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Right-of-Way Pest Control

Category 6

Missouri Manual 88

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Preface

This training manual provides you with the information you need to meet the minimum Environmental Protection Agency (EPA) standards for certification as commercial applicators in Category 6, Right-of-Way Pest Control. It also prepares you for an examination, based on this manual, given by the Missouri Department of Agriculture.

It **does not** provide all of the information you need for safe and effective use of pesticides. Examine the label for each pesticide you use. Labels must list directions, precautions and health information — all of which are updated regularly when a pesticide is registered in Missouri. If you notice information on a current pesticide label that conflicts with the information in this manual, follow the label.

Manufacturers will supply additional information about products registered for use in controlling pests that clutter the rights-of-way in Missouri. Information also is available from the Office of Pesticide Coordinator, 45 Agriculture Building, University of Missouri-Columbia, Columbia, MO 65211, (573) 884-6361.

Missouri's Pesticide Applicator Training Program is a cooperative effort. The Missouri Department of Agriculture is the state lead agency. University Extension, the University of Missouri-Columbia, is responsible for the content of the Pesticide Applicator Training Program. The Missouri Departments of Health, of Conservation, of Natural Resources and the EPA also contribute to the development of educational materials and participate in the training program.

(**A note on this manual:** Terms highlighted in bold type throughout the text also are found in the glossary, beginning on page 23.)

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Acknowledgments

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- Stacy Armstrong, Missouri Highway and Transportation Department
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The information given in this manual is supplied with the understanding that no endorsement is implied or discrimination intended.

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Spring 1994

Introduction

When stopped at a rural intersection, the average driver checks for oncoming traffic without giving a moment's thought to the workers who ensure his or her ability to see that traffic. The effort of **right-of-way** personnel has a significant impact on our daily lives, yet in most cases, the public takes for granted the dedicated efforts of right-of-way personnel.

The objective of this manual is to educate the reader about pesticide application along Missouri's rights-of-way.

What are rights-of-way?

For our purposes, we define rights-of-way as areas involved in common transport. Examples include:

- Federal, state, county and township highways and roads;
- Electric utility lines, including transformer stations and substations;
- Pipelines, including pumping stations;
- Public airports;
- Railroads;
- Public-surface drainage systems, or ditches;
- Telephone and other communication networks; and
- Bicycle, hiking, bridle and other public paths or trails outside established recreational areas.

Reasons for rights-of-way vegetation management

The objectives of a well-planned vegetation-management program are to safely, efficiently and effectively maintain rights-of-way and rights-of-way facilities so that vegetation does not interfere with their intended use.

More than 15 million acres of land in the United States currently are in use as rights-of-way for electric power lines, telephone lines, highways, railroads, pipelines, navigation channels, airport runway approaches, drainage and flood-control canals, spillways, levees and communications structures. All of these require periodic vegetation management to assure they continue to be safe and efficient. One way to provide this management is with **herbicides**. You should apply herbicides only as they are needed for safe and efficient use of the right-of-way.

The aesthetic, economic and environmental benefits of a good vegetation-management program include:

- Improved highway pavement management: Properly managed roadside vegetation improves air circulation and increases the amount of sunlight that reaches the pavement, which keeps it dryer and extends its life.
- Improved highway safety: Drivers have better visibility of signs, curves, intersections, traffic signals and driveways. You also enhance safety by maintaining a safe shoulder area and by keeping the deflection area behind guardrails free of trees and vegetation. In addition, you should manage vegetation to maintain a free-draining road surface, which reduces the potential for hydroplaning or skidding on ice.
- Preservation and enhancement of scenic resources: This includes planting, encouraging natural plant growth and selectively restricting plant growth to screen, preserve, create or enhance views.
- Providing wildlife habitat: Conversion of areas from their existing condition (i.e., woods, woody vegetation, open turf, bare ground, unshaded streams, etc.) to shrubs and herbaceous plants may provide wildlife with cover, nests and food.

Pesticide usage considerations

With pesticides, licensed applicators can quickly and efficiently improve the appearance and function of rights-of-way. Clearing **brush** and **herbaceous weeds** from rights-of-way is time consuming and labor intensive. However, herbicides and **plant growth regulators** can transform vegetation to improve visibility, landscape beauty, safety and the function of rights-of-way. You, as the applicator, must match the pesticide to the pests and the conditions of control.

For example, topography and soil types vary. Urban and rural areas, waterways and adjacent farmland used for crop and animal production pose diverse and special problems when using pesticides in right-of-way upkeep. In special cases of pest invasion, you may need **insecticides** or **fungicides**. However, in most pest-control decisions, you will choose herbicides and / or plant growth regulators. This manual discusses the impact of pesticides on **non target sites**. Always plan your use of pesticides in advance. You should include practices that minimize **spray drift**, runoff, washoff and other types of off-site pesticide movement.

For special environmental and safety hazards, you must review the pesticide label because of the wide variety of areas rights-of-way traverse. A principal concern when using chemicals in rights-of-way is containing the treatment within the rights-of-way themselves. In all cases, take steps to avoid or to minimize the impact of treatments on areas adjacent to the right-of-way.

Specialized areas: considerations

Aquatic areas: When treating areas adjacent to aquatic sites such as ponds, use herbicides that are labeled for that purpose. Avoid drift and **vaporization**, and keep spray out of the water. Avoid **lateral movement** or run off from the treated area into the aquatic habitat.

Desirable vegetation: These areas include gardens, crops, ornamentals, etc. Do not apply herbicides to areas where the roots of desirable plants may **absorb** the chemical. Desirable plants located off the right-of-way often have much of their root systems under the right-of-way.

Sloping areas: These areas, stripped of vegetation by the use of herbicides, will encounter **erosion**. In such areas, maintain a cover or mulch by occasionally skipping retreatment or use **selective herbicides** that leave grasses growing.

Metal surfaces: Certain herbicides are corrosive. Therefore, when you apply them, avoid spraying automobiles, buildings and other metal surfaces.

Use of herbicides around people and livestock

Near people: The best guide is to handle all herbicides with care. Avoid splash or spray contact, and keep exposure to a minimum. Keep herbicides in containers that are properly labeled, and do not make them easily accessible to children. Never dump unused herbicides where they can contaminate water supplies. The best solution is to mix just enough spray solution for the job you are planning. It is better to spray excess solution out over an area at the treatment rate than to dump excess mix onto a small area. Avoid spraying particles or herbicides on yourself or other people and domestic animals that are in or near the treatment area.

Near livestock: Herbicides sprayed on plants are generally not toxic to livestock. However, livestock may be poisoned by eating unused herbicides left in open containers or by drinking water contaminated with herbicides.

Certain unpalatable or poisonous plants may become more palatable to livestock after being treated with herbicides. Be sure that livestock cannot have access to poisonous plants that have been treated with herbicides. Observe grazing and hay-cutting restrictions where pastures have been treated.

Weed identification

Accurately identifying undesired vegetation, or weeds, is the first step in developing an **integrated management program**. This is particularly true if you plan to use herbicides because many herbicides are effective in controlling only some of the many plant species you may encounter. Plant identification manuals are available through various agencies, including university, government and private chemical companies. These can aid you in plant identification. If you are unable to identify a plant, send or take specimens, which include flowers if possible, to your local University Extension center.

Weeds include any unwanted or undesired vegetation; weeds are plant growth that is unsightly, potentially harmful or hazardous to animal or human health. More simply, a weed may be defined as a plant “out of place.”

Next, this manual discusses plants that are considered weeds according to the manner of their growth habit and life cycles.

Monocots: When monocots germinate, they have a single primary leaf or **cotyledon**. The cotyledon does not emerge above the soil surface, and the first leaves seen are actually secondary or true leaves. All monocots have narrow leaves with parallel veins, and they usually have a **fibrous root system**. They most commonly reproduce by seed, **stolons** (creeping stems above the soil surface) or **rhizomes** (creeping stems below the soil surface). The growing point in monocots is frequently at or below the soil surface, particularly in young plants. Monocots include grasses, sedges and cattails. These plants often are desirable in right-of-way sites.

Dicots: When dicots emerge from the soil, they have two primary leaves or cotyledons. The cotyledons often don’t look like the later true leaves. Dicots usually have broad leaves (thus the term broad-leaved plants) with veins that form a netlike pattern; the plants generally have a **taproot**. All species can reproduce by seed, but some have vegetative buds either in the **crown** or on the taproot, and still others reproduce by spreading rootstocks.

We further classify dicots as either herbaceous or **woody plants**. Woody dicots include brush, shrubs and trees. Brush and shrubs have several stems and are less than 10 feet tall at maturity. When trees are present, the brush and shrubs are considered understory. Trees usually have a single stem and are more than 10 feet tall at maturity. They may be **evergreens** or **deciduous**. Some woody plants can spread vegetatively as well as by seed (e.g., sumac). In contrast to monocots and herbaceous dicots, woody plants can be controlled at any time of year if you select an appropriate method.

Life cycles of weeds

We also categorize weeds according to how long they live and the season in which they grow. The categories often are mentioned on herbicide labels and are important in determining how best to control a particular weed. (See Figures 1 and 2)

Annuals: **Annual weeds** live less than 12 months, and annual dicots have taproots. Annual weeds can produce a multitude of seeds du ring a single growing season and, generally, are most troublesome in newly planted areas and in cultivated soil. Many seeds of annual weeds will germinate during the following year, but some seeds may remain dormant in the soil for as many as 50 years before they germinate and emerge as plants.

Summer annuals: These germinate from seed in the spring, flower and produce seed during the summer and die in the late summer or fall; they overwinter as seed. They are best controlled in the seedling stage. Redroot pigweed, common lambsquarters and common ragweed are examples of broadleaf summer annuals; grassy summer annuals include foxtails and crabgrass.

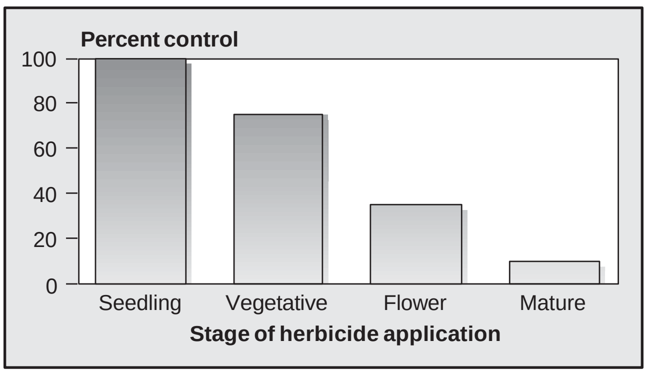


Figure 1. Weed control of annuals.

Winter annuals: These germinate from seed in the late summer and fall, overwinter as low-growing plants, flower and produce seed the next spring and then die. They are easiest to control in the seedling stage. Shepherdspurse and pennycress are broadleaf winter annuals, and downy brome grass is a grassy winter annual.

Biennials: These are weeds that live for two growing seasons and have tap roots. They germinate from seed in the spring or summer and produce a **rosette** of leaves on the soil surface. Biennials overwinter in this rosette stage and require a cold period to flower. The following year they flower, produce seed and then die. They are most serious in pastures, roadsides and neglected areas. You achieve the best control of biennials when they are in the seedling or rosette stage the year they germinate or in the rosette stage the second year. Once the flower stalk is formed (it is known as the bolting stage), biennials are difficult to control with herbicides. Examples of biennials include bull and musk thistles, common mullein and wild carrot. There are no biennial grasses, brush or trees.

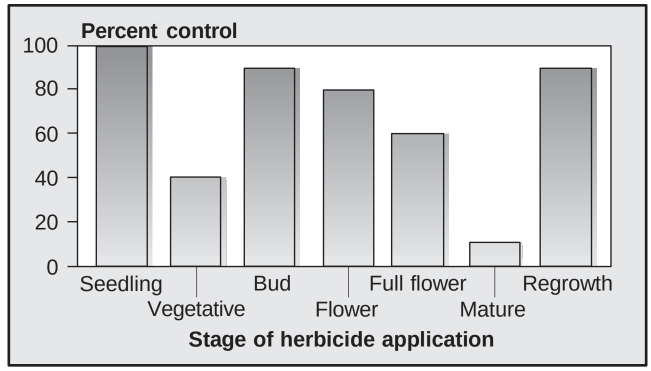


Figure 2. Weed control of perennials.

Perennials: These are weeds that live for more than two years and may live almost indefinitely. Perennials may reproduce only by seed (e.g., dandelion) or may also spread vegetatively by:

- Stolons (e.g., ground ivy),
- Rhizomes (e.g., cattails),
- Spreading rootstocks (e.g., Canada thistle and field bindweed), and
- **Tubers** (e.g., nutsedge).

These may serve as survival or reproductive structures. Taproots (dandelion) serve as survival but not reproductive structures.

Perennials may germinate from seeds in spring or summer but normally don’t flower du ring the season they are established from seed. Their topgrowth freezes back each winter, so their survival depends on underground structures. Perennials resume growth the following year from buds on the crowns, roots or tubers; they then flower and set seed that year and each year thereafter. Perennial weeds are the most persistent and difficult to control. However, not all perennials are undesirable in rights-of-way, particularly if you want a permanent ground cover.

Weed alert: Missouri’s noxious weeds

Noxious weeds are weeds that must be controlled, according to state law. Currently, seven species are listed as noxious weeds in Missouri: johnsongrass, purple loosestrife, field bindweed, multiflora rose, musk thistle, Scotch thistle and Canadian thistle. Because many thistle species exist in Missouri, and because they are difficult to distinguish from one another, you should control all thistles. Noxious weeds are competitive with desirable vegetation and may spread to adjacent properties.

Herbicide classification

Herbicides may be placed into groups by chemical names, by the way they are applied, how they control weeds or by the type of **formulation**. A simple classification scheme is as follows:

Selective: These herbicides have true physiological selectivity if they are applied to a mixture of plant species growing on the same site. Selectives control only certain species while causing little, if any, significant injury to others. You may selectively control one or more species by using chemical sprays on the lower portions of tall-growing plants or under trees onto the foliage of smaller plants that grow underneath. Selective control allows the desired plants to grow normally as the affected plants are controlled. For example, you may use 2,4-D to control dicot weeds in grassy areas without adversely affecting grass growth and normal seed production.

Nonselective: Herbicides that damage all plants they contact are nonselective. You can apply them selectively by directing their placement as noted above. For example, johnsongrass may be controlled in a stand of crownvetch by applying Roundup with a rope-wick type of applicator when the johnsongrass grows higher than the crownvetch around it.

Contact herbicides: These affect only the leaf or stem tissue that is sprayed. They usually affect plant functions rapidly after application. Plants that germinate afterwards most likely won't be affected. Most contact herbicides bind to organic matter or clay soil particles and therefore do not affect plants. You may control annual weeds with contacts, but you'll only retard temporarily the growth of perennials. Examples of contact herbicides are MSMA and paraquat.

Translocated herbicides: Plants absorb these herbicides into their foliage or their roots. Because these processes are slow, it may be days or even weeks before the herbicide reaches its site of action. The target site of action may be a specialized **enzyme**, **cell membranes** or the **chloroplast** where a plant traps carbon dioxide for sugar production. Translocated herbicides are effective for control of perennial weeds that may regenerate from crown-root buds or from buds that arise at the junction of branches with the main stem of the plants.

Bare-ground herbicides: Soil-sterilant herbicides are applied to prevent all plants from growing on the site for six months or more. A good use of these materials is to control vegetation around buildings, in fence rows and areas where a fire hazard exists. Because the herbicidal dosage determines how long the residue will be active, several herbicides may serve as temporary sterilants if high dosages are applied. Avoid herbicides with high **water solubility** or **vapor pressure** because of the possibility of leaching into ground water or vapor movement out of the soil.

