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DISCLAIMER

Every effort has been made to ensure the accuracy of this guide for use by Alabama Department of Transportation (ALDOT) employees, consultants, and contractors. No guaranty is given as to the accuracy of the contents of this guide for use on work other than that for ALDOT. No responsibility is assumed by ALDOT for any errors caused by incomplete or inaccurate information contained in this guide relating to work outside the oversight of ALDOT.

Trade names used in this publication are for the purpose of providing specific information and no endorsement is implied. No discrimination of comparable products or equipment is intended. In the event of registration cancellation, the pesticide use recommendation is automatically cancelled.
CHAPTER 1: MOWING

GENERAL GUIDELINES

The roadsides are a very important component of both the functional and aesthetic aspects of any highway system. Moreover, they are the most influential aspect governing a traveler's perception of the State. It is the responsibility of ALDOT to economically manage roadside vegetation with appropriate priorities for safety and appearance in its operations.

Because roadsides are so important to the safety and enjoyment of the traveling public ALDOT has developed some general guidelines for vegetation management. These guidelines are as follows:

- The Alabama Department of Transportation will encourage the growth and preservation of naturally occurring wildflower areas.
- Wildflowers that have naturalized within the rights-of-way should be allowed to remain. Every effort should be made to mow around them and avoid spraying herbicides with the exception of spot treatments to eliminate certain weed species. Naturalized species occurring in wet areas such as irises, lilies, and cattails, will be allowed to remain when they do not obstruct drainage. The District Administrator will decide when plants are obstructing drainage or sight distances and will take the necessary action to correct the deficiency.
- Litter should be removed prior to mowing designated areas. For roads in the Adopt-A-Mile Program, it would be beneficial to contact the sponsoring agency and advise them of the mowing schedule so they can assist in the removal of litter.
- Sight distance at horizontal curves, vertical curves, intersections, railroad crossings, signs, signal lights, delineators, hazard markers and warning devices should be clear of obstructions. Sight distance can be obtained on the inside of horizontal curves by mowing the area 30 feet from the edge of the surface, or from the edge of the surface to the right-of-way line, or from the edge of the surface to the fence line, whichever is the shortest distance. Transition should begin 150 feet prior to the beginning and end of the curve.
- All vegetation shall be maintained to permit clear visibility for all traffic signs.
• Trees that interfere with proper sight distance, side and/or overhead clearance should be trimmed or removed.

• All dead, diseased or leaning trees with weakened root systems within the right-of-way, which may endanger traffic by falling across the highway, shall be removed and disposed of in a timely manner. Stumps within a mowable area will be removed. If the stumps are located in an area designated not to be mowed, or outside the clear zone, they may remain.

• In order to ensure proper drainage; mow to the back edge of the ditch bottoms and one mower width up the backslope. When ditch bottoms are inaccessible and impeding drainage, treat unwanted vegetation with an approved aquatic herbicide.

• Mowing heights should be 6 inches, because shorter cutting heights may cause too much stress on the vegetation. Do not mow during long rainy spells or when the right-of-way is too wet. Mowing during these times will cause rutting and loss of vegetation, resulting in excessive erosion and can ultimately lead to earth slides.

• Initiate appropriate erosion control procedures, including turf renovation, when necessary.

• Blend the highway right-of-way with the adjacent land uses. For example, forestlands should extend into the right-of-way, and right-of-way adjacent to crop and pasture lands should remain relatively open, etc.

"GOOD NEIGHBOR POLICY"

Vegetation management standards address activities that concern ALDOT objectives and the needs of the traveling public. Of equal importance, however, are our neighbors who own and utilize property adjacent to highway right-of-way. Therefore, in the spirit of a "Good Neighbor", ALDOT personnel will endeavor to manage the right-of-way vegetation in a manner that will not hinder the reasonable lawful activity, safety, or aesthetic appearance of adjacent property. Activities included in this policy are mowing and spraying operations, drainage considerations, wildflower preservation and vegetation pruning.
TYPES OF MOWING

This section describes each of these three types of mowing and provides standards for how the work is to be done. Illustrations of typical mowing operations are provided at the end of this chapter.

Full-Width Mowing
Full-width mowing includes all unpaved right-of-way, except for designated non-mow areas (areas where the grade is too steep, or the area is covered with desirable plants), or as directed by the District Administrator. The frequency and limits of full-width mowing for a given roadway will depend on the current mowing guidelines.

Strip Mowing
Mowing the area from the edge of the travel lane or paved shoulder to the roadway ditch and one mower width (about 5 feet) up the backslope is called strip mowing. In addition to the mowing pattern described above, all strip mowing operations will include:

- mowing from the pavement or shoulder edge to the right-of-way line next to developed areas (cemeteries, schools, churches, private dwellings, community centers, etc.)
- all mowing necessary to maintain adequate sight distances for intersections, private entrances, curves, off-ramps, on-ramps, signs, delineators, and other appurtenances
- mowing around all appurtenances (signs, delineators, guardrail, culvert headwalls, etc.) that are within the designated strip width
- mowing full width, from right-of-way to right-of-way for drainage where appropriate
- mowing a smooth and gradual transition that will blend the designated strip width with other areas that require a greater or lesser mowing width.

Spot Mowing
Spot mowing is the mowing of individual areas within the right-of-way to increase the aesthetic, functional, or safety aspects of the highway as opposed to full-width or strip mowing the entire length of the roadside. Spot mowing will be performed when and where necessary to maintain adequate sight distances for inside curves, off-ramps, on-ramps, intersections, cross-overs, private entrances, signs, delineators, and other
appurtenances. Spot mowing is generally performed when safety needs arise between scheduled strip mowing cycles. During spot mowing, areas around rural intersections or interchanges will be mowed as necessary to provide adequate sight distances.

Special Situations

Mowing operations at rest areas, welcome centers, and other enhanced areas should be performed more frequently than normal roadside mowings so that these improved areas may be properly featured. Fine turf areas should be mowed at the appropriate heights.

Frequent mowing in areas of new construction (anywhere newly seeded, sprigged, plugged, or sodded right-of-way is being established) may be necessary to reduce competition from weeds and nuisance grasses. Mowing should be initiated when vegetation reaches twice its desired mowing height.

Mowing and Herbicide Applications

Targeted herbicide applications must be coordinated with mowing operations to ensure effective control of undesirable plant species and to avoid damage to desirable plants. Targeted herbicide applications are used to eliminate undesirable weeds and to control growth of desirable turf species. The following conditions will ensure that optimum results are obtained from mowing and spraying operations.

- The target species must be in a growth stage at which it is susceptible to control at the time of mowing or spraying. See discussions in Chapter 3: Pesticides for Vegetation Management for timing of spray operations.
- The herbicide may require as much as 10 days to translocate from the leaf surface to the root system of the target weed before the area is mowed.
- When mowing precedes spraying, the vegetation should be allowed to regrow to an acceptable height before spraying in order to gain the longest growth control from the herbicide or growth regulator application.
- Litter pickup operations should be conducted before mowing operations. Mowing a littered roadside increases the risk of the mowers striking unseen objects and causing harm to people, machinery, and passing vehicles. Shredding of litter increases labor for pickup operations and exposes more litter to view.
MOWING PRECAUTIONS

The main purpose of the vegetative cover on the right-of-way is to protect the roadside from erosion. Left unprotected, deterioration would occur, threatening the paved surface of the roadway. Mowing is an important component of roadside vegetation management, but it must be conducted with care to preserve the vegetative cover. Observing the precautions contained in this section will help ensure safe, efficient and environmentally sound mowing operations.

Delay Mowing When Soil is Wet

When the soil is wet, delay mowing. Tractor tires cause severe rutting in wet soil. Rutting, especially on slopes, causes erosion, destroys turf cover and increases weed problems. Erosion leads to deterioration of the roadside and threatens the paved surface of the roadway.

Avoid Mowing Steep Slopes

Avoid mowing steep slopes (1:3 ratio or steeper), even in urban areas, whenever possible. Mowing steep slopes increases soil compaction, causes rutting, and decreases the vigor and density of the vegetation. This loss of plant cover will eventually lead to erosion of the slope.

NOTE: If the slope rises one vertical unit for every three horizontal units, then the ratio is one to three (1:3). Therefore, a 1:2 slope is steeper than a 1:3 slope.

Use Appropriate Cutting Height

Never set mower cutting height lower than 6 inches in non-landscaped areas. Low cutting or “scalping” is undesirable because it puts undue stress on the turf plants, especially during dry weather. Any resulting loss of vegetative cover also deprives ground-nesting birds of cover. Finally, mowing too low increases the number of objects thrown by mowers. Note: landscaped areas, which are mowed more frequently, can be mowed at lower heights.
Avoid Mowing Too Frequently

Without supplemental watering and fertilization, frequent mowing weakens roadside turf and may allow weeds to dominate the area.

Coordinate Mowing with Seed Production

Effective mowing operations require coordination with seasonal cycles, as well as with other roadside maintenance activities.

In late spring and early summer tall fescue produces many seed-heads. Seed-heads develop very rapidly during this time and, if cut, will regenerate in 8 to 12 days. Mowing operations during seed-head production result in wasted time and money. After seed-heads mature in May and June, tall fescue will become dormant. Mowing after this period will result in a clean right-of-way for several weeks.

Where warm season grasses such as bahiagrass are the dominant turf species, seed-heads can be expected from mid-season until first frost. The final mowing of these areas should be delayed until late in the season when regrowth will not become too high before the turf grasses go dormant.

NO-MOW AREAS

Each District Administrator or designated representative must evaluate all unpaved areas of right-of-way, such as steep slopes, wide areas of right-of-way, wildflower areas, and other locations covered with desirable vegetation not suitable for mowing, to establish no-mow areas and calculate acres to be mowed. The accurate determination of acres to be mowed is very important for planning and reporting purposes whether the mowing will be done by the department or by contractors.

Establishing No-Mow Areas

Each District Administrator should designate no-mow areas, and inform contractors and mower operators of the location of said areas. If necessary, markers should be used to keep mowers out of designated no-mow areas.

Calculating Acres to be Mowed

In addition to the establishment of no-mow areas, the amount of full-width and strip mowing must be calculated in acres for each section of roadway. These figures will be used in drawing up contract bid proposals and for determining equipment and personnel time required and other factors involved in maintenance costs.
MOWING PROCEDURES

Mowing procedures may vary across the state due to the type of vegetation, right-of-way, location and equipment used. The specific procedures will be determined by the District Administrator for all mowable acres in his/her area. However, the following general procedures and rules will be common throughout the state.

- Mowing shall not be done when ground conditions are too wet or when vegetation is extremely wet. This rule applies especially to mowing of any slope because of the increased damage to the turf cover and danger to the operator and equipment.
- Mowing with rotary mowers should be in such a manner that cuttings and debris are ejected away from the roadway when possible.
- Each operator should know the direction of rotation of the blades of the mower he/she operates and set up the direction of travel correctly.
- Operators should follow equipment checklist when preparing it for use.
- Operators should see that the mower is set at the proper height.
- Operators should see that all chains and other protective devices are in place.
- Operators should know that any objects that may be thrown are to be removed from the roadside prior to beginning mowing.
- Operators should know the location of headwalls, steep slopes or other obstructions that may cause overturning or mower damage.
- Operators should use all personal protection equipment designated and have the seat belt fastened.
- No mowing job is complete until all vegetation has been controlled around plantings, signs, bridge ends, guardrails, fences and other obstacles.

EQUIPMENT SELECTION

Specific areas of work will be designated to each type of mower on a given section of road in order to reduce deadheading, unnecessary passes, and mower congestion. Mowing assignments should be made so that no more than three mowers are operating close together. The following teams of mowers have proven effective:

- On Interstates and other areas with wide rights-of-way, the mowing crew should include one service truck and 4 mowing units, one of which will be a trim mower.
- Mowing crews for other areas will vary according to terrain and width of right-of-way, but will generally consist of a service truck and three mowing units, at least one of which will be a trim mower.

**Servicing Units**

A truck equipped with fuel, lubricants, air compressor, spare tires and/or repair capability, spare parts, extra blades, etc., will be provided for mowing crews. Each mower will be stopped and serviced individually, as required, on the job site.
DAILY CHECKLIST AND SERVICE SCHEDULE

Before Operation
- Walk around equipment, visually checking for damage, defects or malfunctions.
- Check tires for damage and inflation.
- Check wheels for broken studs or loose nuts.
- Check for water, fuel or oil leaks. Check engine oil level.
- Check radiator cap and coolant level.
- Check belts, hoses, clamps and wires.
- Clean radiator coils and grill of grass, dirt, leaves, sticks, trash, etc.
- Check battery compartment, cables, clamps and posts for corrosion and check battery for proper fluid level.
- Check air cleaner and service as necessary (twice daily under dusty conditions).
- Lubricate all tractor and mower fittings.
- Check mounting bolts, keeper pins and pivot pins.
- Check blades and safety shields and chains.
- Remove grass and trash from deck and around blades and PTO shafts.
- Check all hydraulic hoses, connections and hydraulic cylinders for leaks.
- Check all cables pulleys and belts for proper tension and position.
- Check trail wheel bushings and tire condition.
- Check service sticker and odometer/hour-meter reading. Is scheduled maintenance service or inspection due?

During Operation
- Check operation of main units and accessories.
- Observe all instruments frequently.
- Check brake, clutch and steering system for firmness and freeplay.
- Watch for changes in operation of engine or power loss.
- Listen for unusual knocks or noises in engine, transmission and rear end.
- Check gearshift lever for smooth engagement and change of gears.
- Check operation of warning devices frequently.

After Operation
- Fill fuel tank, if practical.
- Clean off mower deck, blades and PTO shafts.
- Report any malfunction or unusual noises in tractor or mowers to supervisor immediately.
- If it is impractical to return the equipment to the area or district yard at night, park it in an area where it will be safe and will not interfere with traffic. Engage the transmission and, if necessary, put chocks under the wheels to prevent rolling. Lock the ignition, toolboxes, battery boxes and doors, and be sure to remove all keys. Cover all vertical exhaust pipes not equipped with raincaps.
SAFETY GUIDELINES FOR ROADSIDE MOWING

- All supervisors and mower operators should be thoroughly trained on mover operational safety. Supervisors should instruct new mower operators in all aspects of their duties and responsibilities before allowing them to operate a mower.
- Direct mower discharge toward the ditch or backslope and away from employees or other pedestrians.
- **Never attempt to unclog or adjust a running machine.** See that the engine is shut off and the mower blades stopped before attempts are made to repair mower, clear blades, or when anyone is near the mower blades.
- Block the mower to prevent its falling before getting under the mower to clear the blades or make repairs.
- Persons other than the operator are not permitted to ride on a tractor.
- Always drive the tractor at speeds compatible with safety, especially over rough ground, ditches, slopes, or when turning.
- Adequate safety distances should be maintained between mowers mowing in the same direction.
- Keep all guards and safety devices in place at all time.
- All rotary mowers should be furnished with a chain curtain or belting guard in front and rear, located to protect the opening but where the guards cannot come in contact with the mower blades.
- All tractors shall be equipped with rollover protection.
- Mowers should be disengaged when crossing driveways and intersecting roads.
- Mowers shall maintain Manufacturer’s recommended safety devices.
- Slopes that are too steep, uneven and dangerous should not be mowed with regular tractor-type mowers.
- If operating on unusual terrain where the ground surface may be hidden by tall grass or kudzu, slow down and watch carefully for any erosion or obstructions that could cause injury to the operator or damage to the equipment.
- Proper advance warning signs shall be used in all mowing operations.
- Fully charged fire extinguishers should be kept in the vehicle attending a fleet of mowers.
- Always crank tractor from operator's seat; not standing beside tractor.
AUXILIARY PRACTICES

The primary vegetation management practice consists of controlling growth and reproduction through mowing and spraying herbicides. However, in some instances, establishment or improvement of the vegetation must take priority. During the normal course of mowing and spraying, vegetation that is growing on slopes or under other adverse conditions may be damaged, resulting in weak turf and bare soil areas. In other situations, the initial establishment during construction may have been inadequate.

Regardless of the cause, areas of weak turf and bare soil occur within mowed areas of the right-of-way. Like potholes in the pavement, these areas will grow and eventually threaten the entire turf area if they are not repaired or renovated.

