemical control is often the only practical way to control vegetation where rights-of-way cross rugged, mountainous terrain.

Tree growth regulators (TGRs) can be used to slow the growth of trees. This allows more effective management of pruning cycles. Also, TGRs can reduce the amount labor needed to prune and clip treated trees.



Applying TGR at base of tree (www.hostedsites.us)

Classification of Herbicides

Herbicides are classified by common characteristics, such as methods of application, selectivity, or chemistry.

Method of Application

Herbicides may be applied to the soil or to foliage. **Soil-applied herbicides** must be taken up by seeds or underground vegetative plant parts. For optimal results, they must be in the soil in an active or available form for a certain period of time - the **soil persistence or soil residual life**. These terms also may apply to certain herbicides that are primarily applied postemergence but also leave some “active” residue in the soil.

Foliar-applied products are commonly referred to as **postemergence herbicides**. They control weeds either by direct contact with the plant tissue or by translocation to other plant parts. **Contact herbicides** are used primarily to control annual weeds. Plants sprayed with contact herbicides usually die within a few hours or days but there is very little, if any, residual control. Weeds treated with translocated herbicides generally require several days to die. These herbicides are often capable of controlling annuals, biennials, and perennials.

Selectivity

Herbicides may be classified as selective or nonselective; however, herbicide selectivity can be rate dependent. At low rates, some herbicides are selective, whereas, at high rates, they become nonselective. **Selective herbicides** kill some kinds of plants but have little or no effect on others. The use of selective herbicides allows the removal of unwanted weeds from desirable crops. **Nonselective herbicides** kill all vegetation.

Chemistry

Herbicides with similar chemical characteristics are grouped into families. Here are some of the common herbicide families used in rights-of-way:

Phenoxy herbicides are usually applied to foliage to control annual and perennial broadleaf weeds. They can also be taken into the plant through its roots. Spray or vapor drift may injure nearby desirable broadleaf plants.



Phenoxy (Photo: programs.ifas.ufl.edu)

Picolinic acid herbicides control many annual and perennial broadleaf weeds. They are readily absorbed by roots and foliage and move within the plant to the growing points of stems and leaves. This causes a variety of growth regulator type effects. These herbicides have a moderate to high leaching potential since they are weakly bound to soil.

Sulfonylurea herbicides control many annual and perennial broadleaf and grassy type weeds. They can be applied to leaves or to soil. A surfactant is used with foliar applications to enhance absorption into the leaves. Injury symptoms are typically slow and may not show up for two to three weeks after application.



Sulfonylurea (Photo: herbicidesymptoms.ipm.ucanr.edu)

Triazine herbicides are generally taken into the plant through the roots; however, some members of this family can also be absorbed through the foliage. When used as a foliar treatment, a surfactant or an oil is generally included to enhance absorption. Triazines provide non-selective control of various grasses and broadleaf weeds when used at rates recommended for non-cropland. Regardless of whether or not they are applied preemergence or postemergence, the triazine herbicides generally accumulate in the leaves where they inhibit photosynthesis.



Triazine (Photo: herbicidesymptoms.ipm.ucanr.edu)

Uracil herbicides are more easily absorbed by the roots than by the shoots of plants. The addition of a surfactant does, however, increase their foliar activity. After being absorbed by the roots, uracil herbicides move to the leaves of plants where they inhibit photosynthesis. The effects of uracil herbicides on perennial weeds are generally slow and may take several months.

Urea herbicides are most effective when applied as a preemergence treatment. However, their postemergence activity can be increased when they are applied with a surfactant. Like the triazine herbicides, the ureas do not prevent germination of weed seed. Instead, they accumulate in the leaves of emerged plants where they inhibit photosynthesis. Although the urea herbicides provide control of both grasses and broadleaf weeds, they are considered to be more effective on broadleaf weeds.

Other Herbicides

The following are other herbicides not included in the above families: Dicamba (Banvel, Vanquish) is used to control woody plants, as well as many broadleaf herbaceous plants. Dicamba is absorbed by the leaves, stems, and roots and translocates throughout the plant. It is relatively mobile in the soil. At label rates it has very little, if any, effect on grasses.