Pesticide application equipment

The equipment you'll use to apply pesticides varies with the vegetation or other target, the type of application, the pest to be controlled and the pesticide formulation. No matter which type of equipment you'll use, there is one requirement: it must apply the proper amount of pesticide equally over the target area. You must know at what rate the pesticide is being applied. This is known as **calibration** and will be addressed in a later section.

Components of pesticide application equipment

Tanks: The tank is a major component of the sprayer. It should be large enough to avoid frequent refilling. Stainless steel and fiberglass are considered the best tank materials because of their corrosion resistance. They are expensive, and buyers must weigh their need for durability against cost. Every tank should have shut-off valves so that any liquid in the tank can be held there without leaking out of the pump, strainers or other parts of the system that are serviced most frequently.

Agitators: The need for agitation depends on the type of pesticides applied. Liquid concentrates, soluble powders and emulsions (E) require little agitation; usually the flow from the bypass hose is enough. Wettable powder (WP) suspensions, however, require vigorous agitation to prevent settling out. Tanks with square corners require better agitation than tanks that are rounded. Two methods exist for agitating spray material in the tank. Paddles or a propeller provide mechanical agitation. The return flow of excess spray material from the pump provides hydraulic agitation. When hydraulic agitation is used to suspend wettable powders, a simple bypass line from the relief valve is not enough. There should be a separate agitator line from the pressure side of the pump to the bottom of the tank.

Strainers: Strainers are used to prevent scales, rust flakes and other foreign material from plugging nozzles or other working parts of the sprayer. You may install them as necessary on the pressure line or may buy them as a part of the nozzle and should place them on the intake line.

Pumps: A good spray pump must deliver the required pressure and volume within its normal working capacity so that it is not constantly working at its limit. If you use abrasive materials, it must be able to pump them over a long period of time without much loss of performance. The metal parts must resist corrosion if corrosive materials will be used. When using most liquid pesticides, you should choose gaskets, plunger caps and impellers that are resistant to swelling or chemical breakdown. If you use wettable powders, the pump must be resistant to abrasion.

Pressure regulators: A pressure regulator is one of the most important parts of a sprayer. It controls the pressure and therefore the quantity of spray material delivered by the nozzles. It protects pump seals, hoses and other sprayer parts from damage from excessive pressure and bypasses the excess spray material back to the tank. Simple relief valves and pressure unloaders are the two types of pressure regulators. The relief valves are simple bypass valves that require the pump and engine to keep working as though one were spraying. However, the unloaders maintain working pressure on the discharge end of the system but move the overflow back into the tank at lower pressure, thus reducing strain on the engine and the pump. When selecting a pressure regulator, be sure that the flow capacity of the regulator matches that of the pump being used.

Pressure gauges: A pressure gauge is essential on any sprayer. Without one, you cannot tell how the sprayer is functioning. If pressure does not remain constant, the amount of liquid coming out of the nozzles will vary. You should mount the gauge so that you can see it easily. Pressure gauges often wear out because they become clogged with solid particles of spray material. A glycerin-loaded diaphragm-type gauge is more expensive, but it will last indefinitely.

Hoses: Consider four main points when selecting sprayer hoses: composition, construction, working pressure and size. High-quality hoses and fittings are expensive but cost-effective when used over a long period of time. The hose liner should be resistant to the chemical action of the spray materials. The working pressure of the hose should be equal to the maximum pressure that the pump delivers. If the hose is too small (inside diameter), the sprayer will not operate properly. If the hose in the suction line is too small, the pump will not get enough pesticide mixture. If the hose in the pressure line is too small, volume at the nozzle(s) will drop.

Nozzles: A nozzle is an atomizing device that spreads the liquid droplets in a definite direction to form the spray pattern. A complete nozzle assembly consists of the body, screen, cap and tip or orifice plate. The function of the nozzle body is to attach the screen and tip to the boom. Several different nozzle body designs are available. All designs perform adequately, but each design has advantages for specific spraying jobs. Nozzles accommodate a variety of replaceable tips or discs to meet spraying requirements. Manufacturers of sprayer nozzles can supply data sheets for the delivery rate, usually in gallons/minute at different pressures for their nozzles. The application rate cannot be specified on these data sheets unless the forward speed of the sprayer and the spraying pressure are specified.

Warning: Never operate nozzles at high pressures to compensate for selecting the wrong nozzle size. Unnecessarily high pressures increase the rate of nozzle wear and increase the drift hazard.

Nozzle tips and discs are made of aluminum, brass, ceramic, plastic, stainless steel or tungsten carbide. Tungsten carbide discs, both ceramic and stainless-steel tips, are more resistant to abrasive wettable powders and are more expensive than brass tips. Nozzles commonly used to apply herbicides to rights-of-way with ground equipment include flat fan, off-center (OC), boomless and whirling disc.

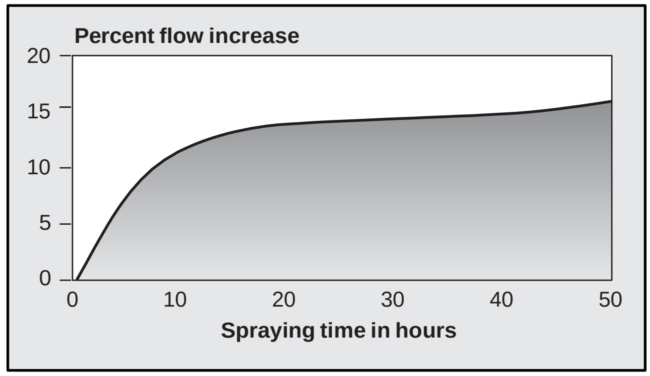


Figure 3. Nozzle wear.

The regular flat-fan nozzle is used for broadcast spraying, such as broadleaf weeds in turf. The pattern is a narrow oval with lighter edges. When a series of these nozzles is properly mounted on a boom and overlapped 30 percent to 50 percent, the pesticide spray is more evenly distributed than with other types of nozzles. At 30 pounds per square inch (psi) to 60 psi, the flat-fan nozzle delivers small droplets to medium droplets that do not drift excessively.

The most commonly used flat-fan nozzles have a spray angle of 65, 73 or 80 degrees; the most commonly used pressure is 40 psi. For most herbicide applications done with a relatively short boom (20 feet to 35 feet), the 80-degree, flat-fan nozzle is best. You may keep the boom relatively low to reduce the drift hazard and give a uniform distribution of spray material over the entire length of the boom.

The flat-fan nozzle is available in brass, plastic, stainless steel and hardened stainless steel. The brass nozzle is inexpensive and satisfactory for spraying pesticides in solution. It is not durable enough to spray more than 20 acres with abrasive wettable powders. (See Figure 3) The plastic nozzle resists corrosion but should not be used to spray more than 60 acres with abrasive pesticides. The hardened stainless-steel nozzle is the most durable, but it is not corrosion resistant.

Note: When using wettable powders, you must calibrate the sprayer frequently. As a nozzle wears, the quantity of spray material delivered increases.

Low-pressure sprayers with specialized booms or off-center nozzles are widely used for roadside and railroad-yard maintenance. Specialized booms include those used to spray under guardrails and around other obstructions. Many variations exist, and their use depends on maintenance requirements.

Off-center nozzles throw a wide-swath, off-center, flat spray pattern that is reasonably uniform across its width. Thus, a spray truck can move along a highway and apply herbicides to a wide roadside right-of-way, or a hyrail truck can treat, in a single pass, multiple railroad tracks in a yard-maintenance program.

The Radiarc sprayer is a precision, boomless, low-volume application device that will apply pesticides in a uniform pattern while controlling spray drift. Its large droplet size and narrow droplet spectrum provide precise targeting with accurate, sharp edges to the spray swath. The spray device oscillates to make a uniform mechanical distribution of pesticide sprays at low-volume applications while controlling drift. The Radiarc sprayer is specifically designed to disperse particulates, suspensions, wettable powders and emulsifiable concentrates.

Boomless sprayers, a modification of OC nozzles, have a central nozzle or cluster of nozzles that produce a wide spray pattern that results in a wide swath similar to that laid down by a boom-type sprayer. Deposit is fairly uniform over the swath.

Rather complex whirling discs used with adjuvants that reduce fine droplets also have been developed for wide-swath application without using a boom. These are used on both ground and aerial equipment and have been developed as small hand-operated units for use on turf.

Factors affecting spray drift

The rate at which particles fall through the air and, subsequently, the distance pesticide spray particles travel is affected by their size and gravity. (See Table 1) Droplet size refers to the size of the individual spray droplets that comprise a nozzle's spray pattern. You measure the diameter of spray droplets in microns; a micron is 1 / 1,000 of a millimeter (diameter of a human hair is approximately 50 microns). All droplets from a nozzle are not the same size. Therefore, spray applications often have droplets that range from extremely fine to coarse. Small, light-weight particles (i.e., 50 microns or less) fall slowly and are more susceptible to drift. The median droplet-size range for nozzles commonly used for right-of-way herbicide applications is from 200 microns to 800 microns. Keep nozzles as low as possible to diminish wind effects. Less spray drift occurs with shorter distances between the nozzle tip and target. Do not, however, position nozzles lower than the recommended height for the nozzle you are using. Nozzles with wide angles of output and those more closely spaced on a boom allow you to place the boom closer to the target.

Spray pressure influences the size of droplets formed. Increasing nozzle pressure creates smaller spray droplets, which are more susceptible to drift. Use the lower or median pressure recommended for your nozzle type.

Table 1. Spray droplet size and relative drift hazard.

Droplet Diameter in Microns	Relative Size of Particle	Time Needed to Fall 10 Feet	Distance Drifted in 3 mph Wind
5	Fog	66.0 minutes	3.0 miles
100	Mist	10.0 seconds	409.0 feet
500	Light Rain	1.0 second	7.0 feet
1,000	Usual Rain	0.1 second	4.7 feet

Effects on nontarget organisms

Pesticides on **nontarget organisms** may cause direct, immediate injury or, if used in the same place over a long time, may cause harm to the environment. We will discuss in the following sections the effects of pesticides on nontarget plants, bees and other beneficial insects, livestock, fish and wildlife and endangered species.

Phytotoxicity: Phytotoxicity is injury to plants because of exposure to a chemical. Phytotoxic injury can occur on any part of a plant: roots, stems, leaves, flowers or fruits. Nearly all pesticides can cause plant injury, particularly if they are applied at too high a rate, at the wrong time or under unfavorable environmental conditions.

As you might expect, however, most phytotoxic injury is caused by herbicides, which are, of course, designed specifically to kill plants. All herbicides kill plants by interfering with one or more of the vital processes of plant life. These processes include germination, cell division, **photosynthesis**, **respiration** and protein synthesis.

Herbicides may damage either the plants they are meant to protect or other plants on adjacent land. Injury to the desirable plants occurs most frequently when the chemical has a narrow range of selectivity between those plants and the target weeds. Damage to plants in adjacent areas primarily occurs because of drift or overspray, although damage sometimes is caused by surface run off, particularly from sloping areas. (See Figures 4 and 5)

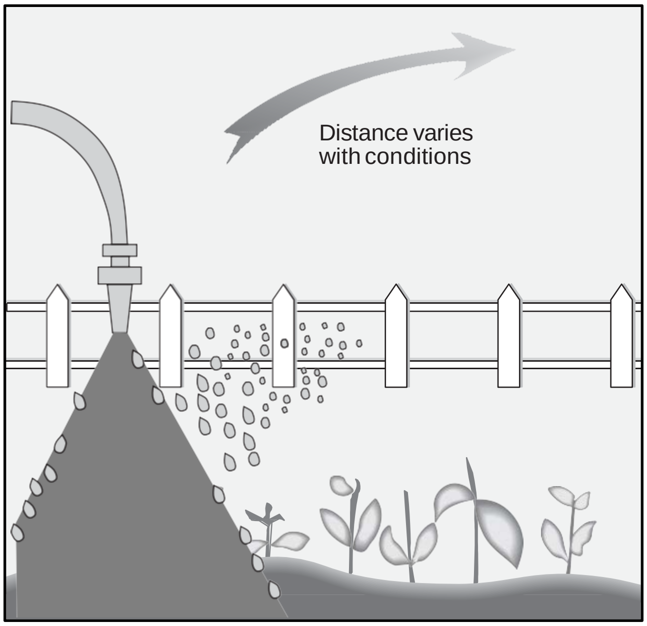


Figure 4. Particle drift: Spray droplets may move to adjacent areas during herbicide application.

Persistent herbicides at the site of application also may injure succeeding plants. Injury to succeeding plants is particularly common when abnormally cold or dry weather inhibits degradation of the herbicide or when application rates are unusually high.

Damage to fish and wildlife: The potentially harmful effects of pesticides on fish and wildlife have been the focus of widespread concern, particularly since the early 1960s. There is, without question, valid cause for concern.

Damage to fish and wildlife may be either a direct and immediate consequence of improper pesticide application (e.g., direct fish kills resulting from overspray or drift into an aquatic environment), a result of contamination of wild plants used as a food source or a result of indirect pollution of fish and wildlife habitats, principally through soil erosion, surface run off and leaching. In the case of pollution, pesticides with longer persistence are a significantly greater hazard; those that are both persistent and accumulative pose the greatest risk.

Pesticides may either kill fish and wildlife or, at sublethal doses, cause harm, including reduced growth, behavioral changes and decreased reproduction. Sublethal effects may be the most serious problem for wildlife; many of the highly publicized effects of the chlorinated hydrocarbons on wildlife, notably on fish-eating and raptorial birds, have been linked to reduced reproduction.

Pesticides have been implicated in the decline of numerous species of native plants and animals. To minimize the harm pesticides can do to federally endangered and threatened species, and to ensure that these species and their habitat will no longer be jeopardized, the EPA is developing a new program of use restrictions under the Endangered Species Act. In the new program, pesticides harmful to native plants and animals will have a warning statement about their use within the geographic range of any endangered or threatened species. The statement will instruct users as to what actions they need to take to safeguard endangered and threatened species.

Sprayer Calibration

Calibration ensures that your equipment delivers the correct amount of pesticide uniformly over the target area. Unfortunately, calibration is the one step in pesticide application that is most often neglected and misunderstood.

A University of Nebraska study found that two of every three pesticide applicators missed their intended application rate by more than 5 percent because of errors in calibration, mixing or both. Errors in application rate ranged from 40 percent underapplication to 60 percent overapplication. Frequent sources of significant error were unknown or inaccurately marked tank volumes, worn nozzles, inaccurate pressure gauges and inconsistent traveling speed. Calibration studies conducted in several other states show similar results.

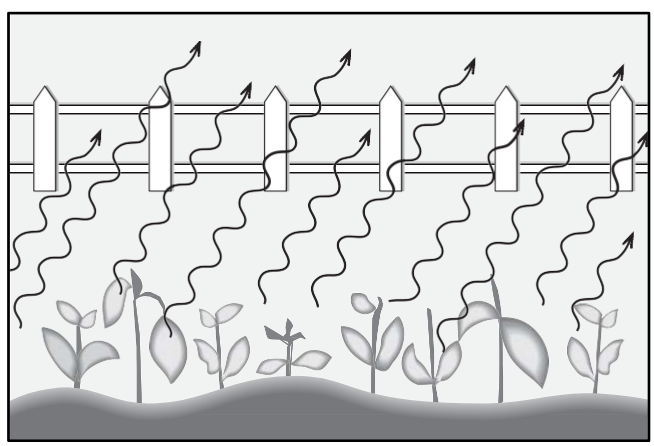


Figure 5. Herbicides vaporize after application and may cause injury to sensitive plants at a considerable distance from the place of application.

A 10 percent overapplication of chemicals adds $1 to every $10 in pesticide costs. Money lost from overapplication can amount to several dollars per acre. Wasted chemical, however, is not the only cost. Overapplication may result in carryover and increase the potential for ground-water contamination. On the other hand, low rates could result in marginal pest control and necessitate a follow-up application. Clearly, over- and underapplication lead producers to lose a substantial amount of money.