Renovation of Damaged or Bare Turf Areas

The first step in renovating damaged turf areas is to discontinue management practices that are causing the problem. If the area is being damaged by continuous use of a soil-active herbicide, such as Oust® XP, then application of an alternative foliar-active herbicide may be in order. If the loss of turf is due to mowing on steep slopes, then mowing should be reduced or eliminated. **It is more important that the area remain vegetated to control erosion than it is that it be mowed to improve appearance.**

Modification of management practices alone seldom is enough to regenerate badly damaged turf or heal bare areas. It will usually be necessary to fertilize and/or seed the damaged areas to obtain full turf coverage and control erosion.

Fertilization

Fertilization of roadside turf should be limited to those areas where growth and/or cover are inadequate. The first step is to take a soil sample from the affected area. A minimum of 20 cores should be taken to a depth of 6 inches and mixed thoroughly. Fill the soil test carton with this soil mixture.

The results of the soil test will often determine whether fertilization or complete renovation is needed. A topical application of lime and a complete fertilizer as recommended by soil test may be sufficient to ensure recovery. If the soil is extremely acid (below pH 4.5) or if available soil phosphorus is very low, then it may be necessary to renovate the turf area, even if a partial stand is present.
Renovation of Existing Turf Areas

Renovation of existing turf areas consists of cultivation, incorporating fertilizer and lime according to soil test recommendation, preparing a seedbed, seeding and mulching the area.

For renovating small areas, a tractor-driven rotary tiller is the equipment of choice. Till the soil to a minimum of 6-inch depth. Apply the recommended lime and complete fertilizer and incorporate it into the soil with the rotary tiller.

After the fertilizer has been incorporated, the seedbed should be prepared by pulling a corrugated roller or cultipacker over the area to firm the seedbed. At this point an additional application of a complete fertilizer should be applied to the surface (8-8-8 at 550 lbs. / acre or 15-15-15 at 300 lbs./ acre or equivalent rates of other fertilizers). Then the area should be rolled again to firm the seedbed.

Seeds of the turf species should be applied uniformly with a mechanical seeder, and the area should be rolled again to incorporate the seed into the soil surface. Drop seeders are available which distribute the seed and roll the area in one operation.

Mulching is necessary to control erosion and provide the best environment for germination and establishment of the turf. There are several mat or fabric mulch materials available in rolls for use on small areas. Pinestraw, cereal straw, or bermuda hay at 2,000 lbs. /acre is satisfactory for larger areas. Straw and hay should be clean and free of nuisance and or invasive weeds such as Johnsongrass.

Regardless of the mulch material used, it is essential that it conforms to irregularities in the soil surface and is anchored to the soil. Staples are often used to anchor mat-type materials while asphalt or other adhesive materials are used on hay or straw mulches.

Once the vegetation is established, it is best to wait at least one year before using herbicides on the new turf. Mowing, on the other hand should begin when the vegetation reaches approximately 12 inches or twice its desired mowing height.

The secret to keeping a good, uniform grass cover is proper maintenance operations and early detection of weakening or declining turf coverage. A good time to make such observations is when scouting areas prior to herbicide application.
During spot and strip mowing operations, the area around intersections or interchanges will be mowed as necessary to provide adequate sight distances.
Spot mowing will be performed when and where necessary to maintain adequate sight distances for inside curves, off-ramps, on ramps, intersections, private entrances, signs, delineators, and other appurtenances. Spot mowing is generally performed when safety needs arise between scheduled strip mowing cycles.
INTRODUCTION

A chemical vegetation control program can only be as efficient and cost effective as its spray operators and its equipment. Different pieces of application equipment are used in conducting the different parts of the vegetation management program. The proper use and routine maintenance of the equipment will produce consistent results and applicator safety.

FOR ALL EQUIPMENT DISCUSSED ON THE NEXT SEVERAL PAGES, THE DAILY CHECKLIST SHOULD BE FOLLOWED BEFORE EACH USE.

LOW-PRESSURE GROUND SPRAYERS

Low-pressure ground sprayers generally use water as a diluent or carrier for most pesticide applications. This equipment is used for broadcast, band, and/or spot spraying of pesticide solutions.

Low-pressure sprayers are like automobiles. They have many different appearances or looks, but they share many important components. These components are the foundation of any spray system and their proper selection, maintenance, and operation permit consistent results. Components common to these sprayers are a tank, an agitator, pump, pressure regulator, gauges, strainers, hoses, and spray tips or nozzles. Pressure generated by a pump is used to force the spray solution through the spray tip or orifice of the nozzle, Figure 1.
SPRAYER COMPONENTS

Tanks

A desirable or useful sprayer tank is one that:

- is corrosion-resistant
- is large enough to prevent frequent refilling
- has a large top opening for cleaning, filling, and inspection
- has a watertight lid to prevent spillage
- has a fill opening fitted with removable screen or strainer to prevent foreign material from entering tank
- is shaped suitably for easy mounting and cleaning and effective agitation
- has adequate openings for pump and hydraulic or mechanical agitation connections
• has easily accessible drain with cut-off valve in bottom of tank for complete drainage when cleaning
• has agitator adequate to ensure uniform mixing of pesticide and water
• has a fluid level sight gauge or tank markings for volume determinations.

Most sprayer tanks are constructed of fiberglass, polyethylene, or stainless steel. Mild steel tanks can rapidly corrode clogging strainers and nozzles and resulting in downtime. Chemical reactions can take place when certain herbicides are mixed in galvanized steel tanks forming combustible gases that may explode.

Agitators

Agitation is essential for a good uniform mixing of spray materials with the water. Soluble liquids and powders generally do not require much agitation once they are in the solution. However, emulsifiable concentrates, wettable powders, and liquid or dry flowable pesticide formulations will separate if not continuously agitated. Agitation can be accomplished by mechanical or hydraulic means. For large sprayers, powered mechanical paddles mounted lengthwise in the bottom of the tank give the best agitation. Most smaller, agricultural-type sprayers have hydraulic jet or by-pass agitation. The by-pass type uses the return hose from the pressure relief valve to agitate the tank. The by-pass agitator hose must extend to the bottom of the sprayer tank. By-pass agitation is not sufficient on sprayers with tanks larger than 55 gallons unless a high capacity centrifugal pump is used. When the pump is running (but spray boom is turned off), all the flow is returned to the tank and agitation is adequate. However, once the sprayer is turned on and spraying begins, much less volume is returned to the tank. In large tanks, the agitation is poor and insufficient to keep chemicals in suspension. Gear, piston and roller pumps require a "jet" agitator on 100 gallon or larger tanks. The agitator must be located in the bottom of the tank and held in place on a pipe (NEVER ON A HOSE). The agitator must be connected to the pressure side of the sprayer and operate at the operating pressure of the sprayer. Never install a jet agitator on the by-pass line!

The amount of flow needed for agitation depends on the pesticide formulation used, as well as the shape and size of the tank. For a simple orifice jet agitator, a flow of 5 to 6 gallons per minute for every 100 gallons of tank capacity is usually adequate. A 55 gallon tank requires one or more jet outlets, 100 to 150 gallon tanks should have
a minimum of three outlets, and 200 gallon and larger tanks should have three or more outlets on a manifold. The manifold should be positioned horizontally about 1 to 2 inches from the bottom of the tank and the jets should discharge horizontally across the bottom of the tank. The tank capacity and operating pressure will determine the minimum jet size. The orifices in the jet agitator must be sized so that the pump can maintain the correct operating pressure when all the nozzles are operating. In addition, some reserve capacity is needed to compensate for pump and nozzle wear.

**Pumps**

The pump is the heart of any sprayer. It must have a pumping capacity sufficient to maintain the desired pressure at the full capacity required by the nozzles and hydraulic agitator. The pump parts must be able to withstand the corrosive effects of the spray materials and, when wettable powders are used, the resistance of the pump to wear is very important. A pump that is subject to wear, such as a roller pump, should be sized to provide a reserve capacity about 50% greater than is needed to meet flow needs of the nozzles and agitator. This reserve capacity will extend the life of the pump. Hydraulic sprayers usually have roller, centrifugal (impeller), piston, or diaphragm pumps. Since most hydraulic sprayers are boom sprayers used for vegetation control where low pressure is adequate, roller and centrifugal pumps are very popular. Spraying is usually done at pressures of 10 to 40 psi (pounds per square inch). Where wettable powders are used, the centrifugal pump is especially good because wear is relatively slow and there is plenty of flow capacity for jet agitation.

Roller pumps are widely used because of their lower initial cost, ease of repair, wide range of pressures available (up to 300 psi), and because they can be directly mounted on a tractor PTO shaft. Their volume is adequate for most vegetation spraying needs. Roller pumps wear relatively fast, especially when pumping abrasive formulations. However, rebuilding kits are available to replace the rollers, gaskets, and in some cases, the seals. Rebuilding a roller pump is an easy job that can usually be completed in about a half-hour using simple tools. Centrifugal pumps, although initially somewhat more expensive, are longer lasting. Since the pressure is produced by an impeller rather than one part moving against another, wear is much slower than in roller or piston pumps. Centrifugal pumps have volume capacities up to 125 g/min, but their low pressures limit them to applications of 50 psi or less (for single impeller units). Centrifugal pumps must operate at rated speeds to produce rated volumes and
pressures. Centrifugal pumps are built to operate in the 2500 to 4000 rpm range. Therefore, they cannot be directly mounted on a PTO shaft, but must be driven with a speed increaser. The pump may also be driven by a direct-connected hydraulic motor operated from the tractor hydraulic system. A motor will maintain a uniform pump speed and output and free the tractor PTO for other purposes. Since performance of these pumps is poor when the inlet is restricted in any way, the in-line screen should be placed in the outlet (pressure) line of the pump, rather than in the suction line. The diameter of the inlet line should not be reduced.

Piston pumps are high-pressure units operating at up to 600 psi or more. They are wear-resistant but low in volume and high in purchase cost. Piston pumps can operate at PTO speeds, but the size of the multi-cylinder models (for higher volumes) may not permit direct mounting. Separate engines often power piston pumps. However, they can be mounted on the sprayer and driven through a PTO shaft. A piston pump produces a pulsating output so a small surge tank should be used to smooth out the pulses. These pumps should be used where high pressure is needed, such as a handgun for shade tree spraying or certain applications of insecticides and fungicides.

Diaphragm pumps are also high-pressure pumps with operating pressures, capacities, and initial costs similar to those of piston pumps. They have become popular in the United States, after an earlier introduction in Europe. Many of the new high-pressure sprayers are equipped with diaphragm pumps because maintenance is easier and less expensive. Replacement of diaphragms is the most common repair, and the sprayer operator, often without removing the pump from the sprayer, can do it.

Flow Control Systems

The flow-control system from the pump usually consists of a by-pass type pressure regulator or relief valve, a control valve, a pressure regulator, a shut-off valve, and a pressure gauge. A generalized flow-control assembly is shown in Figure 1. By-pass pressure-relief valves usually have a spring-loaded ball, disc, or diaphragm that opens with increased pressure so that excess flow is by-passed back to the tank. This feature prevents damage to the pump and other components when the boom is shut off.

A pressure gauge is necessary on every sprayer because nozzle tips are designed to operate within certain pressure limits. Without a gauge, it is impossible to
know if the correct pressure is being maintained. The pressure gauge is also necessary for accurate calibration of the sprayer. The most desirable gauge is one designed for the pressure range at which the sprayer is normally operated. A range of 0 to 100 psi is generally adequate for most pesticides. For accurate calibration of the sprayer, the pressure gauge should be located at or near the boom or exit orifice. A gauge may also be in the cab so that the operator can monitor the pressure. Liquid-dampened gauges are often necessary for accurate pressure readings because of the excessive vibration. Importance of the correct pressure in the system cannot be over emphasized. The pressure determines the amount of mixture expelled, the size of the droplets, and also assists in the agitation of herbicide within the tank.

CAUTION - IF THE PRESSURE BEGINS TO DROP, SHUT THE SPRAYER OFF AND CHECK TO SEE THAT AN ADEQUATE AMOUNT OF SPRAY SOLUTION IS IN THE TANK. NORMALLY, A FLUCTUATING PRESSURE INDICATES THE TANK IS APPROACHING EMPTY. OPERATING THE PUMP WITH AN EMPTY TANK WILL DAMAGE THE PUMP IMPELLER.

A shut-off valve allows the spray to be turned off while the pump and agitation system continues to operate. This feature allows the chemicals to be kept in solution when the sprayer is not operating and when moving from location to location.

Pressure regulators must be of a size to give full control of pressure within the required range, usually from 15 to 60 psi. For low pressure spraying, a diaphragm pressure-relief valve is recommended. Regulators can be placed on main and branch lines to control volume and pressure. A pressure-relief/regulator valve must be adequate to handle all the flow of a pump when the nozzles are shut off.

Cut-off valves are essential on every sprayer. A quick-acting valve (or valves) should be placed between the pressure regulator and the nozzle tips to control the flow of spray material. One valve may be used to cut off the entire operation, or a combination of two or three valves may be used to control the flow of individual sections of the boom. Flow cut-off valves should be easily accessible to the operator.

Hoses

A good hose for sprayers is flexible, durable, and resistant to sunlight, oil, chemicals, and general abuse (such as twisting, vibration, pulling, or "hydraulic hammer"). Spray lines and suction hoses must be the proper sizes for the systems.
The suction hose should be airtight, non-collapsible, and as short as possible. It should have the same diameter as the pump intake opening.

Other lines, especially those between the pressure gauge and the nozzles, should be as straight as possible, with a minimum of restrictions and fittings. The proper size of these lines will vary with the size and capacity of the sprayer. A high, but not excessive, fluid velocity should be maintained throughout the system. If the lines are too large, the velocity will be so low that the pesticide may settle out and clog the system. If the lines are too small, an excessive pressure drop will occur causing poor nozzle pattern distribution.

To prevent nozzle plugging, distribution hoses and fittings must have adequate strainers, and the inside diameters of the hoses must be properly sized and in good condition to minimize pressure loss. The following are suggested hose sizes for various flow rates.

Table 1: Hose Size Requirements for Different Pump Output Capacities

<table>
<thead>
<tr>
<th>Pump Output</th>
<th>Suction Line</th>
<th>Pressure Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>g/min</td>
<td>inches</td>
<td>inches</td>
</tr>
<tr>
<td>1.0 – 3.0</td>
<td>0.50</td>
<td>0.38</td>
</tr>
<tr>
<td>3.0 – 6.0</td>
<td>0.75</td>
<td>0.50</td>
</tr>
<tr>
<td>6.0 – 12.0</td>
<td>0.75</td>
<td>0.60</td>
</tr>
<tr>
<td>12.0 – 25.0</td>
<td>1.00</td>
<td>0.75</td>
</tr>
<tr>
<td>25.0 – 50.0</td>
<td>1.25</td>
<td>1.00</td>
</tr>
<tr>
<td>50.0 – 100.0</td>
<td>1.50</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Peak pressures occur as the sprayer shuts off. Hoses should be of neoprene or other oil-resistant materials and strong enough to take peak pressures. Spray hoses and fittings must be kept in good condition to prevent ruptures and personnel injury. Hose pressure rating should be twice the operating pressure. The suction hose should
be made of 2-ply fabric. It should be larger than the pressure hoses (boom, jet agitator, by-pass, etc.) because it must provide the total pump flow through the suction hose, suction strainer, fittings and valves. Suction hoses must be airtight, non-collapsible, short as possible, and have a minimum diameter the same as the pump intake. Collapsed suction hoses restrict flow and "starve" or cavitate a pump, damaging seals and impellers. The pressure drop in pressure hoses, fittings, valves and strainers should not exceed 10% of the operating pressure. Hose clamps of the worm screw type are best and are required when the operating pressure exceeds 100 psi.

The lines between pressure gauge and nozzles should be as straight and short as possible, with minimum restrictions. Proper line sizes vary with sprayer size and capacity. Fluid velocities of 3.5 to 5.0 in/min should be maintained throughout the system so that the pesticide will not settle out and clog the system.