Fosamine ammonium (Krenite) is used to control woody plants. It should be applied during a two-month period prior to fall coloration. When applied to deciduous plants at this time of the year, there is little or no effect until the following spring when bud development is prevented or limited. Pines, however, show a response shortly after application.

Glyphosate (Accord, Roundup) is used to control many annual and perennial weeds including grasses, broadleaves, brush, and certain trees. It can be applied to the foliage of actively growing plants where it is absorbed by the leaves or as a tree injection or cut stump treatment. Glyphosate is rapidly and tightly adsorbed by soil.

Imazapyr (Arsenal, Chopper, Habitat) controls many annual and perennial weeds, including certain grasses, broadleaves, vines, brush, and trees. Plant growth is inhibited within a few hours after application but injury

symptoms may not appear for 2 to 3 weeks after application. Arsenal can be applied to the soil or to the foliage of plants.

Triclopyr (Garlon, Crossbow) is a growth regulator type selective herbicide for control of many woody plants and broadleaf weeds. Most grasses are tolerant to Garlon. It can be applied as a ground or aerial foliage spray or as a basal or tree injection application. Garlon is absorbed by both foliage and roots and translocates throughout the plant. Some leaching may occur in light soils under high rainfall conditions.

Herbicide Application Methods and Equipment

Right-of-way sprays can be applied by ground or air, depending on the situation. Ground applications may include foliar spray, basal bark treatment, stump treatment, tree injection, and soil treatment with pellets. Foliar application includes both high and low volume techniques.

High volume spraying is normally done with truck-mounted equipment that delivers 60 to 400 gallons of solution per acre at high pressure through a hand-directed nozzle. This type of foliar spraying is fast and, in some instances, can deliver herbicide through dense brush. However, the **risk of drift and unwanted effects on nontarget plants is relatively high**. This technique requires more planning and precautions than other ground application techniques.

Low volume spraying is normally done with hand-held equipment, such as backpack sprayers, low pressure ATVs, or tractor-mounted sprayers that deliver 10 to 60 gallons per acre at relatively low pressure through a hand-held wand. Low volume spraying also includes using boom sprayers and fixed height nozzles to apply herbicides to low-growing grasses and weeds with a great deal of control over the amount and distribution of herbicide. This type of low volume technique is often used for band or strip spraying. **All types of low volume spraying are likely to cause fewer environmental problems** compared to high volume techniques.



Low volume spraying (Photo: www.dowagro.com)

Both high volume and low volume hand-held wand techniques generally require that mixes contain a specific percentage of herbicide in the final water-based solution. Labels also indicate that a specific amount of solution be applied per acre, ensuring that all foliage be sprayed to a point of runoff.

Individual stem applications are used to apply herbicides directly onto or inside the stems of individual woody plants (trees or shrubs).



Hypo-Hatchet™ tree injector (Photo: www.forestrytools.com.au)

Basal bark treatments are used to apply specific formulations of herbicides to the outer bark of the small woody plants. The herbicide is absorbed through the bark and eventually contacts the transport tissues and growing portions of the stem. A number of different methods including the use of tree injectors, frill and squirt techniques, Hypo-Hatchets™ or similar devices, and cut stump treatments are used to deliver herbicides directly to the transport and growing tissues beneath the bark of woody plants. These treatments should not be applied to trees or shrubs where non-target plants of the same species or genera are nearby (generally within 10 to 20 feet). Trees and shrubs of the same species or genera may form root grafts or sprouts from the same rootstock. In these cases, the herbicide can be translocated from one tree to another, killing or injuring the non-target tree.

Basal bark treatments consist of several techniques of applying herbicides to the lower stem of small (less than 6 inches in diameter) trees and shrubs. Unlike the majority of ground application herbicides, which are mixed with water, those labeled for basal bark treatments are mixed with oil.

The **full basal technique** requires that the herbicide be thoroughly applied around the circumference of the lower 18" of the tree. This is normally done using a backpack sprayer with a cone or flat fan tip.



Full basal bark treatment (Photo: www.techlinenews.com)

The **streamline technique** is used on trees or shrubs less than 3 inches in diameter and requires that a 6 inch-wide band of herbicide be applied to one side of the stem. Enough of the solution should be applied to allow it to spread around the entire circumference of the stem.