For proper calibration, you need a few basic tools, including a stopwatch, a collection container graduated in ounces, a tape measure and flags or stakes for marking. Unless your sprayer is new, it will have a certain amount of pesticide residue; therefore, you should wear a pair of rubber gloves. Additionally, a pocket calculator may help you calculate correctly and minimize mathematical errors.

In this section, we provide formulas that should make calibration easier for you. Some of these formulas have numbers that are constants; by that we mea n that the number remains in the formula whenever you use that formula. To make calibration easier, we provide you with the constants rather than give you the complicated calculations from which the constants are derived.

Applications in rights-of-way are done on either a per-acre basis (i.e., 2 quarts per acre), or individual plants or patches of perennial weeds are sprayed to the point of run off with a solution that contains a certain percentage of herbicide (i.e., a 1.5 percent solution). We will discuss calibration for both methods.

Application on a per-acre basis: You should seldom make broadcast applications to large areas of rights-o f-way. However, you can treat patches of wee ds with fixed- boom sprayers set up to deliver an exact gallonage of spray solution per acre. This application method also is used to treat substations and other areas where you want total vegetation control. Calibrating a sprayer will ensure that it delivers the intended volume of spray mixture to the target area. To do this, you must deter mine each of the following:

- How much mixture your sprayer applies per acre,
- How many acres you can spray per tank,

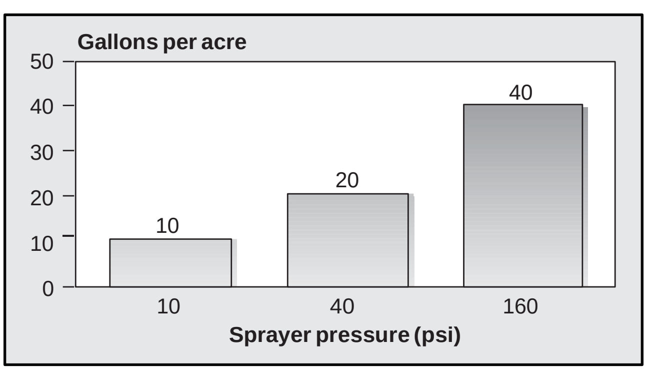


Figure 6. Nozzle flow rate.

- The recommended rate of pesticide application, and
- The amount of pesticide to add to the spray tank.

Always make sure that your application equipment is working properly. We will now discuss these aspects of calibration in detail.

Variables that deter mine the spray rate: Only two variables affect the amount of spray mixture app lied per acre (most commonly expressed in gallons per acre): the nozzle flow rate (see Figure 6) and the ground speed of the sprayer (see Figure 7). You must understand the effect of each of these variables on sprayer output to properly calibrate and operate your sprayer.

Nozzle flow rate: The flow rate through a nozzle varies with the nozzle pressure and the size of the nozzle tip. Increasing the pressure or using a nozzle tip with a larger opening will increase the flow rate. Increasing pressure will not, however, give you a proportional increase in flow rate. For example, doubling the pressure will not double the flow rate; you must increase the pressure fourfold to double the flow rate. Pressure cannot be used, therefore, to make

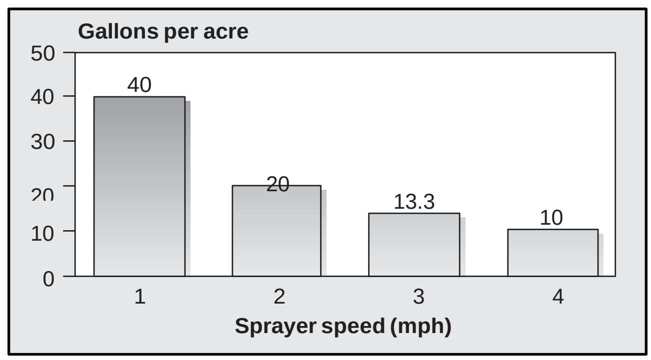


Figure 7. Sprayer ground speed.

major changes in spray rate, but it can be used to make minor changes. Keep in mind that you must maintain operating pressure within the recommended range for each nozzle type to obtain a uniform spray pattern and minimize drift.

The easiest and most effective 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 nozzle spacing, small changes in nozzle size can significantly change sprayer output per acre. Use nozzle manufacturers' catalogs to select the proper tip size for the output, speed and pressure that you desire. However, you must do the calibration procedure even if your sprayer has new nozzles.

Ground speed: Provided the same throttle setting is used, as speed increases, the amount of spray applied per unit area decreases at an equivalent rate. For example, doubling the ground speed of a sprayer will reduce the amount of spray applied by one- half.

To determine the new output after changing speed:

$$\text{New output} = \frac{\text{old output x old speed}}{\text{new speed}}$$

Some sprayers are equipped with control systems that maintain a constant application rate over a range of travel speeds, provided the same gear setting is used. Pressure automatically changes to vary the nozzle flow rate in proportion to changes in ground speed. Even so, do your calibration at a set ground speed. As you spray, you must keep the travel speed within certain limits to keep the nozzle pressure within the recommended range.

Nozzle uniformity: After making sure the system is clean, fill the tank approximately half full with water. Fasten a graduated container under each nozzle, and operate the sprayer at a pressure within the recommended range. Check to see that the flow rate from each nozzle is approximately the same; replace or clean any nozzle that has an output that differs by more than 5 percent from the average for all of the nozzles, and again check the flow rates. (See Table 2)

The average nozzle output is 240/6 = 40.0 ounces. Five percent of 40 ounces is 40 x .05 = 2 ounces. You should clean or replace any nozzle that has an output that differs from 40 ounces by more than 2; for example, replace any nozzle with an output greater than 42 or less than 38 ounces . Therefore, nozzle No. 5 should either be cleaned or replaced. The flow rate of nozzle No. 2 is too high; this indicates the nozzle is worn and should be replaced.

Table 2. Flow rates.

If the following flow rates are obtained for six nozzles:

Nozzle	Output (oz/min)	Nozzle	Output (oz/min)
1	40.0	4	40.5
2	43.0	5	37.5
3	39.5	6	39.5

Total = 240.0 ounces

When a nozzle output varies by more than 10 percent from the manufacturer's specifications, you should buy a new set. This is particularly important when using flat-fan or flood nozzles because proper spray overlap becomes difficult to maintain with worn nozzles.

Spray pattern uniformity: A uniform spray pattern is crucial to apply pesticide effectively. It's not enough to apply a pesticide only in its correct amount; you also must apply it uniformly over the target area. The effects of nonuniform application are most obvious when herbicides are applied and streaking results. Uniformity is affected by boom height, spacing and alignment of nozzles on the boom, condition of nozzles (worn, damaged) and operating pressure. Also check that all nozzles are of the same type; frequently, using nozzles with different spray angles on the same boom causes poor spray patterns. To check the uniformity of the spray pattern, adjust the boom height for the spray angle and nozzle spacing. Align flat-fan nozzles at a slight angle to the boom. Using water, operate the sprayer at the desired speed and pressure on clean, dry pavement or on another smooth surface. Observe the spray pattern as the water evaporates. Clean or replace nozzle tips that produce a poor spray pattern; if necessary, readjust boom height and recheck the spray pattern. If you replace any nozzles, recheck the flow rates.

Other equally effective calibration methods may vary in their basic approach and degree of difficulty. For the purposes of this manual, we have chosen several methods that are simple and will let you calibrate quickly.

Methods:

Spray an acre

1. Choose the speed, pumping pressure and nozzle or nozzles that you want to use.

2. Fill the sprayer tank with water and operate the sprayer to fill all pipes and hoses.

3. Determine the distance over which the sprayer must operate to treat one acre by dividing the boom or swath width by 43,560 square feet.

43,560 square feet = 1 acre

For example, if your swath width is 18 feet, how far must you travel to treat an acre?

43,560 square feet/18 feet = 2,420 feet

4. Measure the amount of water needed to refill your tank. This is the application rate per acre. If it takes 20 gallons to refill the tank after spraying one acre, you are spraying at the rate of 20 gallons per acre. If it takes 70 gallons to refill the tank, your sprayer is applying 70 gallons per acre.

Spray less than one acre

Because an acre is a sizable piece of ground, it may be easier to spray only part of an acre:

1. Mark out a measured test area to be sprayed, as in the previous example.

2. Fill the spray tank with water.

3. Spray the measured run using the pressure and speed appropriate for the sprayer. Be sure the sprayer is at correct speed when you reach the test strip. Turn off the sprayer as you cross the other end.

4. Refill the tank to the initial level, carefully measuring the quantity you add.

5. Deter mine the number of acres that were sprayed in the test run.

$$\text{Acres sprayed} = \frac{\text{swath width (feet) x distance (feet)}}{\text{43,560 square feet}}$$

For example, if your test run was 500 feet and your swath width was 18 feet, then how many acres did you spray?

Acres = 18 feet x 500 feet = 9,000 square feet

9,000 square feet /43,560 square feet = 0.21 acre

6. Deter mine the application rate per acre. For example, if 10 gallons were required to refill the tank, then:

10 gallons/ 0.21 acre = 47.6 gallons per acre

Stationary calibration

In some cases, it is most convenient to make adjustments on the sprayer, measure the output and determine the output in gallons per acre without having to move the sprayer. However, you must know the correct operating speed of the sprayer or assume a speed and make sure you drive that fast on the treated site. Two numbers must be determined: 1) gallons per minute — how many gallons your sprayer pumps out in a minute; and 2) acres per minute — how long it takes to treat an acre. We can deter mine these numbers by the following steps:

First, deter mine the p m ping rate (gallons per minute or GPM).

1. Fill the spray tank and sprayer plumbing completely full of water.

2. Put vehicle in neutral at the throttle setting (rpm) desired.

3. Open the spray valve and pump for a predetermined time, such as one minute, with the sprayer pressure the same as in actual operation.

4. Close the valve, shut down the equipment and measure the amount of water needed to refill the tank. You may find it more convenient to catch the sprayer output and measure that than to measure the amount needed to refill the tank. For the boomless spray devices, you can tie a plastic bag over the unit to direct the water into a bucket. For a boom with several nozzles, catch each nozzle separately. Remember, the output from each nozzle should be similar. Add each nozzle output together for the total output for the boo m.

5. Divide the number of gallons needed to refill the tank, or the number of gallons caught, by the time of pump operation to get pumping rate in gallons per minute.

$$\frac{\text{Gallons}}{\text{minute}} = \frac{\text{gallons to refill tank or caught}}{\text{minutes of pump operation}}$$

For example, if it takes 36 gallons to refill your tank after operating the pump for three minutes, what is your GPM?

Gallons/ minute = 36 gallons/ 3 minutes = 12 gallons/ minute.

Next, determine how many acres your sprayer will treat in a minute.

1. Deter mine the number of feet the sprayer moves at the desired speed and throttle.

2. Measure the width of the spray swath.

3. Calculate the area (See Figure 8, next page), in acres, that the sprayer covered in one minute (distance traveled x boo m width). You did this in a previous problem.

For example, if your sprayer treat s a 20-foot swath width and travels at 10 mph for one minute, how many acres would be treated?

1 mile/hour (mph) = 88 feet/minute (fpm)

If 1 mph = 88 fpm, then 10 mph is 10 times as fast, which means that you covered a distance of 880 fpm (10 mph x 88 fpm). We can now determine the number of treated acres by remembering the constant, 43,560 square feet per acre.

Acres/ minute =

880 fpm x 20 feet = 17,600 square feet

17,600 square feet /43,560 square feet

= 0.40 acres.

Now that we know 12 GPM is the output rate and 0.40 acres per minute are covered, it is simple to deter mine the number of gallons per acre (GPA) applied.

$$\frac{\text{Gallons}}{\text{acre}} = \frac{\text{gallons}}{\text{minute}} \times \frac{\text{minute}}{\text{acre}}$$

Therefore, in our example:

12 gallons/ 0.40 acres = 30 GPA

Acres per tank

After deter mining your sprayer's rate of application, GPA, you then measure your spray tank's capacity to establish how many acres you can treat with each full tank. This dictates how much chemical you add to the tank.

$$\frac{\text{Acres}}{\text{tank}} = \frac{\text{tank capacity}}{\text{output (GPA)}}$$

For example, if your tank has a capacity of 300 gallons and the sprayer's output is 30 GPA, how many acres will be treated by a full tank?

300 gallons/ 30 GPA = 10 acres

Amount of product per tank

You have adjusted your sprayer and know how many gallons of solution your equipment will apply per acre. You also know how many acres your tank will treat. Now you must decide how much herbicide to put in the tank. To do this, you need to know the amount of product to be used per unit of area, usually acres. Information is on the label and in your instructions. For example, your tank holds 1,200 gallons of spray solution. Your sprayer has an output of 30 GPA. The directions say to apply 2 quarts of XYZ and 2 ounces of ABC per acre. How much of each product should you add to the tank?

1. Calculate the number of acres one tank of solution will treat. We already know how to do this from a previous example:

1,200 gallons/ 30 GPA = 40 acres per tank

2. Now we can deter mine the amount of XYZ to add to the tank:

40 acres per tank x 2 quarts XYZ = 80 quarts or 20 gallons per tank

3. We can calculate the amount of ABC in a similar fashion:

40 acres per tank x 2 ounces ABC = 80 ounces or 2.5 quarts per tank

Mixing percent by volume

In some applications, herbicides are mixed as a percent of the volume of the tank, and the mixture is sprayed-to-wet (spray until solution drips from foliage). This is often done with handgun s and back-pack sprayers. Mixing percent solutions is also done for wiping applicators, and some **surfactants** are added as a percent of volume. The percentages for herbicides may be 1, 2, 3, 10, 20, 30 or 50 percent. For surfactants, the percentages may be one-fourth or one- half percent. (See Table 3)

Table 3. The decimal equivalent of percents.

Percent (%)	Decimal equivalent
50	0.50
20	0.20
3	0.03
2	0.02
1	0.01
1/2 (0.5%)	0.005
1/4 (0.25%)	0.0025

For example, the instructions call for a herbicide to be applied to the point of run off using a 2-percent solution with a surfactant at one- half percent by volume. How much of each should you add to a 3-gallon tank?

Herbicide = 0.02 x 3 gallons = .06 gallons
Surfactant = 0.005 x 3 gallons = .015 gallons

Often, when dealing with small quantities, you may need to convert units to ounces or, in some cases, grams. (See Table 4) This makes for more precise measuring of products added to the tank.

Knowing that 1 gallon contains 128 ounces, we can then convert:

Herbicide = .06 gallons x 128 ounces/gallon = 7.7 ounces
Surfactant = .015 gallons x 128 ounces/gallon = 1.9 ounces

Ounces per 100 gallons

It is not unusual for surfactants, such as drift-control agents, to be added at the r ate of ounces / 100 gallons of solution.

For example, the instructions call for a product to be added at the rate of 8 ounces per 100 gallons. How much product should be added to the 1,200 - gallon spray tank?