**Strainers**

Strainers are designed to catch foreign material; they filter out grit and debris that will clog nozzles and damage pumps and valves. Strainers can be placed at several locations in the system. Three types of strainers are generally used on low-pressure sprayers: tank-filter strainers, line strainers, and nozzle strainers.

Strainers are classified by mesh numbers (20-mesh, 50-mesh, etc.) which indicate the number of openings per inch. The higher the mesh number - the smaller the opening. A 16-mesh to 20-mesh strainer is usually recommended for the tank-filter strainer.

Sprayers with a roller pump should have a 40-mesh to 50-mesh suction-line strainers. Sprayers with a centrifugal pump generally do not have a suction-line strainer because the inlet to a centrifugal pump should never be restricted. With a centrifugal pump system, a line strainer of about 50-mesh is placed on the pressure side of the pump to protect the nozzle and agitation system.

Nozzle strainers or screens usually are necessary for nozzles with flow rates of less than 1.0 g/min. In general, 100-mesh strainers are recommended for most nozzles with flow rates below 1.0 quart/min, and 50-mesh strainers are recommended for nozzles with flow rates between 1.0 quart/min and 1.0 g/min. Frequent cleaning of strainers, once or twice a day, is important for continued system performance and accurate rate applications. More frequent cleaning is required when using high-grit water sources.
Nozzles

Nozzles (spray tips) are a very important part of a sprayer. They control the amount of material applied, the formation of the droplets, the distribution of the droplets (pattern), and the uniformity of application.

Nozzle tips are available in various materials, including brass, plastic, stainless steel, ceramic, and nylon. Wear destroys the proper working of a nozzle, so worn nozzles should be replaced. To reduce wear rates, especially with wettable powders, use nozzle tips made of a hard, wear-resistant material, such as hardened stainless steel or ceramic. Brass tips are the most common and least expensive. Nylon and other synthetics are resistant to corrosion and abrasion, but swell when exposed to some solvents. Stainless steel tips resist corrosion and abrasion and have a long life, but their big disadvantage is cost. Ceramic tips also have very long life, but are also very expensive. Manufacturers are now making a nozzle with only a small portion of the tip made of ceramic material for long life and lower cost. The purchase price is more, but in the long run, nozzles of hardened stainless steel and ceramic may be better than brass because of their long life.

Nozzle tips are classified by capacity, type, and angle of spray pattern. The flat-fan nozzle, for instance, produces a fairly coarse spray in a fan pattern that provides uniformity with proper pattern overlap along a boom. It is well suited to most weed control practices and those insecticide applications where foliage penetration is not required. Flat-fan nozzles produce patterns with various spray angles. For pre-emergence broadcast herbicide applications, flat-fan type nozzles with 65° to 110° spray angles are used. Tips with an 80° spray angle are most commonly used. A wide-angle nozzle (110° for example) can be operated closer to the ground to minimize drift. The pressure range for this type of nozzle is 30 to 60 psi. The use of air induction nozzles is increasing with encouraging results in drift reduction. Air induction nozzles are flat fan nozzles in which an internal venturi creates negative pressure inside the nozzle body. Air is drawn into the nozzle and mixed with the spray liquid resulting in the creation of larger droplets and a reduction in fine droplets.

The best nozzle arrangement for broadcast application is uniformly spaced tips on a boom. This setup can provide the uniform application required for good weed control. Adjust the boom height so patterns overlap on each side (about 33 percent overlap between flat-fans tips and 50 percent for flooding-fans). Boom height will vary from 12 to 24 inches, depending on the spray angle and operating pressure. It is important to adjust the boom height to achieve the correct pattern overlap between each adjoining tip. For
example, if Tee Jet 8003 flat-fan nozzles are 20 inches apart on a spray boom, the spray boom should be 17 to 19 inches high and the adjacent patterns should overlap 8 inches.

When banding applications, use the even-flow fan-type nozzle that applies uniform coverage across the band width. This type of nozzle is designated by Spraying Systems with an "E" in the tip number (8004 E). The "E" series tips should only be used for banding. For broadcast herbicide application, 65° to 110° fan-type nozzle tips are used at pressures of 15 to 40 psi. For insect control, cone-type nozzle tips are arranged with the required number to give complete coverage of plants. One or two nozzles may be used for small plants, but for large plants, three or more nozzles may be required. For fungicide application, hollow-cone type nozzle tips are used with a sufficient number to give good coverage. Pressure of at least 70 psi provides good penetration of foliage. Both the hollow and solid cone nozzles are designed to operate at high pressures from 40 to 400 psi and break the spray into small droplets. This design provides more complete coverage of the sprayed area however; the production of smaller, lighter, droplets increases the likelihood of fogging or drifting. Cone nozzles are generally used for insecticides, fungicides, and growth regulators where complete coverage and foliage penetration is needed.

Flooding-fan spray nozzles can spray a wide swath while operating close to the sprayed surface. These nozzles are normally placed at 3-foot spacings on a boom. Operating at 10 to 20 psi on a boom, the nozzles produce patterns that are resistant to drift and satisfactory for broadcast distribution of herbicides. It is recommended, however, that at least 30 gallons of carrier per acre be used when applying contact herbicides. The flooding-fan nozzle is also ideal for applying post-emergence chemicals because of the low discharge level. The pattern distribution is not as uniform as the regular flat fan nozzles, but is best if the tip is oriented about 30 degrees up from horizontal with proper overlap.
TYPES OF LOW-PRESSURE SPRAYERS

Truck-Mounted Sprayer

The "stacked manifold" truck-mounted sprayers utilized by the Alabama Department of Transportation are designed to operate in the following mode:

**Broadcast:** Speed – 1000 ft./min or 11.4 mph (miles per hour)
Spray output – 25 g/A (gallons per acre)

**Guardrail:** Speed – 440 ft./min or 5.0 mph
Spray output – 80 g/A at 30 to 35 psi

The spray system is equipped with a pressure gauge that is visible to the driver. The gauge is most often located above the spray boom and forward of the truck hood. The system is designed to operate at 30 psi. Consult the operating manual for specifics. This equipment should only be operated on the roadway. The herbicide spray trucks utilize different tips for distributing different herbicide mixtures. It is extremely important that the proper tips be installed in their correct position for the type herbicide being used.

Tractor-Mounted Sprayer

Tractor-mounted, boom sprayers are used for off-roadway spraying operations. Tips should be of flat fan, low volume O.C. (off-center), or flood jet design and should be integrated into the boom configuration to deliver 10, 15, 20, or 25 g/A at 30 psi spray pressure. Maximum operating speed should be 9.0 mph.

CALIBRATION

Pesticides must be applied at a uniform and specified rate in order to obtain effective and economical results. Consequently, **proper calibration of the sprayer cannot be overlooked as an important part of a successful vegetation management program.** This is especially true when working with multiple nozzle booms, fixed nozzles and off-center nozzles which operate at uniform distribution widths, spray pressures and known speeds.

Calibration of a low-pressure ground sprayer is the process of adjusting a sprayer to give the desired application rate with uniform coverage of foliage or soil. This must be
done to insure that a pesticide is being applied according to label directions. Too much pesticide use is costly, inefficient, and could be dangerous; too little will not do a good job; and uneven application results in spotty control. Only by calibrating correctly can you safely get the best results. Proper adjustment and calibration of the equipment can prevent waste of pesticides. There are many accurate and easy ways to calibrate chemical sprayers. Depending upon the method used a given area of land sprayed and the amount of material applied is usually determined on the basis of gallons per acre.

The area sprayed for calibration purposes is often some easy-to-calculate fractional portion of an acre. Errors in calculation can cause serious errors in application rates of sprayers. Care must be taken to avoid miscalculations. A calibration method that involves few or no calculations is generally best unless you have paper, pencil, and calculator. The type of sprayer, the area to be sprayed, the pesticide formulation and several other variables may determine the most desirable method to use. The following methods are popular and accurate ways of calibrating liquid sprayers.

"Stacked Manifold" Sprayer Method
The "stacked manifold" sprayer is easy to calibrate since only a few variables exist. It is extremely important that the proper tips be installed in their correct position for the type of herbicide being used. Failure to replace worn nozzle tips, to clean nozzle tips and screens, or to install the correct tips in their appropriate position will result in incorrect calibration and poor weed control. To calibrate a "stacked manifold" sprayer, select a speed that will allow for accurate placement of the herbicide to the target area. The speed selected should be the most appropriate considering factors such as traffic conditions, obstacles near or in the area to be treated, and experience of the vehicle operator.

Refill Method
This method involves filling the spray tank with water and spraying a measured area of land. The amount of water required to refill the tank to its original level is then determined to be the amount applied to the spray area.

This method begins by choosing the speed, pumping pressure, and appropriate nozzle tips. Fill the spray tank with water and operate the sprayer in place to fill all hoses. Refill the tank to a known volume and spray a measured area as if you were applying the pesticide. Measure the amount of water needed to refill the tank to the initial volume. This is the application output volume per unit of area. If it takes 20 gallons to refill the
tank after spraying 1 acre, you are spraying at the rate of 20 g/A. You should spray an area large enough to use at least 10 percent of the tank capacity.

For **BARE GROUND** applications on shoulders, guardrails, signs, etc., use the small boom with the "stacked manifold" sprayer. After selecting the appropriate ground speed and adjusting the spray pressure to the fixed setting, determine the output from Table 2.

**Table 2. Stacked Manifold Sprayer Output for Bare Ground Applications**

<table>
<thead>
<tr>
<th>GROUND SPEED</th>
<th>SPRAY PRESSURE</th>
<th>OUTPUT g/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft./min</td>
<td>psi</td>
<td></td>
</tr>
<tr>
<td>440</td>
<td>30</td>
<td>80</td>
</tr>
<tr>
<td>500</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>600</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>700</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>800</td>
<td>30</td>
<td>42</td>
</tr>
<tr>
<td>900</td>
<td>30</td>
<td>39</td>
</tr>
<tr>
<td>1000</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>1100</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>1200</td>
<td>30</td>
<td>29</td>
</tr>
</tbody>
</table>

ft./min = feet per minute  
psi = pounds per square inch  
g/A = gallons per acre
For **SELECTIVE** applications in the right-of-way and foliar applications on brush, use the W-4 boom that sprays in four 9-foot sections for a total swath of 36-feet. After selecting the appropriate ground speed and adjusting the spray pressure to the fixed setting, determine the output from Table 3.

**Table 3. Stacked Manifold Sprayer Output for Selective Applications**

<table>
<thead>
<tr>
<th>GROUND SPEED</th>
<th>SPRAY PRESSURE</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft./min</td>
<td>psi</td>
<td>g/A</td>
</tr>
<tr>
<td>500</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>600</td>
<td>30</td>
<td>41</td>
</tr>
<tr>
<td>700</td>
<td>30</td>
<td>36</td>
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<td>800</td>
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<tr>
<td>900</td>
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<td>1000</td>
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<td>25</td>
</tr>
<tr>
<td>1100</td>
<td>30</td>
<td>23</td>
</tr>
<tr>
<td>1200</td>
<td>30</td>
<td>21</td>
</tr>
</tbody>
</table>

ft./min = feet per minute  
psi = pounds per square inch  
g/A = gallons per acre
Measured Distance Method

1. Prepare sprayer as described under "Checklist for Spray Equipment".
2. Set desired pressure not to exceed 40 psi.
3. Determine the effective spray width in feet.
4. Determine desired application rate in g/A.
5. Calculate the distance the sprayer must travel to cover 1 acre.

\[
\frac{43,560 \text{ ft.}^2}{\text{spray width in feet}} = \text{feet sprayer must travel to spray 1 acre}
\]

6. Fill tank with clean water to a specific depth. Operate sprayer over the distance calculated in Step 5 at normal operating speed and pressure. Determine amount of water used by measuring the amount of water required to refill tank.
7. Repeat Step 6 varying operational speed until predetermined amount of water determined in Step 4 is reached.
8. Recheck the procedure for accuracy using same gearing and tachometer reading as before.

Arithmetic Calibration Method

This method requires some understanding of the different factors involved in calibration as well as pencil, paper, and calculator. The following formula can be used to determine the correct output.

\[
g/A = \frac{\text{gallons}}{\text{minutes}} \times \frac{\text{minutes}}{\text{acres}}
\]

The different parts of this formula can be calculated by following the steps outlined below:

First, determine the output rate in g/min:

1. Fill spray tank and sprayer lines 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.
4. Close valve, shut down the equipment, and remeasure the amount of water needed to refill the tank.
5. Divide the number of gallons of water needed to refill tank by the time of pump operation to get pumping rate in g/min.

Next, determine a/min (acres sprayed per minute):
1. Determine the number of feet the sprayer moves per minute in the desired gear and at the throttle setting used to measure output.
2. Measure the width of the sprayer boom or band width in feet.
3. Calculate the area that the sprayer covered in 1 minute (distance traveled x boom width). Area will be expressed as ft² (square feet).
4. Convert the area sprayed per minute to A/min (acres sprayed per minute). Remember: 1 acre = 43,560 ft².

Finally, determine the amount of solution applied per acre (g/A):
By entering the values calculated earlier for g/min and A/min, the spray output in gallons per acre may be determined by using the equations below:

\[
g/A = \frac{\text{gallons}}{\text{minutes}} \times \frac{\text{minutes}}{\text{acres}}
\]

**CALCULATING THE AMOUNT OF PESTICIDE PER TANK**

After the calibration has been completed, the number of acres that can be sprayed with each tank of spray solution can be determined by dividing the size of the tank in gallons by the output volume of the sprayer in g/A. After the number of acres that can be treated with the spray tank is calculated, multiply the number of acres by the amount of pesticide required per acre.

**Example:** The desired application of Method is 6.0 oz./acre; Sprayer out-put at 30 psi = 25 g/A; Tank capacity = 1000 gallons.

1. Area sprayed per tank = 1000 gallons divided by 25 g/A = 40 acres treated per tank.
2. Ounces of Method per tank = 40 A/tank x 6.0 oz./A = 240 oz./tank.
CONTROLLING APPLICATION VOLUME

There are four factors that determine the volume of spray applied. These factors are:

- Nozzle spacing or spray width (ft.)
- Nozzle orifice size (g/min)
- Pressure at the nozzle (psi)
- Ground speed (ft./min or mph)

The first two factors are not generally changed once set; the pressure and ground speed are the primary factors in the calibration procedure. Changes in pressure result in only small changes in the volume applied. Lower pressure means less spray delivered; higher pressure means more spray delivered. Pressure must be increased four times to double the output. This is not a good method because a significant pressure change may distort the nozzle pattern or reduce the droplet size to a fine mist.

Changing ground speed is the best way to make moderate adjustments in spray output. Slower speed means more spray delivered; faster speed means less spray delivered. This method is practical for moderate changes in delivery rate. If you drive half as fast, you double the delivery rate. The best method for making major changes in the delivery rate of sprayers is to change the size of the spray tips. If more than a 25% change in spray output is required after the first calibration, changing the nozzle tip size is usually necessary. The larger the hole in the tip, the more spray delivered. Always select nozzles for the job you want done. Use the manufacturer's performance charts to make your selection. After any change in sprayer setup is made, the sprayer should be re-calibrated.

MANUAL (HANDGUN) SPRAYERS

Manual (handgun) sprayers are designed for spot treatment and for small areas not suited for larger units. For pressurizing the spray solution, most manual sprayers use compressed air or carbon dioxide that forces the spray solution through a nozzle. These sprayers are relatively inexpensive, simple to operate, maneuverable, and easy to clean and store.

Types of Handgun Sprayers

Handgun spraying with mechanical pumps is utilized by the ALDOT and is designed for a spray output of 100 g/A at 80 psi. A variety of orifice tips and guns are in
service. Applicators should spray to wet foliage only, not to the point of runoff.

Manual sprayers powered by compressed air or carbon dioxide are generally of small capacity and are used on small areas. It is recommended that the amount of spray to be applied should be determined on small areas such as 100 ft². Most manual compressed air sprayers do not have pressure gauges or pressure controls. The pressure in the tank will drop as the material is sprayed. This pressure drop can be partly overcome by filling the tank only 2/3 full with spray material, so that considerable air space is left for initial expansion, and by re-pressurizing the tank frequently. If the sprayer has a pressure gauge, re-pressurize when the pressure drops approximately 10 psi from the initial reading.