The **thin line technique** is similar to streamlining, with the exception that undiluted herbicide is used and only a thin band is sprayed completely around the stem. The streamline and thin line techniques are often applied with a hand jet, which shoots a stream of solution, rather than a hand wand and nozzles used for the full basal technique.

Cut stump treatments are applied on freshly cut stumps to prevent sprouting (coppicing) of hardwood trees and shrubs. Best results are obtained when stumps are treated with undiluted herbicide within 1 to 2 hours after cutting. Once the cut surface dries, this treatment quickly loses its effectiveness. For small stumps, less than 10 inches in diameter, the entire surface should be covered. For larger stumps, only the outer 3 to 4 inches should be treated. Backpack sprayers with hand wands or handheld spray bottles can be used to apply the herbicide.



Cut stump (Photo: www.cornellforestconnecting.com)

Tree injections can be used to apply herbicide to the living tissues inside the bark of standing trees or shrubs. Tree injectors, specially designed 4- to 5-foot-long tubes with an injection pump and 1½- to 3-inch blade or injector on one end and are used to apply either liquid or pellet herbicides to trees of any size. Several companies make devices that combine the squirt mechanism with a specially designed hatchet. Brand names such as Hypo-Hatchet™ and Silvaxe™ are examples. The liquid herbicide is placed in a container on a belt or backpack and is attached to the hatchet with a hose. The hatchet has a pump mechanism and injection ports built into the head. Striking the stem creates a slit and injects a calibrated amount of solution into the slit. Liquid tree injectors have blades that produce a slit through the bark, and the pump delivers a calibrated amount of solution into the slit.



Tree injector bar (Photo: <http://www.bugwood.org/PAT/07tools.html>)

Pellet injectors have a head on the tube that drives the pellet into the bark. The frill and squirt technique is also used to apply herbicides inside the stems of woody plants. This is done by using a hatchet to slit the bark and then applying a calibrated amount of herbicide into the slit using a hand sprayer.

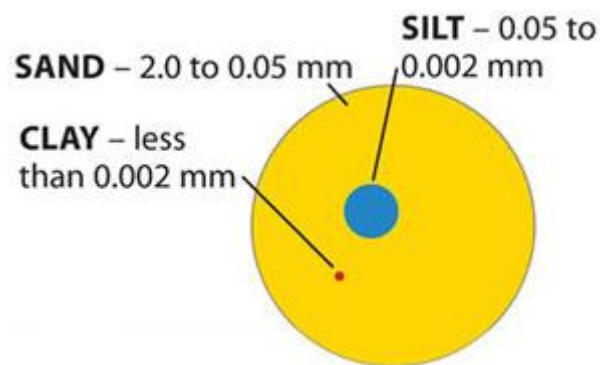
Herbicides labeled for tree injection will indicate the amount of herbicide needed per inch of stem diameter and the spacing of injections around the stem.

Soil applied pellets can be used in very small amounts by hand broadcasting or specific placement around the stems of trees and shrubs (e.g., multiflora rose) or brush. After a rain, the solution is moved into the roots of woody plants that have their root systems within the dispersal area of the herbicide.

Factors That Affect Herbicide Applications

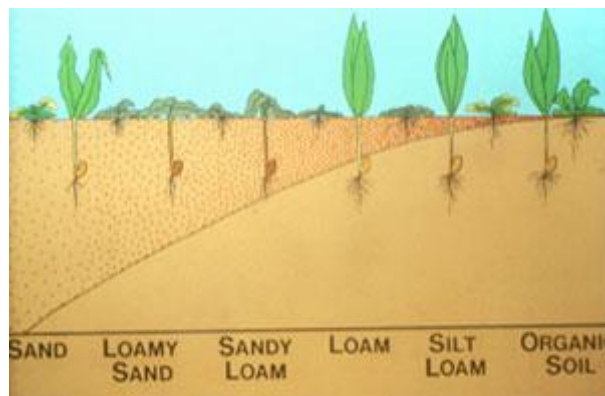
Physical Factors

Texture, organic matter, pH, and moisture content are some of the major soil properties that influence the efficacy of a soil-applied herbicide.