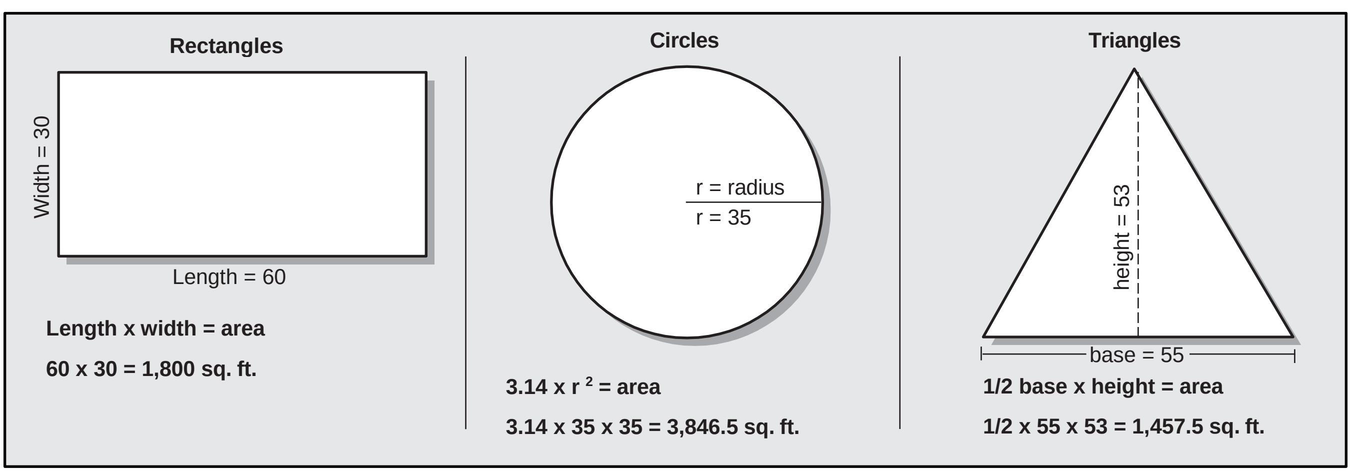


Figure 8. Area measurements.

Table 4. Conversion Table.

Area			
144 square inches	1 square foot		
9 square feet	1 square yard		
43,560 square feet	1 acre		
4,840 square yards	1 acre		
160 square rods	1 acre		
640 acres	1 square mile		
2.5 acres	1 hectare		
Length			
1 inch	2.54 centimeters	25.5 millimeters	
1 foot	12 inches		
1 yard	3 feet		
1 rod	5.5 yards	16.5 feet	
1 mile	320 rods	1,760 yards	5,280 feet
1 meter	39.4 inches	1.09 yards	
1 kilometer	1,000 meters	0.62 miles	
Volume			
1 tablespoon (tbs. or T)	3 teaspoons (tsp. or t)		
1 fluid ounce	2 tablespoons		
8 fluid ounces	16 tablespoons	1 cup	
16 fluid ounces	2 cups	1 pint	
32 fluid ounces	946 ml	1 quart	
128 fluid ounces	3.78 liters	1 gallon	
1 liter	33.9 fluid ounces	1.06 quarts	
Weight			
1 ounce	28.3 grams		
1 pound	16 ounces	453.6 grams	
2.2 pounds	1 kilogram	1,000 grams	
1 ton	2,000 pounds	907 kilograms	
1 metric ton	1,000 kilograms	2,205 pounds	

1,200 gallons/tank x 8 ounces/100 gallons
= 96 ounces or 3 quarts

Or, there are twelve 100-gallon units in a 1,200-gallon tank. If you add 8 ounces for each 100-gallon unit, then you have to add twelve 8-ounce units or 12 x 8 = 96 ounces/tank.

Nonselective vegetation control: guiderails, posts, storage areas

Reasons for nonselective vegetation control: Nonselective weed control reduces the need to trim by hand around signs, guiderails, posts, fences, etc. The bare-ground result of spraying around guiderails and other highway structures enhances visibility for motorists and highway crews responsible for maintenance. You can keep yards and storage areas cleaner and safer with complete weed control. Pretreating stabilized shoulders with a nonselective **residual herbicide** can extend the life of the shoulder substantially.

Guiderail and shoulder weeds collect winter sand and run off from the road pavement. Eventually the sand builds up dikes or **berms** that slow pavement water run off, creating large puddles and ice patches. On fill slopes, trapped run off is channeled against these berms, building up velocity before finding a discharge point over the slope. A concentrated discharge usually causes erosion and slope failure. Although machine grading can remedy this problem on open shoulders, guiderail sections are another matter. Mowing weeds under guiderails by hand is dangerous to workers as well as time consuming and expensive. Applying soil-residual herbicides gives complete control of all guiderail weeds. One treatment usually will last a growing season.

Planning the control program: You must plan ahead with a nonselective weed-control program to make the best use of personnel and equipment.

Usually, you'll achieve the best results from soil residuals before the weeds emerge or when they are small. In general, this means early spring. If experience tells you there has been lateral movement of residual herbicides in former years, you could apply lower rates later in the season with a contact herbicide to minimize further movement. Some areas that have been treated for several years may not need treatment at all.

Equipment: By adjusting boom and nozzle combinations, the same type of low- pressure equipment used for other types of weed control also can be adapted for use along guider ails. Generally, it is sufficient to treat a 3-foot strip under the guiderail. You can do this with a single hand-held spray bar with a single nozzle, or you may place a spray bar with one nozzle high enough to clear the rail posts on a fixed mount on the truck. Equipment that automatically adjusts to obstacles is available, making hand-held spray bars unnecessary.

A nozzle arrangement that can be useful in this situation is the mounting of two smaller, off-center nozzles approximately 18 inches apart and 15 inches above ground level, on a bar in line with the direction of travel. By adjusting the nozzles so that the forward nozzle is angled in the direction of travel and the other toward the rear, you'll eliminate shadowing. The pattern width is determined by adjusting the nozzle angle.

Vegetation in pavement cracks and joints: Herbicides can substantially reduce da mage to pavement from vegetation growing in cracks and joints. Vegetation can expand the crack, which then collects silt and moisture and encourages more growth and further pavement deterioration. A systemic herbicide such as glyphosate (Roundup) is ideal for control in this situation. Soil-residual herbicides could extend the life of an application to cracks, etc. However, you should consider this option carefully because rain can lift a residual herbicide from the joint or pavement surface and carry it to nearby lawns or gutters.

Tree and shrub management

Reasons for tree and shrub management: Trees and shrubs are controlled along roadsides to maintain visibility, particularly along curves, at corners, intersections and in advance of signs. Suppressing trees and woody vegetation along roadsides can reduce shading as well as uneven thawing and pavement drying in the winter. Woody vegetation also impedes the functioning of ditches and drainage ways. Spraying woody vegetation generally controls poison ivy in planned work locations and near homes, schools and playgrounds, which may otherwise be untreated because of the lack of time and funds.

Methods used: Several methods of managing woody vegetation are available to roadside managers and certified pesticide applicators. Most of these combine mechanical cutting with pesticide treatment of stumps and/or regrowth.

Ideally, you should identify and chemically treat areas of woody-plant invasion before the plants become so mature that they require cutting. This often can be accomplished by spraying in a manner similar to broadleaf weed control, with the spray directed from the edge of the pavement. A variation of this is cutting extensive areas of woody vegetation in one operation and scheduling a foliar treatment of the regrowth for the following spraying season.

In areas where brownout or standing dead vegetation can be tolerated, foliar treatment of larger plants is an alternative. You should always cut to the ground large trees in these areas and treat the stumps with a basal herbicide.

After you've brought the woody species under control, you should control extensive regrowth with periodic mowing, spot spraying of regrowth, low-volume basal applications or combinations of methods to avoid extensive cutting and broadcast spraying. Basically, you can follow a program of controlling woody vegetation by cutting and treating stumps year round.

Planning the management program: You can follow a woody-vegetation management program of cutting and treating stumps year round, except during spring, when upward sap flow makes this application less effective. Timing is not as important as in broadleaf or guiderail treatment. However, depending up on the area, planning what pesticides to use is important. You should not use residual pesticides on slopes where you should avoid injury to downhill vegetation. When brownout is a concern, you should time foliage treatments toward the end of the summer, thereby reducing the duration of a brownout.

Fosamine (Krenite) might be the herbicide of choice because it prevents growth the following season but does not cause brownout of the foliage at the time of treatment. Fosamine also can eliminate brownout problems if the woody vegetation is cut and sprayed at the end of the first gr owing season after it has resprouted. The amount of herbicide you'll use is significantly reduced, and the treated plant is not much bigger than the surrounding weeds and grasses.

Equipment for woody vegetation management: For stump treatment on a moderate scale, backpack sprayers will probably suffice. Large-scale treatment may require the use of a hose and handgun supplied by a power sprayer. Low pressures are sufficient, and you can use the same sprayers as those used for guiderail application. You also can use this equipment to apply herbicides to poison ivy.

If you use water-based sprays for foliage sprays, a high-pressure sprayer with hose and handgun will be faster and give better coverage than low-pressure equipment. Remember that these are for special uses only.

Problems and precautions in woody-vegetation management

Foliar brownout is unsightly and may cause criticism from the public, so it is imperative that you accomplish this work with professionalism and sensitivity.

You should wear waterproof foot gear and cover for your legs when ground spraying in tall grass and woody vegetation; this prevents excessive exposure to the pesticide you're using. When leaving these areas, you and other employees should avoid walking through valuable plantings to prevent damage from residues you may be carrying.

Utility rights-of-way vegetation management

Telephone and electric power lines

Vegetation management is necessary along telephone and electric power-line rights-of-way for two reasons: to control tall woody plants that could interrupt overhead transmission line performance, and to improve accessibility for maintenance, emergencies and routine and aerial inspections. A well-managed right-of-way increases both food and protection for wildlife and other animals. More than four million acres of transmission line rights-of-way in the United States represent a substantial wildlife habitat. Rights-of-way that cut through forest areas, with the subsequent growth of herbaceous plants, bushes and young trees, support more animal life than the original tree cover. Wildlife such as rabbits, deer, fox and birds that normally live along the forest edge find food and shelter along rights-of-way.

The soil beneath telephone and electric power lines should not be bare. This area often is planted with perennial grasses that provide erosion control, support maintenance equipment and compete with tall or vining brush that should not be allowed to grow onto the lines. You can control most undesirable vegetation in established turfgrass with occasional mowing or treatment with selective herbicides.

Transformer stations and substations

Total vegetation control (TVC) is required in these areas. You must keep them free of vegetation to prevent short circuits and to alleviate fire hazards that could result from dead vegetation. These sites are usually covered with gravel. Treat the soil periodically with nonselective herbicides that have a relatively long soil-residual activity that prevents weeds from growing up through the gravel.

Pipelines

Pipelines do not require TVC, but you should keep brush to a minimum to allow for line maintenance and aerial inspection. Establishing perennial grass after the pipes are laid will help control erosion. Mechanical removal or periodic treatments with selective brush herbicides maintain these areas.

Railroads

These are similar to other rights-of-way in that they pass through a variety of privately and publicly owned lands with all the problems, such as drift and public relations, that may result. Vegetation control on railroads is different than other utility rights-of-way in that most of the area treated is owned by the railroad; therefore, the treatment can be more easily planned and managed. You'll primarily apply herbicides with ground equipment.

General reasons for vegetation management along the railroad include:

- Allowing inspection of track, ties and roadbed;
- Improving working conditions;
- Increasing safety;
- Reducing the potential for track-side fires;
- Conforming with state, city and local laws;
- Reducing the source of weed seeds to farmers' fields;
- Preventing overgrowth and noxious weeds in urban and suburban areas;
- Improving the appearance of the railroad; and
- Maintaining visibility at road crossings.

Specific areas and reasons for railroad vegetation control include:

- **Ballast** section: maintains drainage; allows inspection of ties, fastenings and switches, increasing the life of the tie; keeps weed seeds out of traction motors on diesel engines; and prevents wheel slippage.
- Shoulder adjacent to ballast: promotes drainage and reduces potential for track-side fires.
- Shoulder: allows unrestricted vision and train inspection.
- Bridges, buildings and other structures: maintains fire safety.
- Yards: maintains safety, convenience and appearance.
- Low switch stands and dwarf signals: assures visibility.
- Inside of curves: allows for train inspection.

- Under communication lines: maintains uninterrupted service.
- Area adjacent to tracks: helps keep trains from fouling.
- Highway grade crossings: allows unrestricted view for both autos and trains.
- Signs (mile posts, whistle boards, etc.): assures optimal view.

Problems common to all phases of railroad vegetation management

Drift: As with any other type of herbicide application, you must avoid drift injury to ornamentals and crops adjacent to the right-of-way. Precautions include using low-pressure, low-mounted booms and nozzles, special application devices coupled with drift-control adjuvants and stopping operations when pesticide begins to drift from the right-of-way.

Brownout: Brownout is not as big a problem as it is along highways because the area along the railroad is not as highly visible. However, you should consider alternative treatments in visually sensitive areas. These could include basal applications or pesticide substitution.

Encroachment of hard-to-kill species: When the same ground is treated year after year with the same herbicides, certain vegetation may not be controlled and may become the predominant species in time. When this happens, you should change herbicides. Long-range planning can help you avoid this problem.

Logistics: Your railroad vegetation-management programs must work with and not impede regular rail traffic because you use the same rails. In other rights-of-way application, there is little if any restriction on the normal use of the highway or utility line. But if you're engaged in railroad vegetation management, you must know train schedules, must plan for track delays (a good time to check equipment) and must be alert and prepared to stop at road crossings. In areas of high commuter traffic, you must spray at night; otherwise the sprayer should be off the tracks before dark.

Evaluating the results

After using any vegetation-management practice, you should inspect the area to evaluate the results. Keep in mind the type and species of vegetation treated, the soil type and weather conditions during and after application. Know the objectives of the control program when you evaluate the results. In some cases, it is sufficient to suppress treated vegetation; in other cases, you'll want selective control; and in still other cases, you'll want TVC. You can determine initial herbicide activity and possible injury to adjacent desirable vegetation two weeks to four weeks after application, in most cases. You should evaluate the results of TVC treatments after about two months and, subsequently, through the end of the season and perhaps for several years. You cannot fully evaluate the effective ness of brush and perennial weed control measures for at least 12 months, and sometimes 24 months, after treatment.

Evaluation must be constant. It allows you to make adjustments in rates, products and timing of herbicide applications, and it allows you to add or adjust nonchemical controls.

Using pesticides to control insects and rodents

The majority of right-of-way pest-control situations include controlling vegetation with machinery and/or herbicides. At times, under certain conditions, migratory insects and rodents also might present problems. Insect pests include grasshoppers, army worms and mosquitoes. Rodent pests include field mice and woodchucks.

Control insect pests with any insecticide registered for such applications. Rodent problems may be reduced by mowing or clipping to remove cover, by trapping or by using registered **rodenticides**. Remember, the Missouri Department of Conservation requires that you get a permit from the department before you can use any chemical to control any form of wildlife.

Resistance to pesticides

As living organisms, pests must adapt to and overcome adverse conditions in order to survive. Plant pests must be able to survive harsh winters and resist attack by parasites and predators. As we know, they have succeeded remarkably well. We shouldn't be surprised, then, that pests also can adapt to any control measures we use against them.

Pesticide resistance is the inherited ability of a pest to tolerate the toxic effects of a pesticide. As pest populations increase their resistance, you should increase the rate or frequency of pesticide application. Eventually, you'll find it impractical or impossible to control the pests with the pesticide to which they have become resistant. In some cases, you won't find any other acceptable pesticide available.

Hundreds of pest species, mostly insects, have become resistant to one or more pesticides. Keep in mind that not all populations of these pests are resistant; however, any population of pests has the potential to develop pesticide resistance.

The development of resistance

Where does pesticide resistance come from? The answer lies in the natural genetic diversity within a pest species. When organisms reproduce, offspring receive copies of the "parent" genetic material. Those copies are not always perfect. Mistakes, analogous to misspelled or missing words, may appear; we call these mistakes mutations. Because the parent was already fine-tuned to its environment, most such mistakes are either harmful or of no consequence. (Imagine the result if you randomly changed one word in your favorite book or one note in your favorite song.)

Sometimes, however, a mutation benefits an organism. That includes mutations that confer pesticide resistance. Because pest populations are so large, it is likely that within a population, a small percentage of individuals will develop resistance to a particular pesticide. These resistant individuals survive when you apply the pesticide, and at least some of their offspring inherit the resistance. Because the pesticide kills most of the nonresistant individuals, the resistant pests will make up a larger percentage of the surviving population. Each time you use the pesticide, this percentage increases, and eventually most of the pest population will be resistant.