When spraying, either hold the nozzle at a steady, constant height and spray back and forth in swaths, or swing the nozzle back and forth at a uniform speed in a sweeping, overlapping motion. A uniform walking speed must be maintained during application.

Calibration
The amount of spray solution applied per 1000 ft² can be determined by the following method:
1. Measure and mark off an area of 1000 ft² (for example, 10 ft. by 100 ft.).
2. Using water, practice spraying the area. To obtain the most uniform application, spray the area twice with the second application at right angles to the first.
3. Place a measured amount of water in the tank, spray the area, then measure the amount of water remaining in the tank. The difference between the amount in the tank before and after spraying is the amount used.
4. Add the recommended amount of pesticide to the sprayer with the volume of water needed to cover 1000 ft².

GRANULAR APPLICATION EQUIPMENT

Drop (gravity) and rotary (centrifugal) spreaders are available for applying granules. They can be used to apply pesticides in a band or broadcast. Drop spreaders are generally more precise and deliver a better pattern. Since the granules drop straight down, there is less chemical drift and better control, with less chance of applying pesticide to non-target areas. Some drop spreaders will not handle large granules, and ground
clearance may be a problem. Since the edge of a drop spreader pattern is sharp, any steering error will cause strips to be missed or doubled.

Rotary spreaders cover a wide swath, and thus, cover a given area faster. However, they are less precise than drop spreaders in terms of uniformity and distribution. Because of the pattern feathering, steering errors are less critical. Rotary spreaders normally handle large particles well, but drift is a problem with fine particles when wind is present. Ground clearance is usually no problem for a rotary. Since rotary patterns vary, more calibration time is needed. A major advantage of rotary spreaders is that they may be constructed with plastics and fiberglass and, therefore, are more resistant to corrosion. Rotary spreaders are also more durable in commercial use, and less likely to be knocked out of calibration than some drop spreaders.

Commercial type rotary spreaders usually have hopper capacities of 200 to 1200 lbs. The application rate is adjusted by changing a gate opening, located between the bottom of the hopper and the disc. The gate regulating the flow of particles is controlled either manually or electrically. Pesticide granules are used to reduce toxicity (safer to handle) for convenience in application, to reduce injury to desirable plants, to increase selectivity and, in some cases, to give better placement of the pesticide.

The application rate of granules applied depends on the size of the metering opening, speed of the agitator or rotor, travel speed, and the flowability of the granules. Granules flow at different rates, depending on size, density, type granules, temperature, and humidity.

**Calibration**

 Calibration begins by determining the correct rate of granules to apply. Granular applicators are calibrated by collecting and weighing the material applied for a measured distance. Recommendations vary according to the amount and type of pesticide being used. Rates are usually expressed as a weight per broadcast area, such as tons/A or lbs./ft². Because of many variables, it is highly recommended that all spreaders, drop or rotary, be calibrated for proper delivery rate with the specific operator and product to be used. Label directions and equipment manufacturer settings are as precise as the companies can make them, but a number of additional factors can add up to a significant rate variation. Equipment manufacturer and label settings should be used only as the initial setting for verification runs by the operator prior to large-scale use. The following procedure can be used to calibrate a granular (spreader) applicator.
1. Collect the sample as follows:
   a. Broadcast tube types with spreaders: Collect the material applied per tube for 100 ft. and determine the broadcast width per tube.
   b. Rotary or centrifugal broadcast type:
      Hand type -- Place the spreader in a large paper or plastic bag and collect the material while operating for 100 ft² at normal speed. Weigh the quantity collected (not counting bag).
      Power type -- Put a quantity of granules in the hopper. If possible, calibrate in a stationary position using a sheet of plastic or container to catch the material. If the applicator cannot be calibrated in a stationary position, operate it over a specified area and collect the material in a suitable container.
   c. Drop-type -- Hang a catch pan under the spreader and push the spreader a measured distance at the proper speed to collect the sample. The drop spreader may also be supported above ground and the drive wheel turned to simulate the distance traveled. By remaining stationary, the granules released by the drop spreader can be collected on a tarp or plastic drop cloth.

2. Weigh the sample with scales.

3. If the rate is not correct, adjust the equipment and recheck.

With rotary spreaders, it is also necessary to check and correct the distribution pattern. Again, the product label may give a recommended setting and width, but it is foolish not to verify the setting and width before treating a large area. A quick pattern check can be made by operating the spreader over a paved area and observing the pattern. However, this method is not highly accurate since even major distribution errors may not be visible because of particle bounce and scatter.

A preferred method is to lay out a row of shallow cardboard boxes on a line perpendicular to the direction of travel. Boxes 1 to 2 inches high, with an area of about 1.0 ft², spaced on 1-foot centers are good for commercial push-type rotaries. The row of boxes should cover one and one-half to two times the anticipated effective swath width. To conduct the test, pour some product into the spreader and set it at the label setting for rate and pattern. Make three passes over the boxes, operating in the same direction each time. The material caught in each box can be weighed and a distribution pattern plotted.
SPRAYER MAINTENANCE

Application accuracy requires a good schedule for sprayer maintenance. During the use season, all operating parts (hoses, fittings, valves, gauges, etc.) should be checked daily. Vibration from the tractor or gasoline-powered pumps can loosen bolts, nuts, parts, and can crack welded joints. Strainers also should be checked and cleaned daily, as a partially plugged strainer will reduce pressure and flow rate. Frequently check the output pattern for poor performance and clogged spray tips. Worn nozzle tips need to be replaced periodically to maintain rate accuracy. Spray tips should be cleaned only with compressed air, an old toothbrush or toothpick, because they won't enlarge the nozzle orifice as a metal object can. Recheck the calibration or delivery flow rate of nozzles regularly. **Always try to end the day with an empty sprayer. Failure to clean the sprayer after each use can result in clogged nozzles, damaged sprayer components, and possible injury to non-target plants.** If you will be using the same herbicide the next day, flushing the sprayer with clean water is sufficient. If a different herbicide will be used, then a more effective cleaning is recommended. The cleaning solution and procedure depend on the herbicide used. Always check the label for specific cleaning instructions.

When cleaning a sprayer, use the area designated for this purpose. Do not allow wastewater or pesticide residue to contaminate water supplies, streams, ponds, or areas with crops and desirable plants. **Maintain a 165-foot buffer zone between the cleaning area and any seasonal streams, tributaries, or well heads.** Do not let wastewater puddle where it will be accessible to livestock or wildlife.

Repeated flushing with water is not a dependable method to remove all pesticide residues from a spray tank, pump, hose, boom, and by-pass system. Emulsifiable formulations such as esters and oil-soluble products are more difficult to remove than water-soluble pesticide formulations. To remove residues of oil-based pesticides use a spray tank cleaning product such as Wipeout® or Vigor. Empty the spray tank, pumps, and lines, flush with clean water and then follow product label directions; be sure to rinse the screens and nozzles with a solution of the tank cleaner.

Because products such as 2,4-D may be persistent and leave a residue and because of other variables involved in tank cleaning it is always wise to test the final rinsate. To do this, retain a small sample of the final rinsate and apply it to an ornamental plant - or better, a sensitive crop plant such as tomato or cotton. Observe the treated plant...
for 48 hours; if damage occurs, repeat the cleaning process until the rinsate test shows no damage.

When the season is over, add 1.0 to 5.0 gallons of light oil to the final flush and spray out. This will leave a protective coating of oil on the internal parts and make the unit easier to start up again next season. This will help prevent rust and corrosion inside the pump and plumbing. Tips and screens will wear longer if they're removed and stored in a container of kerosene or diesel fuel until needed again. Drain the pump and plug its openings or fill the pump with light oil or antifreeze. Store the sprayer in a dry building. Be sure to flush the system with clean water prior to the initial use after off season storage.
DAILY CHECKLIST FOR ALL SPRAYING EQUIPMENT

Before Operation
1. Fill tank half full with water and check for leaks in tank, shut-off valves, and fill opening. Lid must fit tight and have required gaskets or seals.
2. Close shut-off valves, clean and replace strainer, open shut-off valve and check for strainer leaks.
3. Check all hose fittings for leaks and tighten as necessary.
4. Check all hoses. Replace all worn or defective hoses before operating equipment.
5. Check all pump drive belts. Replace all worn or defective belts before operating equipment.
6. Check engine oil level and service air filter and cooling system as necessary.
7. Check all valves for correct operation. Replace or repair any valve that is not operating freely.

During Operation
2. Close by-pass valve until operating pressure is reached - 30 psi.
3. Open spray valves and regulate pressure until operating pressure of 30 to 40 psi is reached.
4. Check spray swath for uniformity. If pattern is distorted or has gaps, check tips immediately for blockage or damage.
5. Calibrate equipment at this time at speed you will travel.
6. Check again for leaks in valves, seals, tank lids and hose connections and make any needed adjustments. Add chemicals to the tank only after the equipment is in operating condition. Do not leave the yard with faulty equipment.
7. Continuously observe pressure gauge and spray pattern; any change in pressure will require you to stop immediately and correct the problem before continuing.

After Operation
1. Wash and clean outside of spraying equipment as necessary to remove chemical residue from the surface.
2. Clean inside of tank when a different chemical mix is to be used or if equipment is not to be used the following day. Rinse water should be applied to right-of-way where the chemical would normally be used. Do not flush rinse water into sewers or drainage ditches.
3. Spray hoses must be examined for chemical residue and cleaned regularly, especially when using dry flowables and water dispersible granules.
4. Report any malfunction of equipment or compatibility problems to your supervisor immediately.
CHAPTER 2 GLOSSARY

Agitation - The process of stirring or mixing in a sprayer.

Agitator - A device attached near the bottom of a spray tank that stirs or mixes pesticide spray mixtures.

Boom - A mechanical structure used to extend and carry nozzles from pesticide sprayer.

Broadcast - A pesticide treatment applied over an entire area.

Calibration - The calculation and/or determination of a pesticide applicator's output per unit area and the correct preparation of an effective spray rate.

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

Cavitate - To starve a pump, resulting in a damaging vibration.

Diluent - Any gas, liquid, or solid material used to reduce the concentration of an active ingredient in a formulation.

Drift - Movement of airborne spray from the intended area of application.

Emulsifier - A surface-active substance that promotes the suspension of one liquid in another.

Flowable - A pesticide formulation that contains a solid pesticide suspended in a liquid and forming a suspension when mixed in water.

Foliation - The leaves of a plant.

Formulation - A pesticide preparation supplied by the manufacturer for practical use.

Fungicide - A chemical used to control, suppress, or kill fungi.

Gauge - A device designed to indicate effective operating pressure in spray system.

Granule - A dry formulation of a pesticide and other components into discrete, rather uniform-sized particles.

Hectare - An area of land equal to 10,000 square meters or 2.47 acres.
**Herbicide** - A chemical used for killing plants or severely interrupting their normal growth processes.

**Insecticide** - A chemical used to kill insects or severely disrupt their normal growth processes.

**Kilogram** - A metric unit of weight equivalent to 1000 grams or 2.2 pounds.

**Kilometer** - A metric unit of distance equivalent to 1000 meters or 3281 feet.

**Kilopascal** - A metric unit of gas pressure equivalent to 0.15 pounds per square inch.

**Label** - The directions for using a pesticide approved as a result of the EPA registration process and attached to the pesticide container.

**Liter** - A metric unit of volume equivalent to 1000 milliliters or 0.26 gallon.

**Meter** - A metric unit of distance equivalent to 1000 millimeters or 3.28 feet.

**Milliliter** - A metric unit of volume equivalent to 0.001 liter or 0.034 fluid ounce.

**Millimeter** - A metric unit of length equivalent to 0.001 meter or 0.0033 feet.

**Nozzle body** - A spray component which is attached to a spray boom and holds the screen, spray tip and cap.

**Orifice** - Opening in the spray tip which controls the spray output volume and spray pattern.

**Pesticide** - Any chemical or mixture of chemicals intended for controlling insects, rodents, fungi, weeds or animal life that are considered pests.

**Post-emergence** - An application made after the emergence or establishment of a crop or weed.

**Pre-emergence** - An application made prior to the emergence of the weed or crop.

**Pump** - A device that forces a liquid or gas into, or draws it out of something, as by suction or pressure.

**Regulator** - A device that controls and maintains a uniform pressure in a spray system.

**Residue** - The quantity of pesticide remaining in or on soil, plant parts, animal tissues, whole organisms, and surfaces.
**Screen** - A filter-like device usually positioned behind the spray tip in the nozzle body to capture particulate material before it plugs the tip orifice.

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

**Solution** - A homogeneous mixture of two or more substances.

**Sprayer** - A machine designed to permit the controlled delivery of solutions and operates usually on the basic principal of hydraulics.

**Spray tip** - The spray component that restricts the volume of a pesticide spray through its orifice and establishes the pattern of the spray.

**Tank** - A container for holding spray liquids or gases.

**Valve** - A device designed to regulate the flow of a liquid in a channel.

**Weed** - A plant growing where it is not desired.
CHAPTER 3: PESTICIDES AND VEGETATION MANAGEMENT

INTRODUCTION

The primary objective of any highway vegetation management program is to establish and maintain dense and permanent vegetation on managed areas. The use of pesticides and other management chemicals to control unwanted vegetation, damaging diseases, and insects is a vital element in any maintenance program. A pesticide is a material designed to inhibit or control a pest as part of the management program. Pesticides are classified according to the pest that they are designed to control. Chemicals used to control insects in sensitive areas are called insecticides. Fire ants, mole crickets, and chinch bugs are examples of problem insects in managed areas. Plant diseases, such as brown patch, dollar spot, and powdery mildew are controlled by a class of chemicals called fungicides. Chemicals used to control or restrict unwanted plant growth are called herbicides. Crabgrass, thistles, johnsongrass and kudzu are examples of problem weeds controlled by herbicides. Since weeds are the most significant pests along highway rights-of-way and other managed areas, considerable discussion and detail will be presented on herbicides and weeds.

FORMULATIONS

Pesticides, in their pure form, are practically useless to the end user. To make these chemicals useful, chemists combine (formulate) the pure chemical (active ingredient) with solvents, diluents, surfactants, and other additives to form a product called a formulation. Each pesticide sold for vegetation management use is available in one or more formulations that increase the flexibility of use depending on equipment availability and size of treatment area. The primary purpose for formulating a pesticide is to allow the end user to easily and uniformly apply a small amount of pesticide over a rather large area in a safe manner. Formulating pesticides may also have the following effects:
• Increase the toxicity of the pesticide on the target pest.
• Provide a safe, useful, and economical form of the product for the user.
• Provide a stable and long-lasting form for safe shipment and storage.

Most pesticides are formulated so that they can be applied as a liquid spray when mixed and diluted with water as the carrier. Some pesticides are formulated to be applied in oil carriers or as dry materials directly out of the bag or can.

Pesticide formulation is usually designated prominently on the product label immediately after the pesticide’s trade name. After the pesticide trade name, there may be a numeric and alphabetic designation. The numeric portion, when present, refers to the amount of active ingredient either as a percentage by weight or as an actual amount per unit volume expressed as pounds per gallon. In the following discussions of pesticides the accepted alphabetic designations and definitions for formulations of pesticides in the United States will be used.

**Liquid Formulations**

**E or EC - Emulsifiable Concentrate.** A liquid formulation in which the active ingredient has been dissolved in a solvent and combined with an emulsifier to allow the mixing with water. Emulsifiable concentrates produce a milky emulsion when mixed with water. After mixing, little agitation is required.

**S or SL - Water Soluble Concentrate.** A liquid form of pesticide that readily mixes with water and forms a true solution that is transparent or clear to the eye. The solutions are commonly colored either by the pesticide or by addition of inert dyes. After adequate mixing, no additional agitation is needed to keep the pesticide uniformly distributed in the solution.

**F, FL and AS - Flowable, Flowable Liquid, or Aqueous Suspension.** Finely ground solids suspended in water or other liquid solvent system. The ground particles are smaller than those in wettable powders. Since the particles are already suspended in a liquid, there is no need to make a slurry prior to tank mixing. Agitation is required to keep the particles in suspension.