*Comparison of sizes of sand, silt, and clay particles
(Photo: <http://www.soilsforteachers.org>)*

Soil texture, the relative amounts of clay, silt, and sand in soil, can determine the availability of certain herbicides. Usually, as the clay content of the soil increases, the amount of herbicide available for uptake in the plant decreases. Clay particles are primarily negatively (-) charged, so they tend to attract or adsorb positively (+) charged particles. Herbicides that tend to be positively charged in the soil are bound to a greater extent by clay particles than herbicides that are negatively charged. This is why the rates of certain herbicides vary with soil texture.



*Herbicide (red dots) movement is greater in sand, than silt loam or high organic matter soils
(Photo: teclinenews.com/herbicides)*

The **organic matter or humus content** of soil is primarily negatively (-) charged so herbicides can bind to it. In general, herbicides are more strongly adsorbed to humus than to clay particles. A small increase in the organic matter content of the soil can greatly reduce the effectiveness of some herbicides.

Soil pH can influence the effectiveness and persistence of certain herbicides. For example, some degrade rapidly when soil pH is less than 6.0. When soil pH is above 6.0, degradation rates are slower and depend more on soil microbes.

A certain minimal amount of **soil moisture** must be present in order for a soil-applied herbicide to be taken up in the plant. Generally, soil-applied herbicides do not work as well under very dry conditions as they do when the soil moisture is adequate. Soil moisture may also indirectly affect the persistence of various herbicides by influencing their breakdown by microbes or certain chemical reactions. Because of this, soil applied herbicides usually last longer when the soil is dry rather than when it is moist or wet.

Soil microorganisms are one of the most important pathways for the breakdown of many herbicides. The type of microorganisms (fungi, bacteria, protozoans, etc.) and their relative numbers determine how quickly decomposition occurs. Microorganisms require certain environmental conditions for optimal growth and utilization of an herbicide. Factors affecting microbial activity are moisture, temperature, pH, oxygen, and mineral nutrient supply. In general, a warm, moist, porous, fertile soil with a near-neutral pH is most favorable for microbial growth, which accelerates breakdown of herbicides that are susceptible to microbial degradation.

Environmental Factors That Influence Herbicides

Results achieved from herbicide applications may vary greatly because of: improper application (e.g., improper choice of herbicide, poor equipment, incorrect calibration, lack of agitation, or ineffective product). Many of these problems can be prevented or corrected by the operator. However, much of the variability is due to factors that the applicator cannot control, such as environmental conditions, variation of soils, and differences in susceptibility of various plant species.

Before evaluating the effect of environmental factors, it is essential to consider how the herbicide is applied. The influence of a given environmental factor may be quite different, depending on the type of application. Environmental conditions have very little effect on stump or basal bark treatments; however, they may have a great effect on soil and foliage applications.

Soil-Applied Herbicides

Rainfall (soil moisture) and temperature are two environmental factors that have the most influence on the performance of soil-applied herbicides. Rainfall is as important for chemical weed control as it is for plant growth. Herbicides applied to the soil surface must be moved into the root zone of the plants to be controlled soon after the application is made. Herbicides generally do not perform as well during periods of drought as they do when moisture is adequate.

The amount of rainfall needed to move a herbicide depends on its water solubility. **Very soluble products water have a higher potential to move with water in soil compared to many other herbicides.** Leaching of water-soluble herbicides is greatest under heavy rain that falls in a short period of time. Excessive movement of herbicide in the soil may cause injury to desirable plants close to treated rights-of-way. The influence of rainfall on the efficacy of herbicides is interrelated with additional environmental factors, as well as soil texture and soil structure.

Temperature influences the performance of soil-applied herbicides by affecting chemical reactions in the soil, microbial activity, and plant growth processes. Decomposition of herbicides by chemical reaction and microbial activity in the soil occurs more rapidly at high temperatures; therefore, herbicides are less persistent under these conditions.

Temperature has a profound effect on the absorption, translocation, and metabolism of soil-applied herbicides by plants. Other factors being constant, the effects of these processes increase with increasing temperatures. Herbicides usually perform best under temperatures at which plants grow rapidly. Under conditions of extremely high or low temperatures, the toxicity and selectivity may be dramatically altered due to the influence of temperature on these physiological processes.