In most cases, pest populations that have become resistant to one pesticide also become resistant to other, chemically related pesticides. This is called **cross-resistance**. This occurs because closely related pesticides kill pests in the same way (e.g, all organophosphate insecticides kill by inhibiting the same function that is vital for insect survival). If a pest resists the toxic action of one pesticide, it usually can resist other pesticides that act in the same way, even pesticides from other chemical families that have the same mode of action.

Factors influencing development of resistance

Given that pesticide resistance is an ever-present threat, you need to understand what influences its development. With this knowledge, you can work to prevent resistance development; at the very least, you should know how to recognize or predict the likelihood of pesticide resistance.

Important factors that influence the development of resistance:

- The frequency of pest resistance before you use the pesticide(s) in question: Resistance may be absent from a pest population, or it may be present in a few or many individuals. Obviously, no resistance is best.
- The chemical diversity of the pesticides you use: If you always use the same pesticide or family of pesticides, you won't kill pests that are resistant, and the proportion of resistant pests likely will increase.
- Persistence and frequency of use of the pesticide: Resistance often develops against pesticides that you apply often and that have greater persistence.
- Specific mode of action: Pest populations are more likely to develop resistance to pesticides that, to kill an organism, attack a single structure or mechanism than those pesticides that attack several vital life processes.
- The proportion of the population exposed to the pesticide: When an entire pest population is exposed to a single pesticide application, most nonresistant individuals are killed, which increases the proportion of resistant pests among the survivors. Weeds, however, emerge sporadically and, at any one time, many seeds lie dormant in the soil. As a result, many susceptible weeds are not exposed to a herbicide and, thus, continue in the population.
- The length of the pest's life cycle: As with any other inherited trait, pesticide resistance will increase faster if the pest has a short life cycle and many generations in a single season. This explains why insect populations show resistance faster than weed populations.

Herbicide-resistant weeds

Many weed species have biotypes resistant to herbicides. Most of these biotypes resist triazine herbicides, such as hexazinone (Velpar), and occur in cropland, not rights-of-way.

A recent concern is that within several weed species there are already biotypes resistant to the new chemical groups of sulfonylurea and imidazolinone herbicides. Some of these are on rights-of-way. One such herbicide used in Missouri is metsulfuron methyl (Escort). Herbicides in these chemical groups have a precise mode of action: they prevent a specific enzyme (ALS) from functioning. This enzyme is essential for the production of three amino acids, and protein synthesis stops and plants die when it is blocked. In resistant biotypes, plants develop normally and the enzyme is unaffected. Farmers often use herbicides in these chemical groups for crop production. Thus, farmers and rights-of-way personnel could cause resistance problems for each other. Both sides should practice resistance management to avoid further resistant-weed problems.

Resistance management

In the past, we responded to pesticide resistance simply by switching products. This was possible because new products continually became available. Unfortunately, we have used up this "easy" pesticide chemistry. Today's new pesticides are more complex, difficult to synthesize and more expensive to develop and use. And, even these products may become ineffective because of pesticide resistance. Obviously, switching products is no longer enough.

In developing a pest-management program, you should probably assume that the pests can develop resistance to any pesticide you use against them; in other words, play it safe. This means that you must place greater emphasis on resistance management. This may seem like more work in the short run, but losing the use of a pesticide because of resistance could be more of a problem in the long run.

Resistance management attempts to prevent, delay or reverse the development of resistance. This complex task involves more than just herbicides. You should incorporate the practices described below into your resistance management plan:

- Use an integrated pest-management program. Combine cultural, mechanical and chemical controls into a practical pest-control program.
- Use pesticides with different modes of action. Try to do this whether you apply pesticides against a pest once a year or several times within a treatment season. This way, pests resistant to the first pesticide will be killed by the second.
- Use pesticides only when needed, and use only as much as necessary. A pest population develops pesticide resistance only when you use that pesticide against it. Therefore, if you use the pesticide when you don't need to, you may unnecessarily increase the number of resistant pests. Likewise, don't apply more than you need to keep the pest population below damaging levels. If you apply more to try to eradicate the pests, you will not only waste money (because eradication is usually impossible), you'll also kill an even larger proportion of susceptible pests. As a result, you'll have even more resistant pests among the survivors.

Pesticide spills

It is your legal responsibility to clean up and decontaminate any pesticide spill that occurs during mixing, applying or storing pesticides. When a spill occurs, take immediate action:

1. Attend to anyone exposed to the pesticide. Administer first aid and obtain medical care, if necessary.

2. Clear the area of all people who are not helping to handle the spill. Be sure that everyone helping is wearing protective clothing and equipment to minimize exposure.

3. Promptly confine the spilled pesticide to keep it from spreading and contaminating a larger area or body of water. Large spills of pesticides or spills of specific products require you to notify state and federal agencies. The outside back cover of this manual provides emergency telephone numbers to call if the spill is too large to handle without help or if notification is required. You also must notify local officials if the spill contaminates a body of water, a well, a drainage ditch or other similar area, or if the possibility exists that these water sources could be contaminated.

4. You can absorb a liquid spill on concrete or other solid surfaces with absorptive clay, vermiculite, pet litter, sweeping compounds, sawdust or sorbent products designed for absorbing liquid spills. Do not use sawdust or sweeping compounds on strong oxidizing pesticides because this presents a fire hazard. Absorb as much liquid as possible into the material; then sweep or shovel the contaminated material into a leak-proof drum and properly dispose of the drum as a pesticide waste.

5. Cover the spill area with a material that neutralizes the pesticide. Examples of appropriate chemicals are hydrated lime, a solution of lye, ammonia, sodium hypochlorite (bleach), or strong detergent and water. Contact the chemical manufacturer to determine which of these materials to use.

6. Rinse the area thoroughly with water. Collect this rinsewater and hold for proper handling. Ideally, you apply this rinsewater on an area that is labeled for use of the pesticide while you take care not to exceed the labeled rate. If the pesticide rinsewater cannot be used in this way, then you must dispose of it as a pesticide waste.

When a pesticide (especially a herbicide) spills on the soil, the area may be unsuitable for plant growth unless you remove the contaminated soil or deactivate the pesticide. You can dig up the contaminated soil and distribute it over a large area that is labeled for the pesticide, if you take care not to exceed the label rate. Otherwise, the soil is considered a hazardous waste, and you must dispose of it at a hazardous-waste landfill. Removing contaminated soil may not be feasible except for small amounts of soil.

Activated charcoal (carbon) deactivates many pesticides, including organic herbicides. Some herbicides, however, are formulated with inorganic components, such as chlorates or borates. Charcoal does not deactivate these inorganic components. The product's composition is listed on the label's statement of ingredients. Consult the herbicide manufacturer for specific guidelines in handling spills of herbicides with inorganic components.

Activated carbon, now widely used in diverse industries, is manufactured by heating or chemically treating organic matter to achieve a porous structure. This process produces a large surface area within a relatively small volume. Most activated carbons are

Table 5. Pounds activated carbon required for pesticide deactivation.

Charcoal Needed (Pound/1,000 square feet)	Active ingredient present (Pound/A)	Active ingredient present (Pound/1,000 square feet)
2.3 - 3.5	up to 1.0	up to 0.02
4.6 - 6.9	2.0	0.04
6.9 - 10.3	3.0	0.06
11.5 - 17.2	5.0	0.11
22.9 - 34.4	10.0	0.22
45.0 - 67.5	20.0	0.45

purified by acid washes and water washes to remove impurities. They are available in both granular and powder form. The charcoal used with outdoor grills cannot be ground up to achieve the same pound -for-pound pore structure that is characteristic of activated charcoal.

You can usually buy activated carbon from a local pesticide dealer, who either carries the product or is able to find it. If you can't find activated carbon locally, contact a chemical company supply house. Activated carbon is available in quantities from 1 pound to 50 pounds, depending on the supplier.

Before applying activated carbon, determine the approximate pesticide concentration in the contaminated area. Only be concerned with the amount of **active ingredient**, not with the total amount of product. For example, if you spill 1 pound of a 50WP product, you will need to deactivate 0.5 pound s of active ingredient. As another example, if you spill 1 gallon of an 8E product, you will need to deactivate 8 pound s of active ingredient. Table 5 lists the pound s of activated carbon needed per 1,000 square feet to deactivate various pound s of pesticide per acre or per 1,000 square feet.

For example, assume that the equivalent of 1 pound of active ingredient per acre was spilled over a 2,000 -square-foot area. Deactivating the pesticide will require at least 4.6 to 7 pound s of carbon, or twice the 2.3 to 3.5 pound s needed for 1,000 square feet. Use at least 2.3 to 3.5 pound s even though your calculations might call for less.

The most accurate method to deter mine the chemical concentration in an area is to run a chemical analysis on the contaminated soil. Sample the soil to the depth that the pesticide moved. A 3-inch sample is usually sufficient unless the spill occurred a considerable time before sampling, heavy rains fell before sampling or the soil is coarse and porous.

Some charcoals are formulated as powders to be applied dry. Others are treated so that they can be added to water and applied as a spray. You should evenly distribute the carbon over the contaminated area. Using a rototiller or some other incorporating too l, thoroughly apply the charcoal to the depth that the soil is contaminated. Water the area thoroughly every day for at least three or four days before replanting. If possible, wait for several more days. The treatment's effective ness depends up on the soil texture and organic matter content, the properties of the herbicide and the sensitivity of the plant species to be grown in the area. Before replanting the area, test it by spot planting to deter mine the effective ness. If the plants die or are injured, water again for three or four days. This additional watering is usually sufficient for deactivation, but occasionally you'll need to add more carbon.

Pesticide fires

Although the majority of pesticide-active ingredients are not flammable and do not by themselves constitute a fire hazard, many of the solvents used in liquid formulations are highly flammable. For this reason, consider all liquid pesticides potential fire hazards. The risk of fire from a stored liquid pesticide is based on its flash point. **Flash point** is the minimum temperature at which a liquid gives off sufficient vapor in the surrounding air to form an ignitable mixture. Liquids are classified by the National Fire Protection Association as flammable (flash point below 100 degrees) or combustible (flash points above 100 degrees). Whenever large quantities of pesticides must be stored, install fire-detect ion devices, and place a dry-chemical fire extinguisher near the entrance.

Prepare a fire plan for each storage facility, and outline the appropriate measures to take should a fire occur. Indicate the proximity of pesticide wastes (e.g., surface water, sewers, wells) and how you will prevent contaminated run off water from fire fighting from entering such waters. It is, in fact, sometimes better to let a fire burn to avoid what are often massive problems with contaminated water. Be sure to discuss the proper way to deal with a fire with the pesticide manufacturer, your insurance carrier and your local fire department.

Be sure your plan contains the emergency telephone number of the pesticide manufacturers and of your local emergency-response personnel. Also include the telephone numbers of the Missouri Department of Natural Resources and the Missouri Emergency Response Office.

Public Relations

Right-of-way operations are highly visible to the public. Because of this, they may be unusually open to criticism. However, much of the criticism may be avoided if you are considerate of public concerns, are knowledgeable and informed and use extra care in applying pesticides. This section discusses ways to work effectively with the public.

Differences in perception

Applicators and those who complain about their work sometimes differ in the way they see things. You may perceive brownout of certain species as a verification that you have done your job properly although property owners may view the situation as a violation of the green space that they consider an extension of their own property. Property owners may realize that right-of-way maintenance occurs, but they may have not understand why it is necessary or how it is done. They are concerned about the visual impact of the your work and their personal safety. For example, they often worry whether the herbicides will contaminate the well or garden vegetables.

Do not patronize property owners. They are not impressed by applicators who say that they know what they are doing or that there is no law requiring them to tell the property owner what they are doing. The best way to deal with many of the concerns of property owners before or du ring treatment is to answer their questions and to respond to their concerns clearly and directly. Be professional; view such questions as an opportunity to educate and improve communication with the public.

Carelessness

Often problems of pesticide application are best resolved by improving operational practices. Most operational problems are within your control; they are not "unavoidable accidents." Commonly occurring violations or misuses result in significant and visual off-target impacts. These misuses include careless mixing or pesticide transfers with resulting spills, roadside disposal of leftover spray mixture at the end of the day, contamination of surface water through drift, spills or improper disposal and injury to off-target vegetation du e to drift, **volatility** or lateral movement of pesticides.

Misuses relating to actual application usually are due to carelessness. It is possible to follow label instructions and still be careless. You are being careless if you:

- Aren't familiar with the area to be treated prior to application,
- Don't take all possible steps to avoid drift,
- Don't use proper pesticides or equipment for the job,
- Don't regularly check application equipment to make sure that it works, and
- Don't wear proper protective equipment.

If you don't follow these precautions, you're taking unnecessary risks.

Other areas of concern

Nearly all parts of a right-of-way are in some form of drainage system. It's easy to recognize drainage ditches, but greenways, contour and overflow areas can be less obvious. Pesticide treatments should have minimal or no impact on these areas. Follow label directions and precautions where right-of-way run off water flows into sensitive areas or where the water is used for irrigation or for livestock.

Sometimes you can cause problems for a landowner without realizing it. Do not cross tiled fields with heavy equipment when the ground is soft. Avoid crossing one hog lot or chicken yard into another without first cleaning the mud off of your equipment's tires. You can spread communicable diseases, such as hog cholera, from one area to another by unwittingly tracking contaminated soil. If the death or injury of an animal is blamed on a pesticide application, a veterinarian should examine the animal. If investigation shows that compensation is justified, make sure you respond fairly and promptly.

You may see marijuana growing on utility rights-of-way in rural areas. When you see this, report it to the proper authorities. These areas should be bypassed until the marijuana has been destroyed. Use extreme caution in these areas, and watch for grower's booby traps.

Often, a landowner's questions concerning pesticide applications go unanswered or are not answered to the owner's satisfaction. This generally results in a formal complaint and polarized viewpoints. Landowners think the applicator is hiding something, and the crew supervisor may view the questions as a nuisance. A simple solution to this problem is to know the answer to the landowner's question before it is asked. A quick, direct response to the public's concerns facilitates better communication and a more enjoyable working environment. Be prepared to respond to commonly asked questions, such as those that follow:

- What are herbicides, and why are they used?
- Do herbicides affect birds?
- If my garden becomes contaminated, is it safe to eat the vegetables?
- Is it safe to eat wild berries from areas that have bee n sprayed?
- What kind of precautions are taken to make sure that pesticides don't get into ground-water supplies?
- Do herbicides and other pesticides pose any

risk to me and my family?

- What happens if herbicides wash from the treated area into my pond; how does it affect the fish?
- If my cattle graze on treated rights-of-way, is the milk and meat safe to consume?

Glossary

Absorption. The process by which a herbicide passes from the soil solution into plant root cells or from the leaf surface into the leaf cells.

Active ingredient. The chemical in a pesticide formulation primarily responsible for its activity against pests. It is identified on the ingredients statement of the product label.

Annual plant. A plant with a life cycle that is completed within one year.

Ballast. Material such as crushed rock, cinders or gravel that is placed both between and below railroad ties to make the track firm and lasting.

Berm. A shoulder along the edge of the ballast.

Biennial plant. A plant with a life cycle that is completed within two years, with seed production occurring during the second year.

Brush. Woody plants, such as brambles, shrubs and vines, that are less than ten feet in height at maturity.

Calibration. Measurement of application equipment's delivery rate.

Cell membrane. Semi-permeable wall that surrounds the inner portion of the cell.

Chloroplast. Organelles present in large numbers within plant cells that contain protein, lipids and pigments such as carotenoids and chlorophyll.

Contact herbicide. This causes localized injury to plant tissue wherever the plant and the herbicide have contact.

Cotyledon. A specialized seed leaf; one is found in monocots and two in seeds of dicots.

Cross-resistance. Type of resistance in which a pest or pest population is resistant to closely related pesticides.