**A - Aerosol.** A liquid formulation designed to suspend the active ingredient in the atmosphere. The active ingredient may be in ready-to-use liquid form that is pressurized by inert gases in the container for application ease. Aerosol liquids may also be available as concentrates suitable for use in fog generators or foggers.
Dry Formulations

**W or WP - Wettable Powder.** A dry, finely ground formulation, resembling dust. The active ingredient is usually mixed with a finely ground mineral clay and other materials that enhance the ability of the wettable powder to suspend in water. This dry-type formulation should be mixed in a small amount of water to make a slurry before the slurry is introduced into a partially filled sprayer. Continuous agitation is needed thereafter to maintain a uniform spray mix.

**DF or WDG - Dry Flowable or Water Dispersible Granule.** Formulations similar to wettable powders, except the active ingredient is combined on a clay granule instead of a fine powder. This form is easier to pour, can be measured by volume, and produces less dust when handled. Dry flowables and water dispersible granules are applied as a liquid spray when mixed with a carrier (usually water). These formulations require continuous agitation to maintain a uniform suspension of the spray mix.

**SP - Soluble Powder.** A dry powder formulation that, when mixed with water, dissolves readily and completely to form a true solution. After thorough mixing, no agitation is necessary.

**D - Dust.** A very finely ground dry formulation of a low percentage active ingredient pesticide, plus an inert carrier. Dusts are preferred for some situations because of ease of application. Several insecticides are formulated as dusts and they are always applied dry.

**B - Bait.** A formulation where the pesticide active ingredient is mixed with a food or attractive source. The bait is dry when applied and is fed upon by the pest. Bait formulations are limited to insecticide and rodenticide materials.

**G - Granule.** A dry formulation composed of the active ingredient and other components to form discrete particles. Granule components can include clay minerals, ground plant residue, dry fertilizer, or starch polymers. These components serve as the carrier for the pesticide. This formulation is applied dry to the soil, but requires somewhat more water to move the pesticide into the soil than sprayable formulations need.

**P - Pellet.** A dry formulation similar to granules except larger in size and often containing higher concentrations of active ingredient.
VARIABLES AFFECTING PESTICIDE PERFORMANCE

Pesticides are compounds composed of chemical elements, such as oxygen, hydrogen, and carbon that affect normal plant, insect, or disease systems in a variety of ways. Since herbicides are the most frequently used pesticide in vegetation management, these chemicals will now be discussed in greater detail. However, the response of other pesticides, such as insecticides and fungicides, will be similar in most situations.

No single herbicide is effective on all weeds and no single herbicide can be used in all situations. Herbicide activity or effectiveness is influenced or affected by many factors. The following are some of the more important variables to be considered when choosing a herbicide for a specific purpose:

- Type of herbicide and species of plant
- Soil type
- Wind velocity
- Humidity
- Rainfall (moisture)
- Temperature (air and soil)
- Application timing
- Adjuvants
- Compatibility of mixtures
- Water quality

**Type of Herbicide**

Herbicides can be grouped according to the way they enter or affect plants and weeds and their persistence in the environment. There are two broad categories that cover all herbicides. These categories are contact-type and systemic-type (translocated). Contact herbicides are few in number. While several of these herbicides are valuable tools in certain agricultural situations, they are of minor importance in most vegetation management programs since they provide little or no residual weed control when applied alone. These herbicides are all applied in liquid sprays and are detrimental to plant tissues by destroying only the portion of the plant they contact. Results are obtained from within a few hours to a few days and require favorable plant growing conditions for
optimum performance. Contact herbicides are sometimes added to root-absorbed materials to speed up plant kill.

Systemic herbicides comprise the majority of the herbicides used in the vegetation management programs. These chemicals move through actively growing plants (weeds) and accumulate in growth centers where they speed up and disorganize cell division or elongation; or in some cases they interfere with food production, energy conversion or protein synthesis. Systemic herbicides enter a weed by two means. They can be foliar-absorbed or root-absorbed, or sometimes both.

Foliar-absorbed herbicides are applied as a spray to the leaves and green stems of plants. They are absorbed through these plant parts (foliage) and are moved (translocated) throughout the plant, interfering with normal growth processes as they go. Since most herbicides of this type have little or no residual activity, repeat treatments may be necessary to control undesirable vegetation emerging from seed. Foliar-absorbed herbicides may be either selective or nonselective.

Root-absorbed herbicides, as indicated, are applied to the soil and enter the plant below the ground. They require rainfall in varying amounts after application to move them into the soil and in the root zone. This type of herbicide is picked up by plant roots and moved upwards (translocated), producing toxic symptoms by interfering with natural growth processes. Root-absorbed herbicides may be residual or non-residual, selective or nonselective, depending upon the particular herbicide and rate used.

Residual activity generally refers to root-absorbed (soil active) herbicides which have a low order of solubility, and tend to remain in the soil for some length of time, adversely affecting plant growth. The length of residual activity is dependent upon the particular herbicide, the amount of herbicide applied, the target weed species, and the amount of rainfall. Non-residual herbicides are those that break down rapidly and completely on the foliage or in the soil and have no prolonged effect on productivity.

Selective herbicides are those that control undesirable vegetation (weeds) without seriously injuring desirable plants. Nonselective herbicides, on the other hand, control most vegetation treated with little or no regard to species.

**Type of Plant and Species**

Proper selection of herbicides and their application rates are dependent on the type and species of the weeds to be controlled, as well as the growing condition of the weed. Some plant species are more tolerant to certain herbicides than are other more sensitive plants. The growing condition of the weed may also affect herbicide efficacy.
Weeds growing actively under good growing conditions are more easily controlled than the same weeds growing under stress or in a dormant condition. The growth stage of weeds (e.g. - seedling, vegetative, flowering, fruiting, mature) should also be considered when deciding where or when to use herbicides. In general, seedling weeds are easier to control than older, more established weeds. The vegetation type is of foremost consideration as plants respond differently to different chemicals. In order to determine the best time to treat a weed or determine the time that a weed would be most sensitive to control measures, it is important to understand something about the biology or the life cycle of the weed in question. This is why it is important to make a positive identification of the weed so that its life cycle is known. Weeds can be divided into three general groups based on the duration of their growth. The three plant life cycle groups are annuals, biennials, and perennials.

Annual plants are plants that typically complete their life cycle in a single growing season. Summer annual plants germinate from seed in the spring of the year, grow vegetatively during the spring and summer, develop flowers, fruit and seed during the late summer and fall, and die back with the onset of frost. Examples of summer annuals include crabgrass, pigweed, and ragweed. Winter annuals are those plants which germinate from seed during the late summer or fall, grow vegetatively during the fall, winter and early spring. These plants will form flowers, fruit and seed during the spring, and die back with the onset of high temperatures during the early summer. Examples of winter annuals include wild mustard, annual ryegrass, and henbit.

Biennial plants are plants that complete their life cycle in two years. Typically, during the first year, the plant germinates from seed, grows vegetatively forming basal cluster of leaves (rosette) and taproot, and overwinters in this stage. During the second year, the plant produces a leafy flowering stem, and the plant dies at the end of the second year. Only a few broadleaf plants are members of this group. Examples of biennial plants are common mullein, cudweed, and musk thistle. Both annual and biennial plants generally are readily controlled with contact or residual type herbicides.

Perennial plants are those that may persist for many years in the same location. Perennial plants may germinate from seed, grow vegetatively, form flowers, fruit, and seed in a single year and may even die back to the ground with the onset of stress temperature conditions. However, perennial plants reproduce in ways in addition to seed. They also produce vegetative reproductive structures, such as fleshy taproots, creeping stolons and rhizomes, or bulbs, tubers or nutlets.
A simple perennial is a plant that essentially reproduces by seed and by root segments. An example of such a plant is the dandelion. A creeping perennial is a plant that reproduces by seed and by spread of either stolons and/or rhizomes. Examples of this type of perennial are bahiagrass and johnsongrass. Bulbous perennials are plants that reproduce by producing bulbs, tubers or nutlets in addition to seed. Examples of bulbous perennials are yellow nutsedge, wild garlic, and Florida betony. Because perennial weeds can reproduce in several ways, they are very difficult to control. The best time to apply a foliar herbicide to many perennial weeds is when they are entering the seed head or fruiting stage (e.g. - the "boot" stage of johnsongrass).

Within these life cycle classifications, weeds can be further divided or separated by plant type based on shared characteristics. The three basic types of plants are the grasses and grass-like plants, broadleaf weeds, and woody plants.

There are more than 1,400 different grasses known to exist in the United States. As a group, they share a number of characteristics in common. Grass seedlings have only one seed leaf as they emerge from the ground. They typically have leaves that are narrow and parallel veined. Many grasses also have a fibrous root system. Grasses have non-showy flowers that are frequently wind pollinated. Grass-like plants, such as rushes and sedges, have physical characteristics similar to grasses. Sedges have triangular, solid stems and leaves with a deep groove along the mid-vein. Rushes have round; solid stems with linear leaves which have fused sheaths surrounding the stems. Both rushes and sedges have non-showy flowers. Examples of grasses and grass-like plants are crabgrass, goosegrass, bermudagrass, yellow nutsedge and path rush.

Broadleaf plants are the largest group of plants. This group includes both herbaceous plants and vines. These plants do not develop persistent woody tissue above ground. Broadleaf seedlings have two seed leaves or cotyledons that are visible as they emerge from the soil. The leaves of broadleaf plants are broad and have a vein pattern on the leaf blade that is net-like. Broadleaf weeds may have either a taproot like a carrot or a fibrous root system like grasses. The growth points or buds of broadleaf plants are typically found at the ends of stems and at the base of the leaf stalks or petioles. And finally, broadleaf plants have showy flowers. These flowers are usually colored and fragrant and are frequently insect pollinated. Examples of broadleaf plants or weeds are dandelions, pigweeds, and clover.

The third group of plants is woody plants. Woody plants typically form persistent woody tissue above the ground in their stems. This group would include brush, shrubs and trees. Trees can be further divided into two groups, hardwoods and conifers.
Hardwood trees usually shed their leaves with the onset of frost each year. However, conifers are evergreen and keep their needles year-round. Examples of woody plants are pines, oaks, maples, willows and sweetgum.

**Soil Type**

Soil type can affect vegetation control. Soil-active (root-absorbed) herbicides are more active and therefore require lower rates when applied to soils that are low in clay and organic matter because of the reduced herbicide absorbance of these soils. In soils that are high in clay and/or organic matter, higher rates of soil-active herbicides are necessary because more herbicide is adsorbed to the soil particles and less is available to the roots of target weeds. Soil pH or the acidic/alkaline nature of soil can also affect the performance of a pesticide. In relatively acid soils, herbicides such as Oust® XP and Telar® are much less soluble and decompose at a faster rate than they do in more alkaline soils.

**Wind Velocity**

Wind can disturb the spray pattern and blow the chemical away from the target area. The higher the wind velocity, the greater the potential for spray movement. The wider the spray pattern, the greater the effects of wind distortion. It is best to spray at wind speeds less than 10 mph. The use of a drift control agent can help to reduce spray drift. If wind velocity exceeds 10 mph, the spray pattern cannot be kept on target and spraying should be discontinued.

**Humidity**

Relative humidity is the percentage of moisture in the atmosphere relative to the maximum amount that the air could hold at the same temperature. Generally, the higher the humidity at the time of application, the more rapid the uptake of foliar-applied herbicides by weeds. However, when the relative humidity is at or approaching 100%, rainfall is likely to wash the herbicide from leaf and stem surfaces. Herbicide applications should be postponed when rainfall is imminent.

**Rainfall (moisture)**

Rainfall affects chemical control of vegetation. Rain can dilute and wash the herbicide off the leaves before absorption by the target weeds. After a rain, dust on leaves will have been washed off and foliar applied herbicides will be more easily absorbed by
After rainfall, always allow foliage time to dry before resuming spraying. Applications made to foliage wet from rain or heavy dew usually yield poor results.

Rain is the vehicle for movement of soil-active herbicides into the root zone of weeds. Soil-active chemicals must be in soil solution before they can be absorbed by the root system of plants. Excessive water may result in the movement of soil active herbicides below the root zone of target weeds, resulting in poor control. In addition, excessive rainfall may lead to movement of herbicides to areas outside the treated area, resulting in serious plant injury to non-target vegetation. Less than adequate rainfall also has an adverse effect on herbicide performance. Timely rainfall is needed to move soil-applied herbicides into the root zone of weeds. Poor results will occur if the herbicide is not at the right place at the right time. Drought-stressed plants have slowed or semi-dormant metabolic processes which retard the uptake and translocation of herbicides. Herbicide effectiveness is usually diminished under these conditions.

Temperature

Temperature affects the results of vegetation control by affecting the growth processes in target weeds and the speed of herbicide action. Cool or freezing temperatures will slow down plant processes to a dormant state, reducing the effectiveness of many systemic herbicides. Conversely, prolonged high temperatures during summer months may cause plants to become semi-dormant during such stress periods. High temperatures may result in reduced effectiveness of systemic herbicides, while increasing the phytotoxicity of contact herbicides on target and non-target vegetation.

Application Timing

Proper application is necessary for the success of any herbicide treatment. Soil-active herbicides should be applied uniformly. Foliar-translocated herbicides should be applied uniformly to the foliage of vegetation at the proper time. Foliar-active and soil-active herbicides both require proper timing and good coverage for effective performance.

Preemergence herbicides are applied to the soil and are absorbed by the roots of germinating seeds before the plant emerges from the ground. For control of summer annual weeds in typical Alabama weather patterns, preemergence herbicides should be applied by March 1 in South Alabama, before March 15 in Central Alabama and by April
1 in North Alabama. For winter annual control, the herbicides should be applied by September 15 in North Alabama, and about October 1 and October 15 for the Central and Southern portions of the state.

Postemergence herbicides are applied after the weed has emerged from the ground. Some of these herbicides act only through the foliage of the plant and can be applied only after the weed has emerged. Some herbicides that are used for preemergence weed control are also effective if applied after the weed has emerged.

**Spray Adjuvants**

Water is not compatible with all chemicals used in herbicide formulations or with all plant surfaces. Water does not mix with oil or oil-like chemicals; the two tend to repel one another. The molecules of a liquid strongly attract other molecules that are close to it. The surface molecules are attracted toward the center of a liquid body. Thus, a water droplet appears to be held by an elastic membrane. An example of this is water beading on a piece of waxed paper. The situation described is known as surface tension. A wetting agent increases the ability of a liquid to moisten a solid. By adding a wetting agent to the drop of water on the waxed paper, the droplet will spread out because the surface tension is decreased. A wetting agent lowers the surface tension of a liquid causing it to spread out over the surface of the plant. This brings the active herbicide into intimate contact with the plant surfaces, but may decrease its concentration. Wetting agents may increase or decrease the effectiveness of herbicide sprays. For example, the effectiveness of contact herbicides depends largely upon uniform and complete wetting of the plant leaves. By adding a wetting agent to the spray mix, the herbicide will spread evenly over the entire treated surface. Wetting agents and emulsifiers are included to overcome these difficulties with water. Materials such as these, which are added to spray solutions to increase herbicide activity or performance of a pesticide, are called adjuvants. Most herbicide formulations include a small percentage of adjuvants. Certain adjuvants are frequently referred to as surface-active agents or surfactants, since they tend to modify the surface of water droplets. Oil can be mixed, with the aid of an emulsifier, in water to form an emulsion that can be easily sprayed.

The wax-like cuticle found on plant surfaces repels water. Leaf cuticle development on woody plants becomes very significant, beginning late June or early July. By adding a surface-active agent, in this instance a wetting agent, the effectiveness of the herbicides can be greatly enhanced. The following are examples of spray adjuvants used in different spray applications to improve herbicide performance, facilitate spray
solution preparation, and increase personal and environmental safety:

- **Antifoaming agent** - An adjuvant for suppressing both surface foam and entrapped air. Use of such an agent allows quicker refilling of spray tanks and reduces risk of exposure to pesticides in foam.

- **Buffering agent** - An adjuvant used to control the pH of the solution used when mixed with a pesticide. If the pH is too high, some pesticides can be inactivated.