Foliar-applied Herbicides

Environmental factors probably have a greater effect on the performance of foliar-applied herbicides than on soil-applied herbicides.

Factors affecting plant growth in general, such as **soil moisture and temperature**, have the same effect on foliar-applied herbicides. Rapidly growing succulent plants are generally more susceptible to postemergence herbicide treatments than are plants in any other condition.

In order for a herbicide applied to the foliage to be effective, it must be absorbed into the plant through the cuticle of the leaf. Plants grown under **drought stress** develop a thicker cuticle than those grown under more favorable conditions. This thicker cuticle limits absorption of the herbicide. The translocation of systemic herbicides may also be limited in plants grown under drought-stressed conditions.

Foliar-applied herbicides usually perform best when applied during a period of high relative **humidity**. This greatly increases foliage absorption by delaying drying of spray droplets and hydrating the cuticle, making it more permeable. High relative humidity also may enhance translocation of systemic herbicides. Very light rainfall, such as a drizzle, dew, or fog, increases absorption and effectiveness by remoistening the dry herbicide on the leaf surface. However, heavy **rainfall** shortly after application may wash the herbicide off the plant. The amount of the herbicide washed from the plant depends on the quantity of precipitation, the rate of herbicide application, the chemical characteristics of the herbicide, and the use of an additive. Water-soluble herbicides,

such as salt formulations of 2,4-D are washed off more easily than oil-soluble herbicides, such as ester formulations of 2,4-D.

In addition to the effect of temperature on the plant's physiological processes, temperature also influences absorption of herbicides into leaves. Plants grown under high temperature frequently develop a thicker cuticle that restricts herbicide absorption. Due to the interaction of these physiological processes, the effect of the temperature at the time of application on herbicide performance depends on the herbicide being applied. In general, best results can be expected from foliar herbicides applied during warm weather to actively growing plants and followed by a period of several hours with no rainfall.

Sunlight is an additional environmental factor that influences the performance of many soil- and foliar-applied herbicides. It is essential for the activity of certain herbicides, but it is seldom a limiting factor in their performance. However, the herbicide paraquat kills plants more rapidly on clear, sunny days and more slowly on cloudy days.

Public Relations Concerns

Vegetation management is necessary and in most cases desirable. But most rights-of-way are long and narrow so they often touch the property of many landowners. Neighbor conflicts may become magnified, especially if vegetation management efforts go beyond rights-of-way boundaries. Public relations problems between right-of-way users and their neighbors are minimized when the public is informed of the vegetation management needs and methods and when vegetation management personnel know and execute a program with definite goals and plans.



Protesting against right-of-way sprays (Photo: www.capecodtoday.com)

Following label directions and proper application practices are absolute requirements to obtaining satisfactory results from any herbicide treatment. All treatments must be applied uniformly at the recommended rate over the area to be treated. Foliar treatments must be applied in a sufficient volume of carrier (usually water) to ensure adequate coverage. When treating rights-of-way, it is **very important to keep the spray mixture within the treated area during and after the actual spray application**. There are two characteristics of herbicides that account for the majority of instances in which herbicides sprayed on rights-of-way reach nontarget locations and result in damage complaints. These characteristics are drift and volatilization of the herbicide.

Drift refers to the **movement of spray particles or droplets through the air to areas not intended for treatment**. The amount of drift that can occur depends on the particle or droplet size and the amount of air movement at the time of spraying. Herbicide **spraying should not be done if the wind speed is greater than 5 miles per hour**.

The following table shows when particles of fog or mist size present the greatest possibility for drift to occur. These size particles are generated readily by high pressure spraying equipment.

Droplet Type	Time to Fall 10 ft in Still Air	Distance Traveled With 3 mph Breeze
Fog	66 minutes	3 miles
Mist	10 seconds	409 feet
Light Rain	1.5 seconds	7 feet
Moderate Rain	1 second	4.7 feet

from Weed Science: Principles and Practices, G. C. Klingman.

Volatilization of herbicides is a chemical process whereby the herbicides change from a liquid to a gas. The herbicide, in the form of a gas or vapor, can move with the air currents for a mile or more to injure sensitive crops. Drift and volatilization are problems of major concern in right-of-way maintenance. They represent potential hazards to sensitive crops, gardens, and ornamentals and may have harmful effects on wildlife, people, livestock, and aquatic areas near rights-of-way.