Crown. That portion of a plant between the shoot and root regions that contains the meristems (buds) from which shoots arise.

Deciduous. Those plants that lose all their leaves during a portion of the year (usually winter).

Dicot. Plants that contain two cotyledons, such as broadleaf plants.

Enzyme. Proteins, formed in plant and animal cells or made synthetically, that act as organic catalysts in initiating or speeding up specific chemical reactions.

Erosion. The movement of soil particles by water or wind.

Evergreen. Plants that are always in leaf.

Fibrous root system. Type of system formed by lateral branching of the primary root, found in monocots (grasses).

Flash point. The minimum temperature at which a liquid pesticide gives off sufficient vapor in the surrounding air to form an ignitable mixture.

Formulation. The pesticide product as purchased, usually consisting of a mixture of active and inert ingredients.

Fungicide. Pesticide used for the control of fungal diseases.

Herbaceous weed. A vascular plant that does not develop woody tissue above ground.

Herbicide. Pesticide used for the control of undesirable vegetation.

Insecticide. Pesticide used for the control of insects.

Integrated management program. A system where at least two pest-control strategies are used.

Lateral movement. Movement of a substance through soil, generally in a horizontal plane, from the original site of application.

Monocot. Plants that contain one cotyledon, such as grasses.

Nonselective herbicide. A herbicide that is generally toxic to all plants. Some selective herbicides may become nonselective if used at high rates.

Nontarget organism. Plant or animal species not intentionally treated by a pesticide.

Nontarget site. Area not intentionally treated with a pesticide.

Noxious weed. A weed specified by law as being especially undesirable, troublesome or difficult to control. Precise definition varies according to legal interpretations.

Perennial plant. A plant with a life cycle that lasts more than two years.

Pesticide resistance. The inherited ability of a pest to tolerate the toxic effects of a particular pesticide.

Photosynthesis. The biological production of organic substances, chiefly sugars, occurring in green plant cells in the presence of light.

Phytotoxicity. An effect that is injurious or lethal to plants.

Plant growth regulator. A substance that alters the normal growth and/or reproduction of a plant.

Post-emergence. Application of a herbicide after emergence of the specified weed or crop.

Pre-emergence. Application of a herbicide to the soil prior to emergence of the specified weed or crop.

Residual herbicide. A herbicide that persists in the soil and injures or kills plants for an extended period of time (several weeks to several months, depending on the herbicide).

Respiration. The process by which living cells utilize oxygen to transform the energy in food molecules into biologically useful forms.

Rhizome. A specialized horizontal stem that grows below ground or just at the soil surface.

Right-of-way. An area involved in common transport.

Rodenticide. Pesticide used for the control of rodents.

Rosette. A circular cluster formed by basal leaves of certain broadleaf plants, particularly biennials.

Selective herbicide. A chemical that is more toxic to some plant species than to others.

Spray drift. Movement of airborne particles from the intended area of application.

Stolon. A specialized horizontal stem that grows above ground.

Surfactant. A surface-active agent that produces physical changes at the surface of liquids. Used in agricultural sprays as wetters, stickers, emulsifiers and penetrants.

Taproot. Type of root system, found in dicot plants, that has relatively little lateral branching.

Translocated herbicide. A herbicide that is absorbed and moved to other plant tissue.

Tuber. A short, thickened stem structure that develops below ground as a consequence of the swelling of a portion of a rhizome and subsequent accumulation of reserve materials.

Vapor pressure. Chemical property of a substance that describes its potential for conversion into a gaseous state.

Vaporization. Process by which a solid or liquid material is transformed into a gas.

Volatility. See vapor pressure.

Water solubility. Chemical property of a substance that describes its potential for dissolving in water.

Weed. A plant that grows out of place.

Woody plant. Perennials that have a thick, tough stem or a trunk covered with bark.

Appendix

Appendix table 1. Foliar herbicide treatment: susceptibility of common brush species.

Species	2,4-D	2,4-DP	Tordon	Escort	Roundup	Krenite
Ash, white (*Fraxinus americana*)	R	R	R	S	S-I	I
Birch (*Betula* spp.)	S-I	S	S	R	S	S
Boxelder (*Acer negundo*)	S-I	I-R	S-I	—	S	—
Brambles (*Rubus* spp.)	I-R	I-R	S	I	S-I	S
Buckbrush (*Symphoricarpos orbiculatus*)	S	—	R	R	I	I
Cherry, black & choke (*Prunus* spp.)	I-R	I-R	S	S	S	I
Cottonwood, eastern (*Populus deltoides*)	S-R	R	S	—	—	S-I
Crabapple (*Pyrus ioensis*)	S-I	S	S	—	S	—
Dogwood (*Cornus* spp.)	R	—	I-S	I	R	I
Elderberry (*Sambucus canadensis*)	S-I	I	S	—	S	—
Elms, American & slippery (*Ulmus* spp.)	I	S-I	S	I-S	S	S-I
Grapes, wild (*Vitis* spp.)	S-I	S-I	S	—	S	S-I
Greenbrier or catsbriar (*Smilax* spp.)	R	R	I-R	R	R	R
Hackberry (*Celtis* spp.)	I-R	I-R	S	—	S	—
Hawthorn (*Crataegus* spp.)	I-R	R	S-I	R	S	I
Hedge-apple or osage orange (*Maclura pomifera*)	I-R	R	S-I	R	R	I
Hickory (*Carya* spp.)	I	—	I-R	R	R	R
Honeylocust (*Gleditsia triacanthos*)	I-R	I	S	R	S	I
Honeysuckle (*Lonicera* spp.)	S-I	S-I	S	R	S	I
Kudzu (*Pueraria lobata*)	R	—	—	I	I	S
Locust, black (*Robinia pseudoacacia*)	S-I	S-I	S	—	S	S
Maple, red (*Acer rubrum*)	R	R	S	S-I	S	—
Maple, silver (*Acer saccharinum*)	I-R	—	S	—	—	—
Maple, sugar (*Acer saccharum*)	I-R	—	S	—	S	—
Mulberry, red (*Morus rubra*)	I-R	I-R	S	R	R	I
Oaks (*Quercus* spp.)	I	—	I	I	S	I
Persimmon, eastern (*Diospyros virginiana*)	I	I-R	S	R	I	I
Pines (*Pinus* spp.)	R	—	S*	R	R	S
Plum, wild (*Prunus* spp.)	S-I	I	S	—	S	S-I
Poison ivy (*Rhus radicans*)	I	I	S	R	S	R
Poplar (*Populus* spp.)	I	—	I*	R	I	I
Redcedar, eastern (*Juniperus virginiana*)	R	R	S-I	R	S	S
Rose, multiflora (*Rosa multiflora*)	R	—	S	I-S	S	S-I
Sassafras (*Sassafras albidum*)	S-I	I	S	R	S	I
Sumac (*Rhus* spp.)	S	S	S	R	S	S
Sweetgum, (*Liquidambar styraciflua*)	R	—	I*	R	I	I
Sycamore (*Platanus occidentalis*)	I	—	I*	R	R	I
Tree-of-heaven (*Ailanthus altissima*)	S-I	S-I	S-I	—	S	S-I
Trumpetcreeper (*Campsis radicans*)	R	—	S-I	R	S-I	I
Virginia creeper (*Parthenocissus quinquefolia*)	S	S-I	S	—	S	—
Willow (*Salix* spp.)	R-S	S	S	R	S	I

Source: Data are adapted from *Response of Selected Woody Plants in the United States to Herbicides*, Agricultural Handbook No. 493, U.S. Department of Agriculture, *Weed and Brush Control Guide for Forages, Pastures, and Non-Cropland in Missour*i, MP No. 581, University of Missouri, and from herbicide companies.
Note: S = Susceptible, I = Intermediate, R = Resistant, — = data not available.
*If tank-mixed with 2,4-D.

Appendix table 2. Basal-bark herbicide treatment: susceptibility of common brush species.

Species	2,4-D	2,4-DP
Ash, white (*Fraxinus americana*)	R	R
Birch (*Betula* spp.)	S	—
Boxelder (*Acer negundo*)	S	S
Brambles (*Rubus* spp.)	I-R	S-R
Cherry, black & choke (*Prunus* spp.)	S-R	S
Cottonwood, eastern (*Populus deltoides*)	—	—
Crabapple (*Pyrus ioensis*)	S-I	S-I
Elderberry (*Sambucus canadensis*)	S-I	S
Elms, American & slippery (*Ulmus* spp.)	S-I	S-I
Grapes, wild (*Vitis* spp.)	—	—
Greenbrier or catsbrier (*Smilax* spp.)	I	—
Hackberry (*Celtis* spp.)	S	S
Hawthorn (*Crataegus* spp.)	I	S-R
Hedge-apple or osage orange (*Maclura pomifera*)	I	R
Honeylocust (*Gleditsia triacanthos*)	I	I
Honeysuckle (*Lonicera* spp.)	S	S
Locust, black (*Robinia pseudoacacia*)	I	I-R
Maple, red (*Acer rubrum*)	R	R
Maple, silver (*Acer saccharinum*)	I	—
Maple, sugar (*Acer saccharum*)	—	—
Mulberry, red (*Morus rubra*)	I-R	I-R
Persimmon, eastern (*Diospyros virginiana*)	I-R	R
Plum, wild (*Prunus* spp.)	S-I	S-I
Poison ivy (*Rhus radicans*)	I	—
Redcedar, eastern (*Juniperus virginiana*)	R	R
Rose, multiflora (*Rosa multiflora*)	—	—
Sassafras (*Sassafras albidum*)	S-I	S-R
Sumac (*Rhus* spp.)	R	R
Tree-of-heaven (*Ailanthus altissima*)	S-R	S-I
Trumpetcreeper (*Campsis radicans*)	—	—
Virginia creeper (*Parthenocissus quinquefolia*)	—	—
Willow (*Salix* spp.)	S	S

Source: Data are adapted from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493, U.S. Department of Agriculture, and from herbicide companies.
Note: S = Susceptible, I = Intermediate, R = Resistant, — = data not available.

Appendix table 3. Injection and cut-surface treatment: susceptibility of common brush species.

Species	2,4-D	2,4-DP	Tordon + 2,4-D
Ash, white (*Fraxinus americana*)	I	—	S
Birch (*Betula* spp.)	I	S-I	S
Boxelder (*Acer negundo*)	—	—	S-I
Brambles (*Rubus* spp.)	R	S	I
Buckbrush (*Symphoricarpos orbiculatus*)	R	—	R
Cherry, black & choke (*Prunus* spp.)	—	S-I	S
Cottonwood, eastern (*Populus deltoides*)	S-I	—	S
Crabapple (*Pyrus ioensis*)	—	—	—
Dogwood (*Cornus* spp.)	I	—	I
Elderberry (*Sambucus canadensis*)	—	—	S
Elms, American & slippery (*Ulmus* spp.)	S-I	—	S-I
Grapes, wild (*Vitis* spp.)	S	—	S
Greenbrier or catsbrier (*Smilax* spp.)	R	—	R
Hackberry (*Celtis* spp.)	S	—	S
Hawthorn (*Crataegus* spp.)	I-R	—	S-I
Hedge-apple or osage orange (*Maclura pomifera*)	S-I	—	S-I
Hickory (*Carya* spp.)	I	—	S
Honeylocust (*Gleditsia triacanthos*)	I	—	S
Honeysuckle (*Lonicera* spp.)	R	S-I	S
Kudzu (*Pueraria lobata*)	R	—	S
Locust, black (*Robinia pseudoacacia*)	S	S-I	S
Maple, red (*Acer rubrum*)	I-R	—	S
Maple, silver (*Acer saccharinum*)	—	—	S
Maple, sugar (*Acer saccharum*)	R	—	S
Mulberry, red (*Morus rubra*)	I	—	S
Oaks (*Quercus* spp.)	I	—	S
Persimmon, eastern (*Diospyros virginiana*)	I	—	S-I
Pines (*Pinus* spp.)	I	—	S
Plum, wild (*Prunus* spp.)	—	—	—
Poison ivy (*Rhus radicans*)	I	S-I	S
Poplar (*Populus* spp.)	S	—	I
Redcedar, eastern (*Juniperus virginiana*)	R	—	I
Rose, multiflora (*Rosa multiflora*)	R	—	S
Sassafras (*Sassafras albidum*)	S	—	S
Sumac (*Rhus* spp.)	I	—	S
Sweetgum (*Liquidambar styraciflua*)	I	—	S
Sycamore (*Platanus occidentalis*)	I	—	S
Tree-of-heaven (*Ailanthus altissima*)	—	—	S-I
Trumpetcreeper (*Campsis radicans*)	I	—	S
Virginia creeper (*Parthenocissus quinquefolia*)	—	—	—
Willow (*Salix* spp.)	S	S-I	S

Source: Data are adapted from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493, U.S. Department of Agriculture, *Weed and Brush Control Guide for Forages, Pastures, and Non-Cropland in Missouri*, MP No. 581, University of Missouri, and from herbicide companies.
Note: S = Susceptible, I = Intermediate, R = Resistant, — = Data not available.

Appendix table 4. Soil herbicide treatment: susceptibility of common brush species.

Species	Tordon	Velpar
Ash, white (*Fraxinus americana*)	R	I
Birch (*Betula* spp.)	S	I
Boxelder (*Acer negundo*)	S	—
Brambles (*Rubus* spp.)	S-I	I
Buckbrush (*Symphoricarpos orbiculatus*)	—	I
Cherry, black & choke (*Prunus* spp.)	S	—
Cottonwood, eastern (*Populus deltoides*)	S	—
Crabapple (*Pyrus ioensis*)	S	—
Dogwood (*Cornus* spp.)	—	I
Elderberry (*Sambucus canadensis*)	S-I	—
Elms, American & slippery (*Ulmus* spp.)	S	I
Grapes, wild (*Vitis* spp.)	S-I	—
Greenbrier or catsbrier (*Smilax* spp.)	R	R
Hackberry (*Celtis* spp.)	S	—
Hawthorn (*Crataegus* spp.)	S	I
Hedge-apple or osage orange (*Maclura pomifera*)	S-I	I
Hickory (*Carya* spp.)	—	R
Honeylocust (*Gleditsia triacanthos*)	S	S
Honeysuckle (*Lonicera* spp.)	S	R
Kudzu (*Pueraria lobata*)	—	R
Locust, black (*Robinia pseudoacacia*)	S	—
Maple, red (*Acer rubrum*)	S	I
Maple, silver (*Acer saccharinum*)	I	I
Maple, sugar (*Acer saccharum*)	S	I
Mulberry, red (*Morus rubra*)	S	I
Oaks (*Quercus* spp.)	—	S
Persimmon, eastern (*Diospyros virginiana*)	S	R
Pines (*Pinus* spp.)	—	R
Plum, wild (*Prunus* spp.)	S	—
Poison ivy (*Rhus radicans*)	S	I
Poplar (*Populus* spp.)	—	I
Redcedar, eastern (*Juniperus virginiana*)	S-I	I
Rose, multiflora (*Rosa multiflora*)	S	I
Sassafras (*Sassafras albidum*)	S	R
Sumac (*Rhus* spp.)	S	S-I
Sweetgum (*Liquidambar styrciflua*)	—	I
Sycamore (*Platanus occidentalis*)	—	F
Tree-of-heaven (*Ailanthus altissima*)	S	—
Trumpetcreeper (*Campsis radicans*)	S	S-I
Virginia creeper (*Parthenocissus quinquefolia*)	S	—
Willow (*Salix* spp.)	S	S-I

Source: Data are from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493, U.S. Department of Agriculture, *Weed and Brush Control Guide for Forages, Pastures, and Non-Cropland in Missouri*, MP No. 581, University of Missouri, and from herbicide companies.
Note: S = Susceptible, I = Intermediate, R = Resistant, — = No data available.