- **Compatibility agent** - An adjuvant that allows tank mixing applications of liquid fertilizers and pesticides, or application of two or more pesticides as a tank mix with a liquid carrier, or improves the stability and uniform distribution of a mixture.

- **Crop oil concentrate** - A mixture of paraffin or vegetable-based oil with surfactants as emulsifiers. They function as spreaders with some holding (sticking) action by oil deposited on the sprayed leaf surface. This is accomplished by creating a more uniform droplet size and reducing evaporation, drift, and wash-off. Where phytotoxicity is a risk, vegetable oil concentrates are used instead of paraffin based crop oil concentrates.

- **Dormant oil** - A highly refined, petroleum based, paraffinic oil useful for the control of certain insect pests on fruit and nut trees. Dormant oil acts to smother insects that are infesting these trees.

- **Drift control agent** - An adjuvant used in liquid spray mixture to help control droplet size thus reducing spray drift.

- **Extender** - An adjuvant added to formulations or spray carriers to prolong or extend the active life of pesticides. Extenders often contain an ultra-violet radiation screening material that protects spray residues from solar heat and ultra-violet radiation, which inactivates many pesticides.
**Foaming agent** - Surface active agent that forms a fast draining foam used to mark swath widths.

**Sticker** - An adjuvant that provides adhesive or sticking qualities for the residue after the spray has dried and makes the active ingredient stay on the leaf surface in spite of rain or wind.

**Spreader/wetting agent/surfactant** - These are synonymous terms referring to a broad group of surface-active agents; chemicals that reduce the surface tension of spray solutions so that spray droplets spread out and are adsorbed onto a greater leaf surface area. **ALDOT requires that surfactants be used with all foliage-applied herbicides for better coverage and more efficient control.**

Some herbicides have the surfactant added as part of the formulation. Those requiring surfactant to be added will be mixed according to the label and the current state program. **All herbicide solutions must contain the appropriate amount of spray drift control agent as recommended on the labels and in the current ALDOT program.** This will assure that the fine droplets caused by wind velocity and shearing action at the tips will be controlled within the traveling speed limits recommended for herbicide application.

**Compatibility of Mixtures**

Two or more pesticides which can be mixed together to control a wider range of pests with a single application are said to be compatible with each other. Sometimes pesticides are formulated together by the manufacturer and they are compatible when mixed in the spray tank. However, sometimes operators must mix separate formulations in the tank. It is important to remember that not all pesticides work well in combination. Mixing pesticides that are not compatible can cause:

- Loss of effectiveness against the target pests
- Injury to desirable vegetation
- Separation of ingredients into layers or settling out of solids
- Equipment damage; loss of productivity.

Some pesticide labels list other pesticides with which the product is compatible and may directly prohibit the tank mixing of other products known to cause compatibility problems.
Unless a label states otherwise, add pesticides in the following order to a half-filled spray tank (water) with agitation.

- Premixed wettable powders (WP) - powders premixed in water
- Dry flowables (DF) or water dispersible granules (WDG)
- Flowables (F) or aqueous suspensions (AS)
- Liquids (L)
- Soluble powders (SP)
- Emulsifiable concentrates (EC)
- True solutions (S)
- Nonionic surfactants
- Crop oil concentrates (C.O.C.)

To insure successful mixing, operators should maintain good agitation at all times. Each product should be thoroughly mixed before adding the next product. The tank should be filled completely following the addition of the last product. Operators should try to make their applications in at least 25 gallons of spray mix per acre. The more concentrated the pesticides are in the tank, the greater the likelihood of mixing problems. **No tank mixture should be allowed to stand overnight without agitation.**

If the compatibility of two pesticides is not stated on either label, operators should conduct a compatibility test before mixing the chemicals in the spray tank. By delaying 20 to 30 minutes, the operator may save hundreds of dollars of expensive chemicals and days of difficult sprayer cleanup.

The best way to determine if there will be a compatibility problem is to conduct a "jar test". Most herbicide labels encourage users to perform such a test before mixing different pesticides. The jar test involves mixing proportionate amounts of each pesticide in the appropriate carrier in a small jar prior to mixing in a spray tank. The procedure is as follows:

1. Fill two small jars about 1 quart in size with 1 pint of the carrier (water) to be used.
2. Add to one jar 0.25 teaspoon of a compatibility agent, such as Blendex®.
3. Label the jar containing the compatibility agent.
4. Add to each jar the appropriate amount of each pesticide. If the spray volume to be used is 25 g/A, add 1.5 teaspoons of a wettable powder pesticide for each pound to be applied per acre. For emulsifiable concentrates, flowables, aqueous suspensions, liquids, and solutions, add 0.5 teaspoons for each pint of pesticide to be applied per acre.
5. When finished, observe both jars for 30 minutes. If flake formation, sludge, gelling, precipitation, or oil particle separation is observed, some type of incompatibility exists.

REMEMBER: ADD IN THE CORRECT MIXING ORDER. IT IS IMPORTANT THAT A COMPATIBILITY AGENT SUCH AS BLENDEX® BE ADDED TO ONE OF THE JARS. SHAKE EACH JAR AFTER THE ADDITION OF EACH PESTICIDE.

If any type of incompatibility exists in the jar containing the compatibility agent, the pesticide mixture should not be made in the spray tank. If incompatibility is observed in the jar without the compatibility agent and not in the jar with the agent, the pesticide tank mixture may be made if a compatibility agent is added to the tank first and the pesticide products are added in the order mixed in the jar test. If layer separation occurs after 30 minutes, but a uniform mixture can be made with gentle shaking, then constant agitation will be needed when mixing or applying such a mixture.

**Water Quality**

Water quality is an important factor affecting the action of herbicides. Use clean water to make herbicide-spraying mixtures because impurities in the water may deactivate herbicides, such as Accord® XRT II or Rodeo®. Be aware also that Oust® XP and Telar® are decomposed faster in acidic water, so an alkaline buffer may be needed when using water with a pH below 6.5. On the other hand, several insecticides are deactivated in alkaline water and require that the water be made acidic by addition of a different buffering agent. As a general rule, water obtained from large domestic water systems will be alkaline, while much of the water in Alabama streams and ponds will be acidic in nature. An additional reason for using only good clean water sources is to prevent sand and other soil particles from damaging the pump, valves, nozzles and other components of the spraying system.

**FATE OF PESTICIDES AFTER APPLICATION**

Chemical characteristics of the herbicide itself contribute to its activity and persistence in the soil.

Solubility and the amount of moisture available determine how fast chemicals will dissolve. The greater the herbicide solubility, the faster the plant uptake and the quicker
it will disappear or leach from the soil. In addition to solubility, leaching is determined by the amount of water passing downward through the soil components.

Temperature, as mentioned previously, determines how fast a herbicide breaks down or undergoes chemical reactions. The length of time to which it is exposed will determine to what extent the life of a herbicide is altered. All things being equal, the hotter the temperature, the shorter the chemical life. Microbial decomposition of most herbicides is accomplished in the soil by various microorganisms, such as bacteria with strange sounding names (Pseudomonas, Bacillus, and Penicillium) that use some herbicides as a food source. Such organisms utilizing the new food supply will likely flourish and increase in number, thus hastening the herbicide decomposition of that material. Generally, the higher the organic matter content, the higher the microbial activity and the shorter the life of the herbicide. Usually about 98% of residual herbicides applied to the soil will disappear within a year. Most of this is due to the action of soil microorganisms.

Photodecomposition is the breakdown of herbicides due to exposure to direct sunlight. This action is generally slight for many herbicides, so little reduction in herbicidal activity is evident.

It is obvious that there are numerous factors that may affect the activity and effectiveness of most herbicides. Because of these variables, which are beyond our control, vegetation management is often as much art as science.

**SPRAY DRIFT CONTROL**

Physical drift can be defined as the movement of spray particles or droplets away from the spray site before they reach the target plant. Temperature inversion can prevent the settling of very small droplets and allow their movement away from the spray site during calm conditions. The amount of drift depends upon (1) the size of the droplets, (2) weather conditions and wind speed, (3) target location/distance and (4) the height above the ground that the spray is released.

Droplet size is determined by the design of the nozzle, orifice or opening size and pump pressure. In general, low pressures and large orifice sizes tend to produce large droplets, whereas high pressures and smaller orifice sizes will produce small droplets. Target setback and height above ground that the spray is released become important since they determine the time required for droplets to reach the ground.

Weather factors include wind speed, temperature and humidity. Wind speed and direction principally determine the direction and movement of the spray droplet after
release from the nozzle. Temperature and humidity can affect the rate of droplet evaporation. As the diameter of a drop decreases, the ratio of surface area (many smaller droplets) to volume increases and evaporation occurs at a faster rate. The time of exposure to evaporation conditions also increases with smaller droplet size. The potential amount of physical drift varies with the method of application. There is a large difference of risk between hand tank, ground and aerial spraying. The hazards from off-target drift depend on (1) nature of the hazard, such as water, plant species, growth state, etc.; (2) legal pesticide tolerances in crops; (3) distance from the application site, (4) wind direction and air stability; (5) type, form and rate of the herbicide; and (6) the mix carrier (water, fertilizer or oil). Herbicides require certain coverage or drops per unit area of leaf surface for effective control.

Spray droplets evaporate more slowly in (wetter) 70% relative humidity and faster in lower (drier) relative humidity. Droplets falling through dry air decrease in size and are subject to drift and possible chemical trespass. To reduce the possibility of chemical trespass, a drift control agent is frequently added to a spray tank in an attempt to minimize spray drift to adjacent sensitive areas.

Many drift control products contain some percentage of polyvinyl polymers or acrylic copolymers. When added to a spray tank, a drift control agent hydrates in the spray solution resulting in larger spray droplets and fewer fine droplets.

There are several inherent problems associated with the use of these products. Some of these products can only be used with water soluble or emulsifiable pesticides. This means they shouldn't be used with wettable powders, dry flowables, water dispersible granules, flowables, aqueous suspensions, or liquid suspensions. Operators must read the drift control agent label carefully to determine if there is such a prohibition.

The use rate varies with the particular product used, the spray pressure and the type of spray tips used. Usually the rate is given in a range of fluid ounces per 100 gallons of spray mix. An operator should, initially add the lowest rate recommended. Increase the rate as needed. A thickened or "stringy" spray mix indicates that too much drift control agent was added. Only the manufacturer of the agent knows if it is possible to "unthicken" a spray mix. This mistake can cause loss of time, equipment, possibly pesticides, and money. Operators must read the label and use the lowest labeled rate.

There is no standard mixing order among the different drift control agents. The proper mixing order discussed earlier is still correct for mixing different products of different formulations together. However, operators will have to read the label and determine the proper time to add the drift control agent in relation to the other formulated
products. In general, products that require agitation to remain in suspension are added to the tank first and agitated well before the addition of any other product. **If an operator mixes his pesticides in the wrong order or adds the drift control agent at the wrong time, he may end up with a "mayonnaise-like" mixture that can't be sprayed.**

Wind conditions are obvious to the applicator and strict procedures must be followed. Spraying must stop anytime the spray solution cannot be maintained within the target area. ALDOT policy is to stop when wind velocity reaches 8 - 10 mph. Often times the crew can treat the downwind side of highways and return later to treat the opposite side when wind conditions are more favorable. Following are a number of field observations that spray operators may use to alert them to wind speed changes. Hand-held wind gauges can verify observations.

<table>
<thead>
<tr>
<th>Field Observations</th>
<th>Wind Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimney smoke rises up, air motionless</td>
<td>0</td>
</tr>
<tr>
<td>Chimney smoke drifts slowly, air rises</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Leaves quietly rustle, flags stir</td>
<td>4 - 7</td>
</tr>
<tr>
<td>Leaves and twigs move</td>
<td>8 - 12</td>
</tr>
<tr>
<td>Branches move and flags flap</td>
<td>13 - 18</td>
</tr>
<tr>
<td>Small trees sway and flags ripple</td>
<td>19 - 24</td>
</tr>
<tr>
<td>Large branches move and flags beat</td>
<td>25 - 30</td>
</tr>
<tr>
<td>Whole trees move and flags extend</td>
<td>31 - 38</td>
</tr>
<tr>
<td>Twigs break and walking is difficult</td>
<td>39 - 46</td>
</tr>
</tbody>
</table>

**PERSONAL SAFETY**

Toxicity is not the only factor that determines how dangerous a chemical is to humans or animals. Anyone who handles pesticides should also be concerned with the hazard of the chemical. The terms toxicity and hazard do not mean the same things. Toxicity is the capacity or **ability** of a substance to produce injury or death. Hazard includes two factors: toxicity and exposure. It is defined as the **possibility** that injury will result from the use of a substance in a given formulation, quantity, or manner.

Some hazards do not include toxicity to humans or other animals. For example, sulfur, oils, and many other chemicals are considered safe or relatively safe to animals, but may pose considerable hazards to some plants (phytotoxicity).
A pesticide may be extremely toxic but present little hazard to the applicator or others when used:

- In a very dilute formulation
- In a formulation that is not readily absorbed through the skin or readily inhaled
- Only occasionally and under conditions to which humans are not exposed
- Only by experienced applicators that are properly equipped to handle the chemical safely.

A pesticide may be low in toxicity, yet present a hazard because it:

- Is normally used in the concentrated form
- Is readily absorbed or inhaled
- Is used frequently by untrained persons, who are not aware of the possible hazards to which they are being exposed.

**How Pesticides Enter the Body**

A pesticide can enter the body through three common routes:

- Absorption through the skin (dermal). Penetration through the eyes and irritation of the skin are special categories of dermal exposure.
- Absorption through the mouth and stomach (oral).
- Absorption through the lungs (inhalation).

Dermal is the most common route of exposure for pesticide applicators. Dermal exposure often results from accidentally spilling or spraying a pesticide directly on the skin. Other causes include wearing clothing on which a pesticide has been spilled and drift of pesticides applied under windy conditions.

There are two very good reasons for using pesticides safely: to keep yourself and others from being injured and to avoid harming the environment. We must not consider the actual application of herbicides as the only safety-related problem. Handling herbicides going into and coming out of storage can be very harmful if done improperly. **Herbicides and equipment within themselves are normally safe; human misuse can change this condition very rapidly.**

In order to minimize both human and environmental hazards, ALDOT has been most selective regarding herbicides that are used in its weed control program. **Restricted-use pesticides are normally not applied to rights-of-way.**
The toxicity of herbicides differs considerably. Toxicity is measured in terms of LD₅₀ which is an abbreviation of Lethal Dosage for 50 percent of the test animals, and it indicates how much of a product, expressed in terms of mg/kg (milligrams per kilogram of body weight), it takes to kill one half of the test population. It is important to remember that the lower the LD₅₀, the more toxic the material. Checking the Herbicide Toxicity Chart below will show that all of the herbicides used by ALDOT are only slightly toxic to almost nontoxic.