In many cases, movement of herbicides off right-of-way areas results in complaints from the public or property owners. Any complaints arising from herbicide application should be answered expeditiously and settled rapidly in a fair and amicable manner.

The general public is often not knowledgeable about the reason for and the nature of herbicide applications to rights-of-way. Applicators and operators can do much to alleviate public fear through a rational approach to effective communication. They should be aboveboard and totally honest in their communications in order to bring about the needed education of the public concerning herbicide use.

Environmental Concerns

Groundwater Advisories

The **potential for contamination of groundwater is an important factor to consider** when choosing herbicides. Several products have groundwater advisory statements on their label. Such statements advise not to apply these products where the water table (groundwater) is close to the surface and where the soils are very permeable (well-drained soils such as loamy sands). Refer to these statements and observe all precautions on the label when using these products.

Endangered Species Act



(Photo: www.naturepreservesky.gov)

The Endangered Species Act (ESA) is intended to protect and promote recovery of animals and plants that are in danger of becoming extinct due to the activities of people. **Under the act, the EPA must ensure that the use of pesticides it registers will not harm the species listed by the U.S. Fish and Wildlife Service as endangered or threatened, or to habitat critical to the survival of those species.** To accomplish this, the EPA has implemented "Interim Measures," including county bulletins showing the area(s) within the county where pesticide use should be limited to protect listed species. Pesticide active ingredients for which there are limitations are listed in table form in the bulletins. The limitations on pesticide use are not law at this time but are being provided for use in voluntarily protecting endangered and threatened species from harm due to pesticide use.

Calculating Rates

The economic value of a herbicide depends on the relative amounts of active toxic chemicals that are contained per pound or gallon of product. This is expressed in percent of active ingredient, acid equivalent, or pounds per gallon for liquids. One pound of an 80 percent wettable powder (WP) formulation of a herbicide contains more active ingredients than 1 pound of a 20 percent granular product (pound for pound).

An amine salt formulation of 2,4-D containing 4 pounds per gallon, acid equivalent, is more valuable than the same formulation containing 2 pounds per gallon. Since mixing charges and cost of containers, freight, and handling have to be paid on twice as much material for a 2-pound-per-gallon formulation as a 4-pound formulation, the cost per pound of active material is less in the 4-pound formulation than in the 2-pound formulation, although the cost per gallon of product is more.

The pounds of active ingredient (AI) or acid equivalent (AE) per gallon are given on the label of liquid herbicides. The percent is given on labels of powders, granules, and other dry materials. To calculate the **amount of liquid herbicide required when the rate is expressed in pounds per acre**, use the following formula:

$$\text{(rate in pounds per acre)} \div \text{(pounds of herbicide per gallon (AE))} = \text{gallons per acre}$$

Example:

If the rate is 1.5 pounds per acre, and the herbicide contains 4 pounds (AE) per gallon, then
 $1.5 \div 4.0 = 0.37$ gallon, or 8 pints $\times 0.37 = 3$ pints.

Use the same formula to calculate **gallons of herbicide per 100 gallons of spray**.

Example:

If the rate is 2.5 pounds (AI) per 100 gallons, and the herbicide contains 2 pounds (AE) per gallon, then $2.5 \div 2.0 = 1.25$ or $1\frac{1}{4}$ gallons.

To calculate the **amount of dry product required when the rate per acre is given**, use the following:

$$100 \div \text{(percent active ingredient)} \times \text{rate per acre} = \text{pounds product}$$

Example:

If the rate is 15 pounds active ingredient per acre, and the percent of active ingredient is 75, then
 $(100 \div 75) \times 15 = 20$.

Mixing

Never pour the concentrate directly into an empty spray tank. Either fill the tank half full, add the chemical, agitate, and complete the filling; or, start filling and add the chemical as the filling is continued.

Operate the sprayer with the nozzles shut off, bypassing the spray through the tank for several minutes to ensure thorough mixing.

Often, **your exposure to concentrated chemicals is highest when mixing**, and many right-of-way herbicides carry signal words indicating that **eye protection is critical**.