Appendix table 5. Foliar herbicide treatment: susceptibility of common herbaceous weeds.

Species	2,4-D	Tordon	Roundup	Karmex	Velpar
Aster spp.	F	G	G	—	—
Barnyardgrass (*Echinochloa crus-galli*)	P	—	G	F	G
Buttercup (*Ranunculus* spp.)	F	G	G	—	—
Cattail (*Typha* spp.)	F	G	G	—	—
Cheat (*Bromus secalinus*)	P	—	F	F	G
Chickweed (*Stellaria media*)	F	—	F	F	G
Crabgrass (*Digitaria* spp.)	P	—	F	G	F
Curly Dock (*Rumex crispus*)	F	G	F	P	F
Dandelion (*Taraxacum officinale*)	G	G	G	P	G
Dogfennel (*Eupatorium capillifolium*)	F	—	F	—	—
Downy brome (*Bromus tectorum*)	P	—	G	P	G
Fall panicum (*Panicum dichotomiflorum*)	P	—	G	F	F
Field pennycress (*Thlaspi arvense*)	G	G	F	F	G
Foxtails (*Setaria* spp.)	P	—	G	G	F
Goldenrod (*Solidago* spp.)	F	G	F	P	P
Henbit (*Lamium amplexicaule*)	G	—	P	F	F
Horsenettle (*Solanum carolinense*)	G	—	P	P	P
Horseweed (*Conyza canadensis*)	F	G	F	F	P
Johnsongrass (*Sorghum halepense*)	P	P	G	P	—
Kochia (*Kochia scoparia*)	—	—	—	F	G
Lambsquarters, common (*Chenopodium album*)	G	—	G	G	G
Marijuana (*Cannabis sativa*)	G	G	G	—	—
Mullein (*Verbascum thapsus*)	P	G	F	—	—
Orchardgrass (*Dactylis glomerata*)	P	—	G	—	F
Oxeye daisy (*Chrysanthemum leucanthemum*)	F	G	G	—	—
Perennial sowthistle (*Sonchus arvensis*)	F	G	G	—	—
Pigweed spp. (*Amaranthus* spp.)	G	—	F	F	F
Prickly pear (*Opuntia* spp.)	P	G	P	—	—
Quackgrass (*Agropyron repens*)	P	—	G	P	F
Ragweed, common (*Ambrosia artemisiifolia*)	G	G	G	P	P
Ragweed, giant (*Ambrosia trifida*)	G	G	F	—	—
Ragweed, lanceleaf (*Ambrosia bidentata*)	F	G	P	F	P
Red Sorrel (*Rumex acetosella*)	P	G	F	P	P
Shepherdspurse (*Capsella bursa-pastoris*)	G	—	G	F	G
Smartweed spp. (*Polygonum* spp.)	G	—	G	F	F
Tall fescue (*Festuca* spp.)	P	—	F	P	P
Thistle, bull (*Cirsium vulgare*)	G	G	F	P	P
Thistle, Canada (*Cirsium arvense*)	F	G	G	—	—
Thistle, musk (*Carduus nutans*)	F	G	F	P	P
White snakeroot (*Sanicula* spp.)	F	G	G	—	—
Wild garlic (*Allium vineale*)	G	—	G	P	P
Wild mustard (*Sinapsis arvensis*)	G	—	G	F	G
Yellow nutsedge (*Cyperus esculentus*)	P	—	F	P	P
Yellow rocket (*Barbarea vulgaris*)	—	—	G	P	G

Source: Data are adapted from *Systemic Herbicides for Weed Control*, AD-BU-2281, 1983, and *Weed and Brush Control Guide for Forages, Pastures, and Non-Cropland in Missouri*, MP No. 581, University of Missouri.
Note: G = Good, F = Fair, P = Poor, — = No data available.

Appendix table 6. Common right-of-way herbicides classified by mode of action.

Photosynthetic inhibitors

Triazines: hexazinone (Velpar)
Ureas: diuron (Karmex)

Meristematic inhibitors

Foliar applied: fosamine (Krenite), glyphosate (Roundup, Rodeo)
Soil or foliar applied: metsulfuron (Escort), oryzalin (Surflan)

Growth hormones

Phenoxy acids: 2,4-DP (Weedone), 2,4-D (many)
Piclolinic acids: picloram (Tordon)

Contact herbicides

MSMA (many)

Note: You should remember that as with most pesticide products, the information presented in the text and tables of this manual is subject to change. This manual is intended to be a guide, and in all cases, actual labels should be consulted, read completely and followed exactly.

Herbicides used by the Missouri Highway and Transportation Department

Escort: Applied as a **post-emergence** foliar application, Escort is a broad-spectrum herbicide. You may use it in combination with Embark and 2,4-D to control weeds and brush. Escort also is applied for brush control in mowed areas. It is effective at low rates.

Surflan: Applied as a **pre-emergence** treatment to the soil, Surflan has no activity on established plants. You may tank-mix it with Roundup in most situations. Major weeds controlled by Surflan are annual grasses such as crabgrass.

MSMA: The primary target species of MSMA is johnsongrass. You may apply it as a post-emergence application; it does not have soil activity. MSMA has the greatest activity on relatively small weeds, especially when temperatures are higher than 70 degrees.

Karmex: A broad-spectrum herbicide, Karmex has both pre- and post- emergence activity. Applied alone at relatively high rates, Karmex is used as a nonselective material for bare-ground control. You also may apply it in combination with Roundup for control of a wide range of weed species.

Velpar: Used primarily as a bare-ground treatment, Velpar also has some post-emergence activity on small plants. This herbicide controls a wide range of species.

Roundup: Many species, including perennials, are controlled by Roundup . Although it is effective on many woody species, some conifers are resistant. Often, you may apply it tank-mixed with another material to increase the spectrum of control. It is a nonselective translocated herbicide that you apply as a foliar treatment; therefore, exercise caution to prevent contact with desirable species. Roundup also contains a surfactant.

Rodeo: This product contains the same active ingredient as Roundup; however, surfactant has not been formulated into Rodeo. The target species are aquatic weeds and brush to be controlled in or near water. Because Rodeo is a nonselective material, be careful to prevent drift and exposure to desirable species.

2,4-D: This is one of the oldest selective herbicides used for the control of broadleaf weeds. It is not soil active and has a short residual period in the soil. Some formulations, such as esters, are relatively volatile; therefore, take precautions because damage can occur as far as a mile off target.

2,4-DP: Similar to 2,4-D, you may apply it in combination with 2,4-D to increase the spectrum of control. The primary target species are brush and various woody plants.

Tordon RTU: This herbicide is a ready-to-use liquid that you apply undiluted directly to the cut surface of tree stumps to control sprouting. You should never apply it as a broadcast application because it is water soluble and can move into the roots of desirable species.

Krenite S: The primary use is brush control in unmowed areas. You may apply it by handgun from midsummer to early fall to a target plant's foliage. The product does not cause brownout, except for conifers. The spring following application, susceptible plants fail to refoliate.

Embark PGR: This product is not a true herbicide but rather a plant growth regulator. It does not kill the plant but in some manner, it alters the growth of the plant. You may apply it to suppress the growth and seedhead development of grasses. Usually, you will tank-mix it with Escort and 2,4-D.

Suggested references for additional information

Weed Identification:

Weed Identification Guide. Southern Weed Science Society, 309 W. Clark St., Champaign, IL 61820.

Weeds of the West. Pioneer of Jackson Hole, 132 W. Gill St., Jackson, WY 83001.

Nebraska Weeds. Nebraska Department of Agriculture, Bureau of Plant Industry, Lincoln, NE 68509.

Pesticides:

Crop Protection Chemicals Reference. C & P Press, Inc., 888 Seventh Ave., 28 Floor, New York, NY 10102-1316.

MSDS Reference for Crop Protection Chemicals. John Wiley & Sons, Inc., 605 Third Ave., New York, NY 10157-0228.

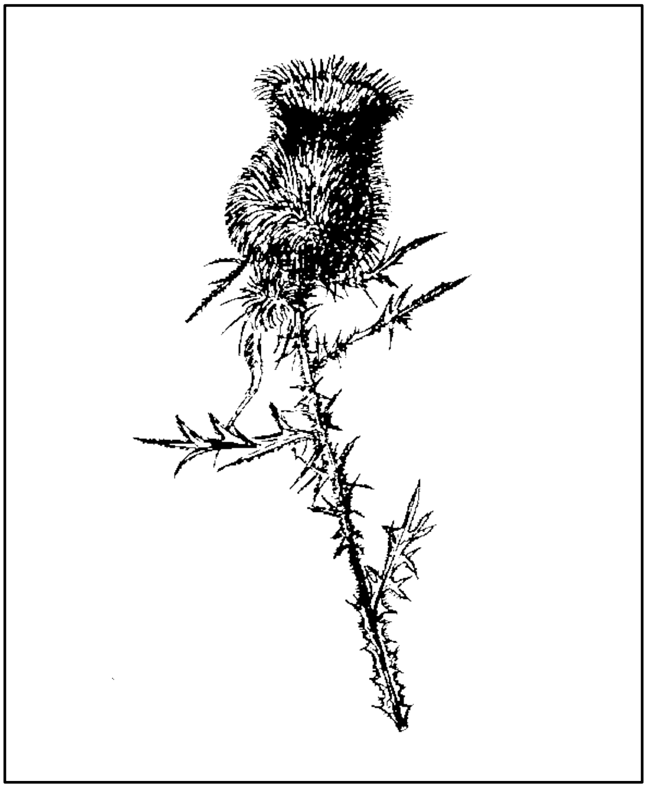
Turf & Ornamental Chemicals Reference. John Wiley & Sons, Inc., 605 Third Ave., New York, NY 10157-0228.

EXTOXNET. Distribution Center, 7 Research Park, Cornell University, Ithaca, NY 14853.

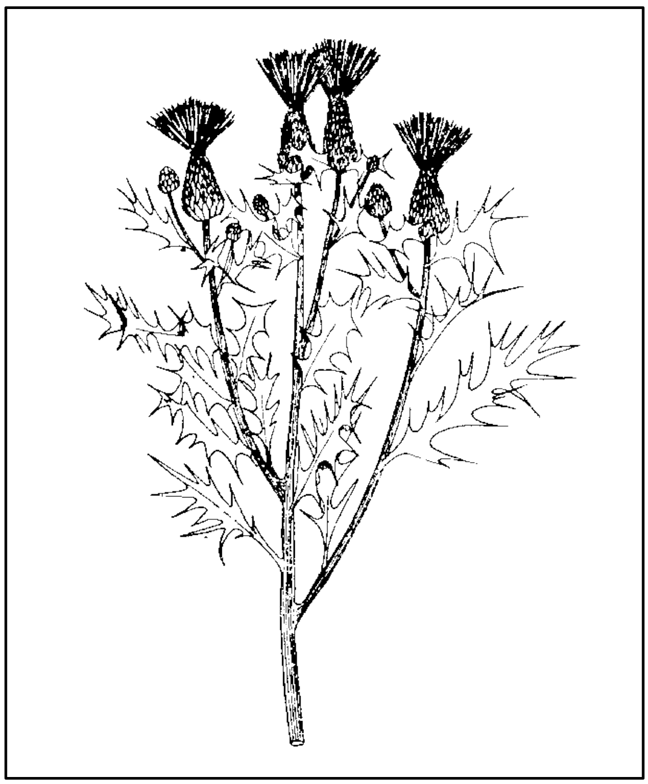
Farm Chemicals Handbook. 37733 Euclid Ave., Willoughby, OH 44094-5992.