**EVEN SO, ALL PESTICIDES SHOULD BE HANDLED AS IF THEY WERE VERY TOXIC.**

Relative Toxicities of Selected Herbicides and Other Materials

<table>
<thead>
<tr>
<th>Common Name or Designation</th>
<th>Some Common Products</th>
<th>Oral LD 50 mg/kg</th>
<th>Signal Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicotine</td>
<td></td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td></td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Caffeine (for an average man, about 100 strong cups)</td>
<td>192</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluridone</td>
<td>Sonar AS</td>
<td>&gt; 500</td>
<td>Caution</td>
</tr>
<tr>
<td>Reward</td>
<td>Diquat</td>
<td>600</td>
<td>Warning</td>
</tr>
<tr>
<td>2,4-D Amine</td>
<td>Various</td>
<td>1161</td>
<td>Danger</td>
</tr>
<tr>
<td>MSMA</td>
<td>Various</td>
<td>1580</td>
<td>Caution</td>
</tr>
<tr>
<td>Acetaminophen</td>
<td>Tylenol</td>
<td>2402</td>
<td></td>
</tr>
<tr>
<td>Triclopyr</td>
<td>Garlon 3A</td>
<td>2574</td>
<td>Danger</td>
</tr>
<tr>
<td>Table Salt</td>
<td></td>
<td>3320</td>
<td></td>
</tr>
<tr>
<td>Baking Soda</td>
<td></td>
<td>3500</td>
<td></td>
</tr>
<tr>
<td>Pendimethalin</td>
<td>Pendulum</td>
<td>3956</td>
<td>Caution</td>
</tr>
<tr>
<td>Hexazinone</td>
<td>Velpar</td>
<td>4120</td>
<td>Danger</td>
</tr>
<tr>
<td>Oryzalin</td>
<td>Surflan</td>
<td>5000</td>
<td>Caution</td>
</tr>
<tr>
<td>Aminocyclopyrachlor</td>
<td>Method</td>
<td>&gt; 5000</td>
<td>Caution</td>
</tr>
<tr>
<td>Aminopyralid</td>
<td>Milestone</td>
<td>&gt; 5000</td>
<td>Caution</td>
</tr>
<tr>
<td>Chlorosulfuron</td>
<td>Telar</td>
<td>&gt; 5000</td>
<td>Caution</td>
</tr>
<tr>
<td>Fosamine</td>
<td>Krenite</td>
<td>&gt; 5000</td>
<td>Caution</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>Various</td>
<td>&gt; 5000</td>
<td>Caution</td>
</tr>
<tr>
<td>Imazapyr</td>
<td>Arsenal</td>
<td>&gt; 5000</td>
<td>Caution</td>
</tr>
<tr>
<td>Indaziflam</td>
<td>Esplanade</td>
<td>&gt; 5000</td>
<td>Caution</td>
</tr>
<tr>
<td>Metsulfuron methyl</td>
<td>Escort XP</td>
<td>&gt; 5000</td>
<td>Caution</td>
</tr>
<tr>
<td>Sulfometuron methyl</td>
<td>Oust XP</td>
<td>&gt; 5000</td>
<td>Caution</td>
</tr>
<tr>
<td>Sulfosulfuron</td>
<td>Outrider</td>
<td>&gt; 5000</td>
<td>Caution</td>
</tr>
</tbody>
</table>
Keeping the toxicology in perspective, the LD$_{50}$ values are those of the active ingredient in the container. However, the general public does not usually handle these containers. Application personnel, dealers, distributors and other handlers of the product are trained in proper use of herbicides. In addition, products are not applied in pure form. A typical dilution in water would be 1 pound of herbicide in 25 gallons of water which increases the LD$_{50}$ indicated in the chart or figure approximately 200 times and reducing the toxicity by 200 fold. All herbicides have a potential to be dangerous, but they are not likely to cause injury if used properly. The hazard potential of a herbicide depends upon two primary variables; **TOXICITY and EXPOSURE**. Toxicity is the inherent capacity of a substance to produce injury or death while exposure refers to the contact with nontarget species. To reduce human hazards posed by the application of herbicides always:

- Read, study, and follow the label instructions and precautions
- Wear protective clothing when mixing herbicides
- Wear rubber gloves and face shield when mixing herbicide solution
- Avoid spilling the chemical on one’s skin and clothing
- Wear adequate protective clothing as indicated on the label
- If a spillage does occur, wash immediately with soap and water
- Do not smoke or eat while mixing or using chemicals
- Wash thoroughly and change clothes after spraying is completed
- Store herbicides only in original containers
- Prevent drift by slowing down, reducing pressure or adding adjuvants
- Be alert and keep your mind on the job at hand.

Get medical advice quickly if you or your fellow workers experience any unusual or unexplained symptoms while applying herbicides or sometime later the same day. It is better to be too cautious than too late.

**REMEMBER! HAZARD = TOXICITY X EXPOSURE**

You are responsible for wearing the required protective clothing when mixing, handling, or applying herbicides.

Find out what protective devices and clothing are required for each herbicide you use. This information is found on the label and Safety Data Sheet.
ENVIRONMENTAL SAFETY

In addition to the care that should be taken to keep the operators and general public safe from any harm as a result of pesticide applications on Alabama roadsides, concern for the environment must also be a part of any operation. Pesticides used incorrectly can cause injury to livestock, wildlife, and crops or other desirable plants.

Livestock and wildlife are more likely to be injured by insecticides and fungicides than by herbicides. Herbicides are designed to control plants and, as a general rule, are not very toxic to animals. However, livestock and other animals may be injured by eating certain herbicides directly from containers or drinking either the concentrate or spray solution. Some plants, poisonous to livestock, may be more readily eaten by livestock after they have been sprayed with herbicides. Roadside spraying may actually benefit wildlife by maintaining desirable cover and food plants in the area. Several herbicides are recommended for control of aquatic weeds, which usually benefit fish populations. However, herbicides should not be applied to aquatic areas except in special circumstances and under strictly controlled conditions.

Farmers are often concerned about the possibility of herbicide injury to their crops resulting from roadside spraying operations. Injury to crops usually results from misapplication or physical drift. Care should always be taken to ensure that the spray is applied only to the designated target area. Do not spray fence lines or adjacent owner maintained areas of roadsides. Do not apply any root-absorbed (soil active) herbicide to saturated soil or when heavy rainfall is likely to occur in the area within a short period of time. Wildflower areas, whether planted or naturally occurring, should be treated as crops and precautions taken to avoid injury from herbicide applications made to other areas of the roadsides. Certain herbicides are recommended for controlling grasses and other weeds in wildflower plantings, but care should be taken to follow all instructions as to timing and rates of application in order to avoid damaging these very important parts of our roadsides.

All pesticide applications made on rights-of-way within National Forests and other Federal lands must be cleared with local United States Department of Agriculture officials. This is normally done at the State level on an annual basis. The presence of endangered plant species within the rights-of-way makes it necessary to obtain permission from Fish and Wildlife Service for any maintenance operations within the area known to harbor endangered species of plants or animals. If in doubt about the safety of crops, livestock,
or other species, stop the operation immediately and contact your supervisor.

<table>
<thead>
<tr>
<th>City</th>
<th>Name and Address</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birmingham</td>
<td>Regional Poison Control Center The Children's Hospital of Alabama 1600 7th Ave., South Birmingham, AL 35233</td>
<td>Emergency (800) 222-1222 Administration (205) 939-9720</td>
</tr>
<tr>
<td>Tuscaloosa</td>
<td>Alabama Poison Center 2503 Phoenix Drive Tuscaloosa, AL 35405</td>
<td>Emergency (800) 462-0800 Administration (205) 345-0609</td>
</tr>
</tbody>
</table>

**PESTICIDE SPILLS**

**Minor Spills**

In the case of minor spills of essentially non-toxic materials, it is usually possible to do the cleanup in-house without involving other agencies. However, before attempting cleanup, contact your supervisor.

- Keep people away from spilled chemicals. Rope off the area and flag it to warn people. Do not leave unless someone is there to warn of the danger.
- If the pesticide was spilled on anyone, give the correct first aid.
- Confine the spill. If it starts to spread, dike it up with sand or soil.
- Use an absorbent material to soak up the spill. You can use soil, sawdust, or a special product made to do this. Shovel all contaminated material into a leakproof container for disposal. Dispose of it as you would excess pesticides. Do not hose down the area. This spreads the chemical.
- Put something on the spill to stop the chemical action. You may be able to use common household bleach or a solution of lye or ammonia. If you are not sure what to use, call the chemical manufacturer. Always work carefully. Do not hurry.
- Do not let anyone enter the area until the spill is cleaned up.
**Major Spills (reportable quantities as defined by ADEM or ALDOT)**

The number one priority is safety for the traveling public and ALDOT employees. Isolate the area and confine the spill. Then, District personnel should contact the Area Emergency Management Engineer (EME) and / or the Area Maintenance Engineer who should make the necessary ALDOT and / or ADEM contacts and decide if the product manufacturer or a company such as CHEMTREC should be called for assistance.

**PESTICIDE INVENTORY CONTROL AND STORAGE**

Inventory control and storage of pesticides are important parts of fiscal responsibility as well as personal and environmental safety. One should consult product labels and SDS for the specific storage instructions. The following are a few general rules that should be followed for inventory control and pesticide storage.

**Rules for Inventory Control**

- Order only those quantities of pesticides needed for the present season's activities.
- Exhaust inventories of the same pesticides on a first in – first out basis.
- Exhaust inventories of pesticides replaced or deleted from the program (with assistance from the ALDOT State Agronomist if necessary) prior to ordering replacement products.
- Contact, immediately, the ALDOT State Agronomist if the registration is cancelled on inventoried pesticides; assistance for the proper disposal of the product will be provided.

**Rules for Pesticide Storage**

- Store pesticides in a posted and locked shelter away from children and animals.
- Make all efforts to keep pesticides in their original container; if for some reason a pesticide must be transferred to another container, label the new container immediately. Never use containers normally used for food products as pesticide containers.
- Replace labels if they become torn or illegible for any reason.
- Keep all containers tightly sealed.
- Store pesticides in a dry, cool well-ventilated area out of the sun.
- Do not allow the pesticides to freeze or get too hot.
- Store pesticides separately from seed, fertilizer and food. Store herbicides away from other pesticides.
- Check storage facility and storage containers for leaks and spills.
- Review and upgrade the pre-fire and contingency plans annually.

PESTICIDE CONTAINER MANAGEMENT

Returnable, recyclable containers should be returned as soon as a full pallet of 9 empty containers becomes available; this is critical to the success of the returnable program. The number for return requests can be found on each container.

After emptying any other pesticide container, it should not be reused again for any other purpose. The empty container should be disposed of in accordance with State regulations. In general, disposal of empty containers should be carried out in the following manner.

- Thoroughly pressure wash the container with water using a recommended pressure rinse nozzle and allow the rinse water to flow into the pesticide sprayer tank mix. A triple rinsed container is considered safe by EPA; however, the pressure washing technique is recommended.
- Remove all paper labels and caps from plastic containers.
- Make sure the outsides of containers are pesticide-free.
- Puncture or slice the container so that it can no longer be used as a water holding device.
- Dispose of the containers in an approved landfill with suitable approved liner.
- Disposal should be accomplished on a daily basis. The only empty pesticide containers on site should be that quantity needed to recapture, if necessary, the fill for the present day.
- Triple rinsing and pressure washing: Both EPA and the Alabama Department of Agriculture and Industries agree that once a container is triple rinsed or pressure washed it is no longer considered a hazard and such containers may be recycled or disposed of in an approved landfill.
- After bags and boxes have been flattened, they may be disposed of in a landfill.

REMEMBER!! NEVER GIVE PESTICIDE CONTAINERS TO UNAUTHORIZED PERSONS OR CARRY THEM HOME FOR PERSONAL USE
CHAPTER 3 GLOSSARY

Absorption - The process by which a chemical moves from one system into another such as from the soil water into plant roots.

Acid - A compound that yields hydrogen ions when added to water; having a pH less than 7.0.

Adjuvant - Any substance in a formulation or additive which enhances the effectiveness of a pesticide.

Adsorption - The adhesion or temporary attachment of a thin layer of molecules or ions to the surface of a solid.

Aerosol - An extremely fine mist or fog consisting of solid or liquid particles suspended in air.

Agitation - The process of stirring or mixing in a sprayer.

Alkaline - A material that is basic rather than acidic; having a pH greater than 7.0.

Annual - A plant that germinates from seed, flowers, sets seed and dies in the same growing season. There are winter and summer annuals.

Bait - A formulation of pesticide in which the pesticide is mixed with a food or other attractive source.

Biennial - A plant that lives two years, usually forming a basal rosette of leaves the first year and flowers and fruits the second year.

Blade - The broad tissue part of a leaf.

Broadleaf plants - A grouping of plants that share several common characteristics. These plants have two cotyledons, broad-bladed leaves with a net-like vein pattern, and showy, colored flowers.

Bulbs - An underground bud with thickened fleshy scales, as in the onion.

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

Compatible - A combination of pesticides that can be physically mixed together in a spray tank without undesirably altering their state or activity.
**Cuticle** - The waxy layer on the surface of a leaf or stem.

**Decomposition** - The breakdown of pesticides in the environment by physical, chemical, and biological processes.

**Dermal** - Pertaining to the skin; through or by the skin.

**Diluent** - Any gas, liquid, or solid material used to reduce the concentration of an active ingredient in a formulation.

**Drift** - Movement of airborne spray from the intended area of application.

**Dust** - A very fine, dry formulation of a low percentage active ingredient that is always applied as a dry material.

**Emulsifier** - A surface-active substance that promotes the suspension of one liquid in another.

**Evaporation** - The loss of water from a solid surface as a gas or vapor.

**Flowable** - A pesticide formulation that contains a solid pesticide suspended in a liquid and forming a suspension when mixed in water.

**Foliage** - The leaves of a plant, collectively.

**Foliar-applied** - Application of a pesticide to the foliage and stems of plants.

**Formulation** - A pesticide preparation supplied by the manufacturer for practical use.

**Fungicide** - A chemical used to control, suppress, or inhibit fungi.

**Germination** - The process of initiating growth in seeds.

**Granule** - A dry formulation of a pesticide and other components consisting of discrete, rather uniform-sized particles.

**Grass** - A grouping of plants that share several common characteristics. Grasses have one monocotyledon, narrow, parallel-veined leaf blades, and non-showy, wind-pollinated flowers.

**Hazard** – The possibility that a product may cause injury or illness.

**Herbaceous plant** - A plant that does not develop persistent woody tissue above ground.
**Herbicide** - A chemical used to suppress or severely disrupt the normal growth processes of plants.

**Humidity** - Water vapor or moisture held in the atmosphere.

**Incompatible** - A combination of pesticides that cannot be physically mixed together in a spray tank without undesirably altering their state or activity.

**Inert** - Inactive or non-reacting part of a pesticide.

**Insecticide** - A chemical used to suppress or severely disrupt the normal growth processes of insects.

**Label** - The directions for using a pesticide approved as a result of the EPA registration process and attached to the pesticide container.

**Landfill** - An approved long-term disposal site for hazardous chemicals, which is underlain with a double liner.

**Leaching** - The downward movement of a water solution through the soil.

**Midvein** - The central vein in the blade of a leaf.

**Nonionic** - A chemical that is uncharged.

**Non-residual** - A herbicide that does not remain active in the soil to inhibit germinating seeds or seedlings.

**Nonselective** - A herbicide that is generally toxic to all plants without regard to species.

**Nontoxic** - A chemical that is not poisonous or injurious when applied at reasonable rates.

**Pellet** - A dry formulation of pesticide and other components in a discrete, uniform-sized particle and larger than a granule.

**Perennial** - A plant that lives three or more years.

**Persistence** - A pesticide capable of remaining in the environment for some time and capable of affecting pests and non-target organisms.

**Photodecomposition** - The physical breakdown of some pesticides in the presence of ultraviolet light.
**Postemergence** - An application made after the emergence or establishment of a weed.

**Preemergence** - An application made prior to the emergence of the weed.

**Residual herbicide** - A herbicide that persists in the soil and injures or inhibits germinating weed seeds and/or seedlings for some period of time.

**Residue** - The quantity of pesticide remaining in or on soil, plant parts, animal tissues, whole organisms, and surfaces.

**Restricted-use pesticide** - A pesticide that because of its toxicity or potential for injury to humans or the environment is limited for sale only to private and certified applicators.

**Rhizome** - A modified underground plant stem that sends out roots and shoots from its nodes. They are sometimes called creeping rootstocks.

**Rodenticide** - A chemical used to control or inhibit the activity rodent pests.

**Root-absorbed** - A pesticide that is taken up by the roots of plants or weeds and may be moved throughout the plant.

**Runoff** - Water that moves across the soil surface, picking up soil, fertilizer, and pesticide residues and then moving to surface water bodies such as lakes, ponds, creeks, and rivers.

**Sedge** - A small group of plants that have one cotyledon, three-ranked leaves, triangular stems, and non-showy flowers.

**Soil-active** - A chemical whose primary effect on pests is in or on the surface of the soil.

**Soil-applied** - Application made primarily to soil surface rather than to vegetation.

**Soluble** - Property of a liquid or solid in forming a true solution (completely dissolves) when mixed with water.

**Solution** - A homogeneous mixture of two or more substances.

**Stolons** - An elongate, horizontal stem creeping along the ground and rooting at the nodes or at the tip and giving rise to a new plant.

**Surfactant** - A material that improves the emulsifying, dispersing, spreading, wetting, or other surface modifying properties of liquids.
**Suspension** - A mixture containing finely divided particles evenly dispersed in a solid, liquid or gas.