Grasses and broadleaf weed diagrams

Bermuda grass

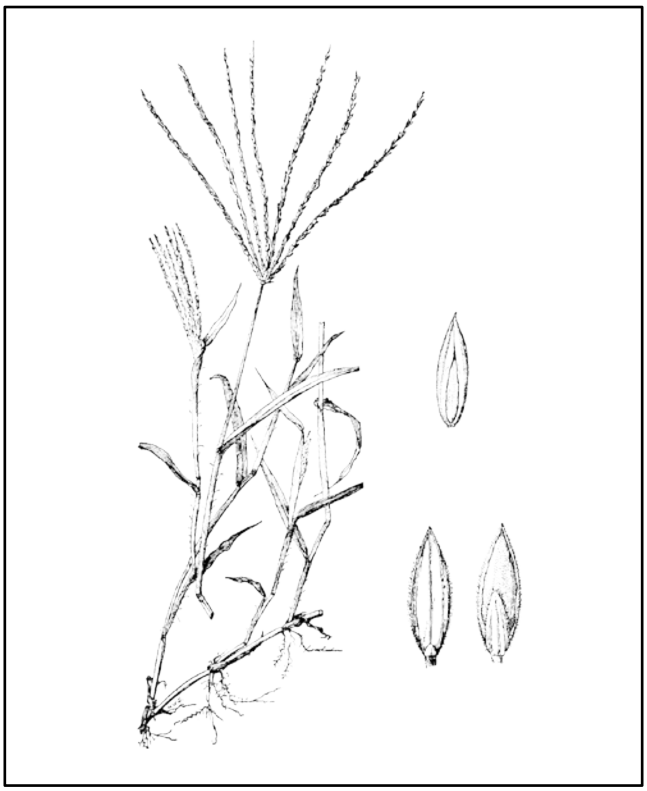


Bull thistle



Canada thistle

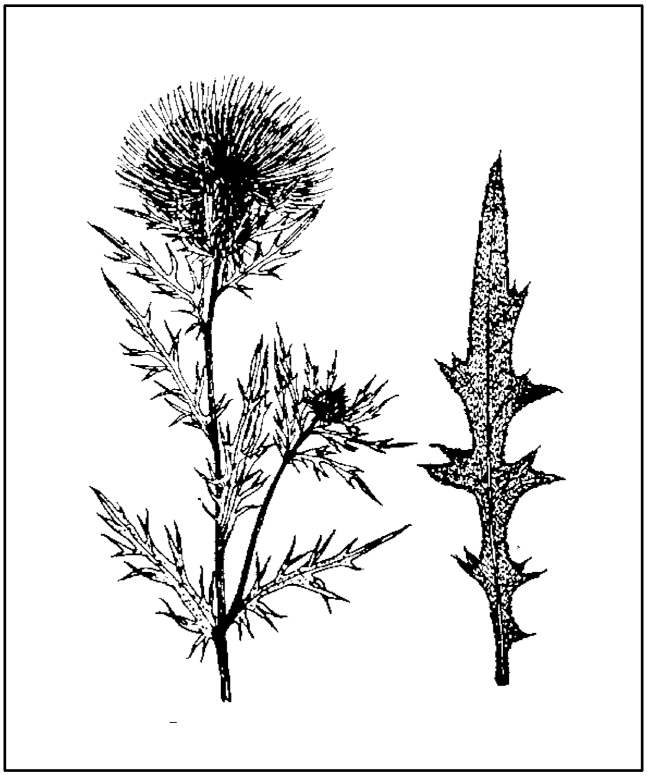
Cheat



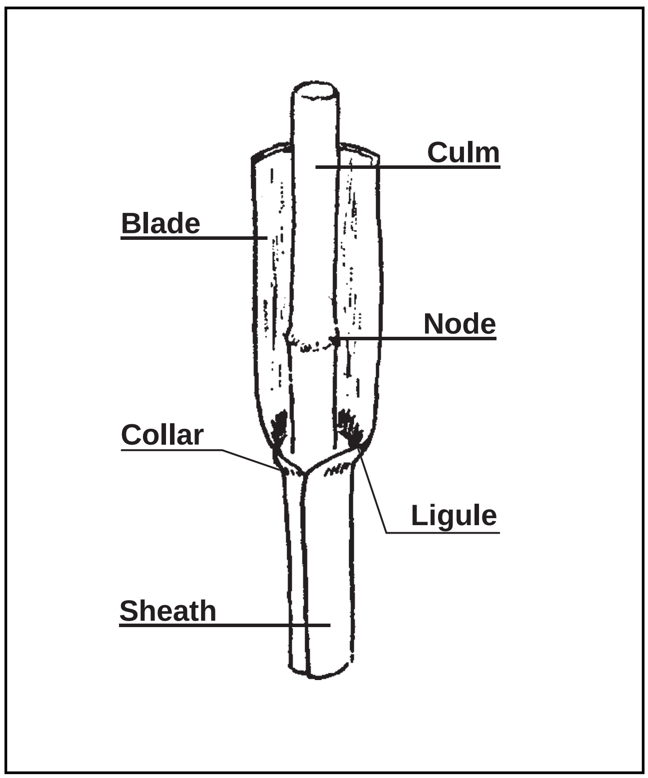
Crabgrass

Common mullein

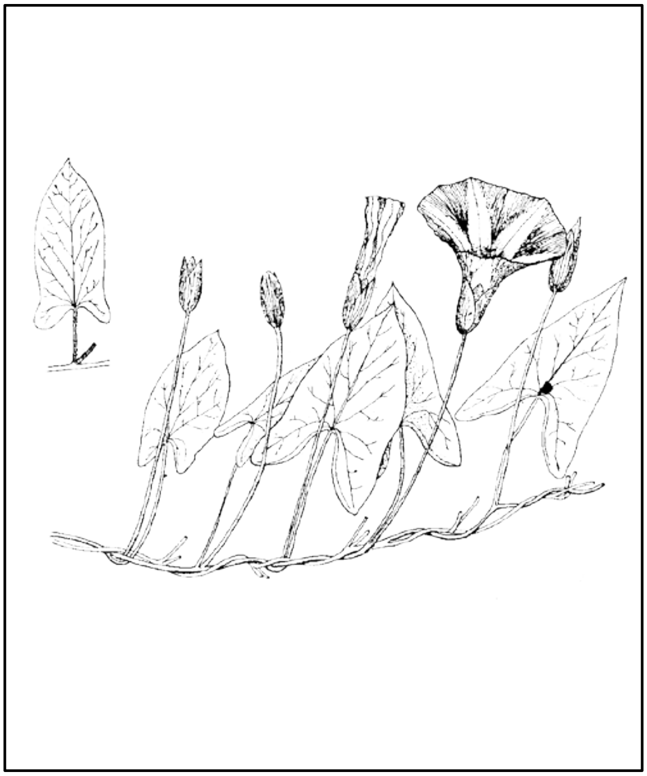
Downy brome



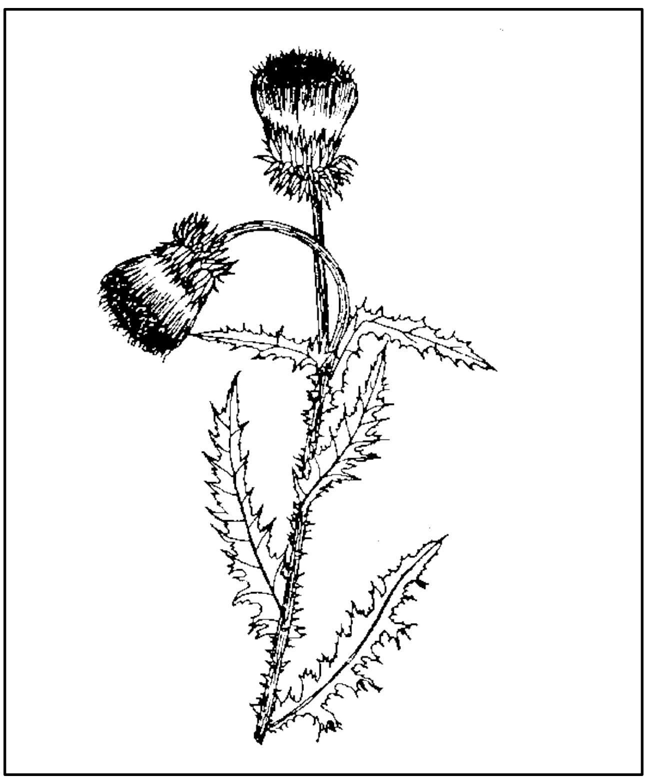
Field thistle



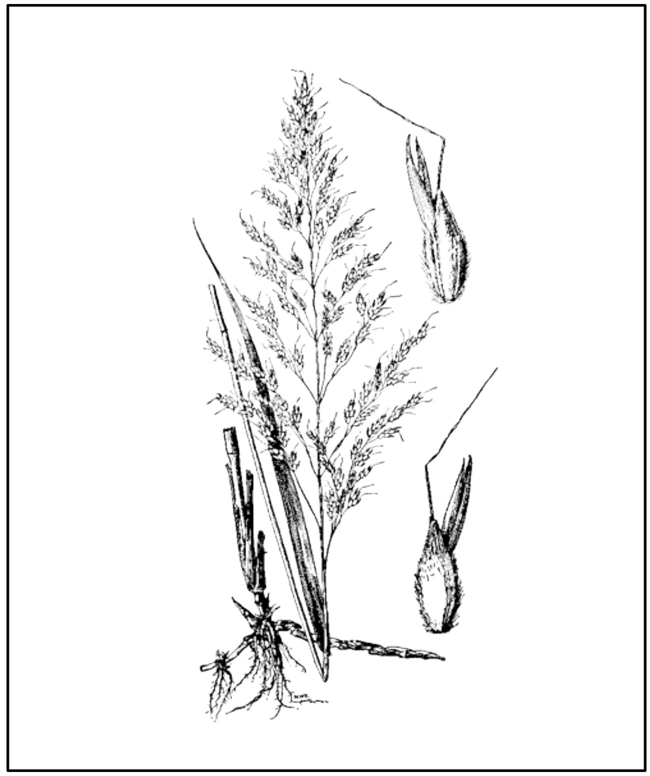
Grass stem



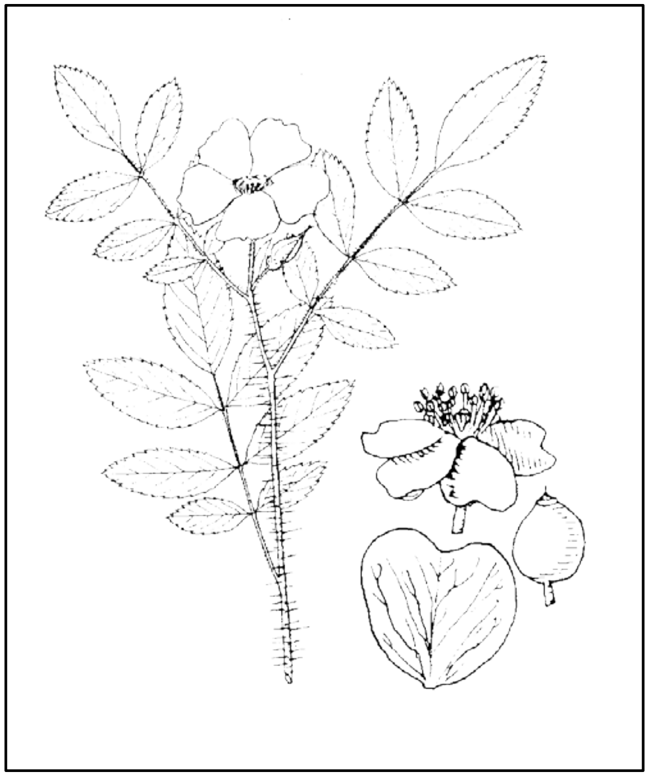
Hedge bindweed



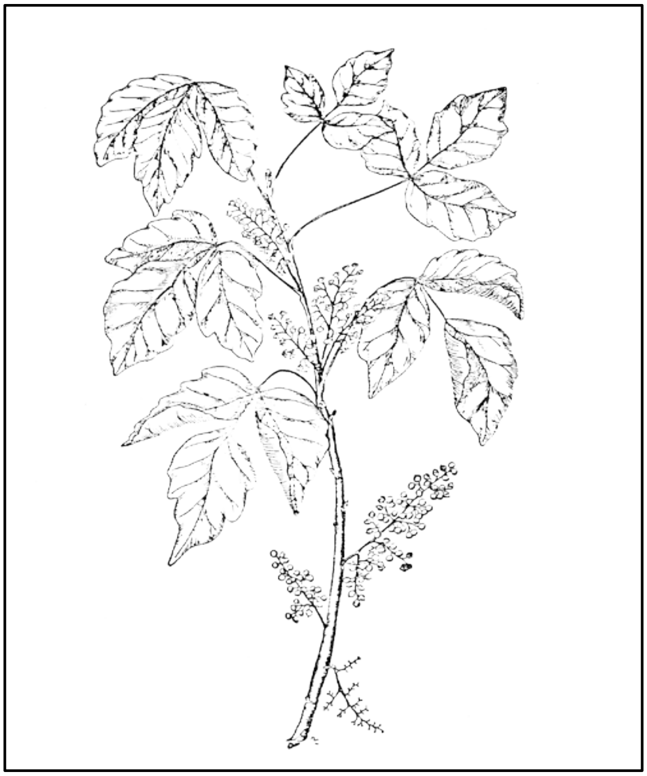
Musk thistle



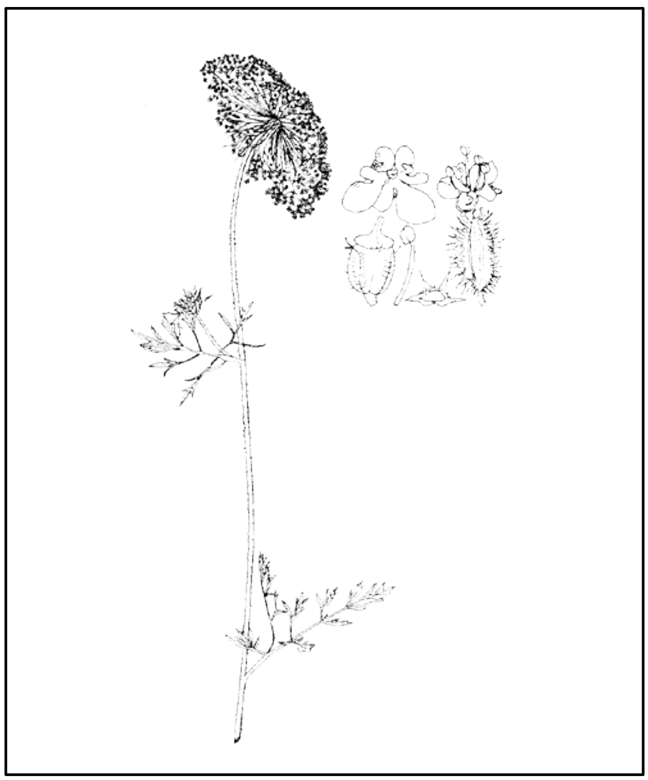
Johnsongrass



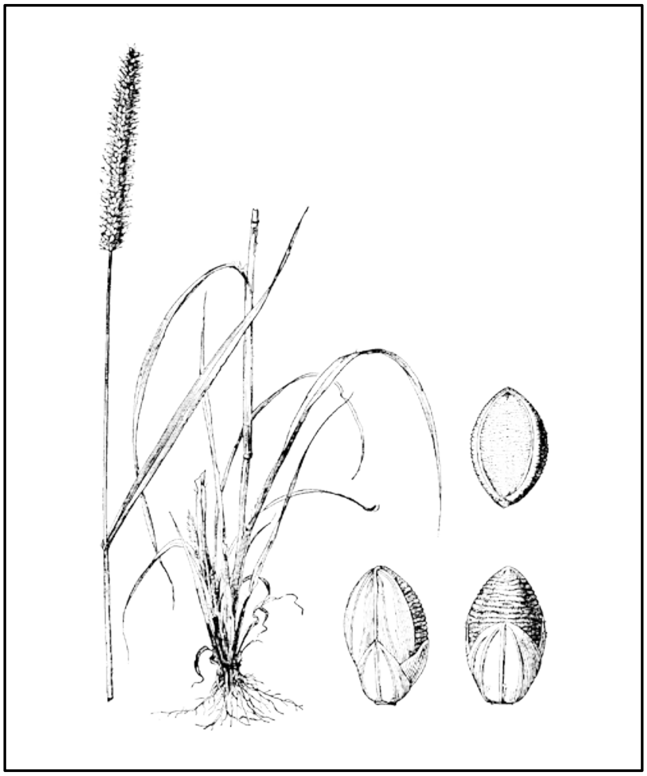
Pasture rose



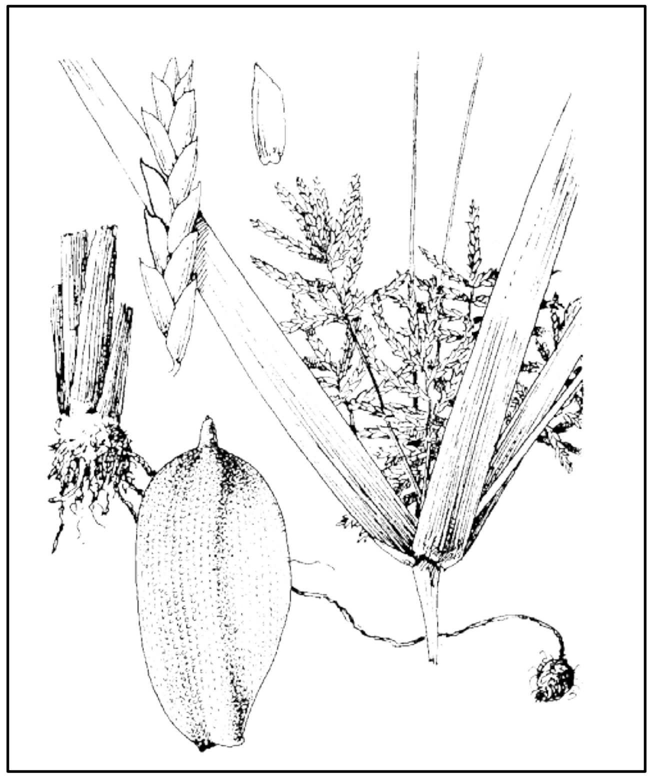
Poison ivy



Wild carrot



Yellow foxtail



Yellow hutsedge

Emergency Telephone Numbers

Missouri Regional Poison Control Center 1-800-366-8888

For pesticide poisoning emergencies, the Missouri Poison Control Center is accessible through a toll free number. The center is located and administered by Cardinal Glennon Memorial Hospital in St. Louis. It is staffed 24 hours daily with medical professionals. The center is equipped to refer poisoning accident victims to a local poison control emergency facility.

Missouri Emergency Response Team (573) 634-2436

For pesticide spill emergencies, the Emergency Response Team handles pesticide spills any where in Missouri. For information, call (314) 751-7929. Contact: Environmental Emergency Response Coordinator, Missouri Department of Natural Resources, Division of Environmental Quality, P.O. Box 176, Jefferson City, MO 65102.

National Pesticide Safety Team Network (Chemtrec) 1-800-424-9300

The National Agricultural Chemicals Association has a telephone network. This network can tell the applicator the correct contamination procedures to use to send a local safety team to clean up the spill. An applicator can call the network toll free and any time.

National Pesticide Tele-Communications Network 1-800-858-PEST

Call the NPTN network toll free.

U.S. Environmental Protection Agency (EPA) (913) 551-7000

All major pesticide spills are required by law to be reported immediately to the U.S. Environmental Protection Agency, Region VII Office, 726 Minnesota Avenue, Kansas City, KS 66101. The following information should be reported:

1. Name, address, and telephone number of person reporting
2. Exact location of spill
3. Name of company involved and location
4. Specific pesticide spilled
5. Estimated quantity of pesticide spilled
6. Source of spill
7. Cause of spill
8. Name of body of water involved, or nearest body of water to the spill area
9. Action taken for containment and cleanup.

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