**Systemic herbicide** - A chemical that is moved or translocated in target weeds causing an adverse effect throughout the plant.

**Taproot** - The main root from which smaller root branches arise, as in the carrot.

**Toxicity** - The ability or potential of a product to cause injury or illness.

**Translocated herbicide** - A chemical that is moved within the plant in the vascular tissue.

**Vegetative** - The non-floral parts of a plant.

**Weed** - A plant growing where it is not desired.

**Woody plant** - A plant usually perennial that forms hard, persistent tissue above ground.
CHAPTER 4: ALDOT HERBICIDE TREATMENT RECOMMENDATIONS

INTRODUCTION

This section introduces the herbicide spray operator to the herbicide treatment program for the Alabama Department of Transportation. A successful program depends on the knowledge, training, and skills of personnel involved in the program. The future of the program and the responsibility for the program are dependent, in large measure, upon the spray applicators. Therefore, there are a number of things that each spray applicator must keep in mind at all times. Safety of the applicator and environmental considerations are first priorities.

The treatment program is not fixed indefinitely. One must stay updated on the ALDOT program as it applies to each respective Region / Area and District. It is important to follow the ALDOT program in accordance with Guideline for Operation 5-17 as revised in June of 1989. All equipment must be in top operating condition at all times, and an accurate herbicide application report must be prepared and submitted each day.

Labels and Safety Data Sheets are periodically amended by the manufacturer, recommendation changes and products are added to or deleted from the program. For these reasons, CHAPTER 4: ALDOT HERBICIDE TREATMENT RECOMMENDATIONS is supplied as a stand-alone segment of the overall VEGETATION MANAGEMENT MANUAL.
CHAPTER 5: MAINTENANCE OF TREES AND SHRUBS

INTRODUCTION

Maintenance of trees and shrubs should include pruning, fertilizing, watering, mulching, and controlling pests. However, pruning is probably the procedure that will be used most often in maintenance.

Pruning of plant material will vary markedly, depending on the plant species or variety. Individual trees and shrubs may require pruning annually or biannually.

There are many reasons for pruning trees and shrubs. Site safety should be an important consideration in how to prune plant material. Pruning for safety includes, but is not limited to:

- maintaining suggested sight distances
- maintaining suggested clear zones on either side of and above the roadway
- removing low branches

Accommodating utility companies is another reason for pruning. Utility companies have special authority to construct and maintain lines on the rights-of-way. This authority includes pruning vegetation as necessary; however, they are requested to follow ALDOT pruning guidelines and observe recognized tree surgery practices as outlined by The International Society of Arboriculture (ISA).

Health and appearance of the vegetation are also reasons for pruning. Nature provides pruning actions for most plants, but these are not always free of problems. For instance, in nature, weak, thin branches die and fall off as they decay, but occasionally larger branches die and the healing process at the junction with the trunk or larger branches is slow. This slow healing process can result in "heart rot" that may cause the decline of the plant or cause the plant to be weak structurally. In some instances, branches are broken or damaged permitting borers or other damaging pests an entryway into the plant. Pruning is used to give smooth cuts that heal rapidly and reduce invasion from insects and diseases.
Proper pruning of trees and shrubs may produce the following desirable results:

- control tree or shrub size
- restore the natural form that is needed in a particular landscape situation
- remove dead, diseased, or injured branches
- increase flower and fruit number and size
- stimulate new growth on older trees and shrubs
- remove crowded or crossed branches to prevent future injury during normal growth and development
- remove lower branches to reveal outstanding characteristics of the trunks of birch, crapemyrtle, and southern waxmyrtle

**PRUNING GUIDELINES**

No matter what the reason for pruning, the plant’s health and appearance should always be considered. Recognized tree surgery practices provide for pruning with a minimum of harm to the plant’s health and appearance.

Pruning should be done in accordance with recognized tree surgery practices outlined by the ISA. The following guidelines represent the mere basics of recognized tree surgery practices pertaining to pruning.

**Aesthetic Principles**

When pruning, strive to preserve the natural character of the plant, and to remove the minimum number of branches necessary. Trees and shrubs that become unsightly because of repeated pruning for clearance should be removed.

**Pruning Effects on Growth**

Removing living branches has six primary effects on trees or shrubs:

- **Loss of food-making machinery.** Leaf and green-stem tissues collect light and carbon dioxide to manufacture food and structural materials. Leaves are physiologically expensive for the plant to maintain. Therefore, removing any leaf by pruning is a major loss to the individual branch that it supports. Decline of a productive branch is a serious loss for the stem and roots.
• **Loss of growth control.** Branch tips (terminal buds) and root tips produce growth regulators that control growth patterns and allocate resources to where the plant needs them. Growth regulators from the branch tips control the rest of the buds on that branch. Removing these branch tips by pruning changes growth patterns and resource availability. Pruning stresses a plant.

• **Internal readjustment of growth.** Each branch controls its own destiny by producing food and growth regulators. Unproductive branches are shut down and sealed off from the rest of the plant. Every branch must produce enough food for itself, and some extra to translocate downward, or it will be closed off. Branch or twig pruning initiates new growing points near the wound and redirects the transport of materials inside the plant.

• **Loss of stored food.** Plants store food in the last few annual rings of living wood in groups of cells called rays. These ray cells absorb sugars as they move downward from the leaves and store the excess as starch. Food is not warehoused in the stem or roots and then shipped to places where it is needed. Food is stored locally and used locally in the branch.

• **Internal reallocation of resources.** Water and essential elements that a plant once transported to the pruned branch now can go to other areas in the plant. Dominant branches usually receive the extra materials. But, because pruning decreases food production, some stem and root areas may die. Loss of roots means the tree is collecting fewer resources for transport. Stunting is a direct result.

• **Changes in flowering patterns.** Growth regulators, food, and sexual maturity of woody tissues are affected by pruning which affects flowering. If flowers are a primary concern, then pruning after seasonal flowering and pruning branches that flower poorly is beneficial. Some species flower on the current year's wood, while other species produce flowers on older tissues. In some species, horizontal branches may produce flowers, while vertical branches do not. Without specific information, pruning for maximum flower production can be difficult and may cause structural damage.
Pruning of living tissue from trees and shrubs results in wounding. Trade-offs are always necessary between the biological health and structure of the plant and the design and maintenance objectives for pruning. The key to pruning is knowing the responses of specific plant materials to different pruning cuts. Ignorance of procedures and species characteristics can doom your pruning program.

How to Prune

General Rules of Pruning. As previously stated, the key to a successful pruning program is an understanding of the plant's response to specific pruning cuts. The first rule of pruning is that pruning cuts are local in effect. This means that when a pruning cut is made any effect will be within about 6 inches of the cut. For example, if a branch has the terminal bud (branch tip) removed, new branches will develop from the axillary buds within about 6 inches of the pruning cut. Secondly, pruning cuts should be made at about a 30 to 45 degree angle 1/4th inch above a bud or at the branch's origin (Figure 6.1). Cuts made at a branch's origin will minimize new growth. Finally, the "May Rule" should be considered for plant material planted for their flower or fruit. The "May Rule" states that if a plant blooms before May 1, prune immediately after flowering has ended because flowers are produced on last year's growth (i.e. forsythia, azalea, etc.). If the plant blooms after May 1, prune during the dormant season because the flowers are produced on current season's growth (i.e. crapemyrtle, lilac chasetree, etc.). As with any rule, there are exceptions such as for oakleaf hydrangea. Although oakleaf hydrangea often blooms after May 1, these plants should not be pruned during the dormant season.
Figure 6.1. (A) Heading cut to remove the terminal bud, cut should be at a 30 to 45 degree angle about 1/4\textsuperscript{th} inch above the axillary bud; (B) Cut at a branch's origin.
When to Prune. Corrective pruning due to injury or dead tissue should be done as soon as evident regardless of the time of year. Clean cuts will expedite the healing process and reduce the potential of insects or disease entering the plant through these injuries. Most plants should be pruned in the dormant season or immediately after flowering during the spring (refer to the "May Rule" for plants planted for flower or fruit). Some evergreen plants that have multiple growth flushes during a single growing season may be lightly pruned to maintain their form several times during a single growing season. However, pruning after August 15 should be avoided so that the plant will "harden off" and not be damaged by an early freeze.

Pruning Styles for Shrubs. The pruning style for shrubs varies depending on the species and growth habit of a plant. Shrubs will generally be pruned in one of three styles: 1) informal or natural, 2) formal or sheared, or 3) cane.

Most shrubs should be pruned using an informal or natural style pruning technique. Before beginning determine the final size and form desired for the plant. The natural form of the plant should be considered in this process. Make individual cuts inside the canopy at the branch's origin or crotch (Figure 7.1). These cuts will not be seen and will reduce heavy regrowth. Bare areas in the plant canopy can be filled by making "heading cuts" (removal of terminal bud) back to within 1/4th inch of a lateral bud (Figure 7.1). Some plants that should be pruned in this way, but are not limited to, include the Chinese hollies, azaleas, abelia, eleaegnus, tea olive, southern waxmyrtle (shrub form), gardenia, and euonymus.

Most shrubs should not be sheared or formally pruned. However, some hedges may require shearing to have the effect desired by the designer. These plants should be cut so that they are narrower at the top than the bottom (Figure 6.2). This allows lower foliage to receive sunlight and will prevent bare areas at the base of the plant. The top edges of the hedge should be rounded not angled. Regrowth for plants pruned using this pruning technique will be prolific requiring repeated pruning through the growing season.

Plants that do not readily branch on their own are often called cane type plants. Cane type plants are pruned by removing 1/3 of the existing branches back to within 6 inches of the ground. The oldest branches should be removed leaving young wood. Young wood will generally have more flowers and fruit. Examples of plants that are cane
pruned include forsythia, nandina, and oakleaf hydrangea.

A fourth pruning technique, renewal pruning, might be used for plants that have become too large, lost their form, or lost their vigor. To renewal prune a plant, all the branches are cut back to within 6 to 12 inches of the ground. These pruning cuts should be made during the dormant season just before new growth has begun or just following flower of spring flowering species such as forsythia. New shoots that develop should have the terminal bud or branch tip removed each time the new branch reaches 6 to 8 inches in length. These heading cuts will promote branching and result in a full thick canopy. Do not use this technique on junipers or boxwoods.

Correct

Incorrect

Figure 6.2. Sheared shrubs should be wider at the base than the top to prevent plants from becoming thin at the base.
SPECIFIC PRUNING SUGGESTIONS FOR VARIOUS SHRUBS

Crapemyrtle

Crapemyrtles flower best when pruned frequently. This small tree produces its flower buds on new or current season's growth. Therefore, plants can be pruned anytime during the winter or early spring before growth begins without loss of flower buds. In fact, pruning increases flower production because it stimulates branching and new growth. Old plants that are not pruned often produce smaller flower heads.

The kind and amount of pruning that should be done each year depends entirely on the plant form desired. Cut out small branches less than pencil size annually.

To develop a tree form, remove all except one to five limbs at ground level. Then cut off all side limbs on these branches up to the area where branches are desired (usually 3 to 5 feet). As the plant continues to grow, more of the lower branches can be removed. It is often necessary to remove any future growth that occurs at ground level in order to maintain the desired tree form.

In pruning any size plant, remember that almost all future growth will be within 3 to 6 inches of where pruning cuts were made unless the cut was at a crotch. Thus, it is possible to predict the location of most of the new growth that occurs after a plant is pruned.

Japanese Holly

It is usually desirable to retain a natural form to Japanese hollies. Pinch off tips of new growth during spring and summer months (multi-flush plant). This will keep the plants compact with little loss of growth.

Dwarf hollies lose their compact growth habit if pruning is neglected. If this should happen, cut out tall, undesirable limbs inside the canopy of the shrub (see informal pruning).

Pruning can be done almost any time of year on Japanese hollies. However, it is undesirable to prune heavily in September and October as this may lead to winter injury to the new growth. Just before growth begins in the spring is a good time to make heavy pruning cuts. Pruning can be continued during the summer months while plants are growing.
Chinese Holly

Chinese hollies should not be sheared. Shearing removes most of the growth terminals and this is the growth that produces next year's berries.

Most Chinese holly varieties, such as Burford, require frequent pruning to keep them in bounds, especially after they have been established for 5 to 10 years. Plants can be reduced in size by cutting out individual limbs within the plant with loppers or a saw (see informal pruning). This type of pruning can be done almost any time except in September and October. Pruning during these months may stimulate new growth that could be injured by early freezes. Early spring, before growth begins, is the ideal time to prune if considerable wood is to be removed to reduce plant size.

When a Chinese holly gets too large for its location, it can be cut back to about 1 foot above ground level and allowed to redevelop (see renewal pruning). This appears to be a drastic procedure. However, growth will be exceptionally fast as a result. This type of pruning should always be done in the early spring just before growth becomes active. The new growth from "cutback" plants will be vigorous. Long shoots should not be allowed to develop. They can be stopped simply by pinching out the tip of the growing limb when they get approximately 6 to 8 inches long.

American Holly (Tree Holly)

In establishing a main leader, do not cut back the terminal growing point (tip) of young American holly plants. Instead, cut back side branches to make growth more compact. Most heavy pruning should be done before growth begins in the spring.

Do not cut off the lower limbs of American holly, leave them branched to the ground. In most situations, much of the beauty of the tree is lost when the lower limbs are removed. The same is true for evergreen Magnolia trees.

Vigorous, Tall Shrubs

Ligustrum, pittosporum, cherry laurel, elaeagnus, and other vigorous, tall growing shrubs produce compact growth only when pruning is heavy and frequent. If these plants become too large or poorly formed, they may be renewal pruned during winter months to within 1 foot of the ground (see renewal pruning). Then to maintain compact growth, prune frequently.
Nandina
Nandinas should be pruned differently than most shrubs (see cane pruning). This shrub may also be renewal pruned during the dormant season if it becomes unsightly or too tall.

Spring Flowering Shrubs
Forsythia, flowering quince, most spirea, and other spring flowering shrubs should be pruned shortly after the flowering period. Remove individual limbs from inside the plant rather than shearing (see informal pruning).

Pyracanthas
Most pyracanthas consist of a tall main stem. To promote basal branches, cut the main stem back to 1/2 its height. After new growth is 6 to 10 inches long, remove terminal buds to promote branching. This will establish a compact, heavily branched plant.

Pyracanthas tend to produce long, tall stems. This type of growth can be checked easily by pinching or cutting out the tips of the new growth during the growing season. This will cause compact growth without the loss of berries.

Over-sized plants can be renewal pruned any time before growth resumes in the spring. However, renewal pruning will result in the loss of berries for one year. Pyracanthas that are not pruned during growing season can easily get out of bounds.

Shrub Junipers
Junipers are difficult to prune. Heavy pruning can cause them to die. Therefore, if these narrow-leaved evergreens become too large, they should be replaced with different shrubs.

SPECIFIC PRUNING SUGGESTIONS FOR TREES

Shade Trees
Shade trees generally need little pruning. During establishment, young shade trees should be shaped to promote the development of a proper form for that species as it matures and to prevent the need to remove large limbs that will leave larger wounds at a later date. Pruning cuts that should be made include the removal of weak branches, suckers and water sprouts (limbs at the trunk base or from roots), damaged branches,
crossing branches, and competing or codominate leaders. A codominate leader occurs when a tree has two or more central main branches or trunks. This will promote one strong central leader and the development of proper canopy form. Young trees should also be limbed up to about 6 feet to allow clearance for mowing equipment to pass underneath without damage. Limbs should not be removed so that more than half the trunk of the tree is void of branches. With the exception of damaged branches, most pruning should be done during the dormant season on shade trees.

The practice of "topping" mature trees results in the death of thousands of shade trees annually. When cutting off large limbs, never leave a stub. Such a wound heals slowly and allows fungal diseases to enter, weakening the tree, and may eventually lead to death. As a tree grows, the strongest limbs are those that have a crotch angle from 30 to 70 degrees. If the crotch angle is too small, the tree may be headed for serious problems. The crotch may split just from its own limb weight or a windstorm could break the tree. If the tree isn't too large, removal of one side of the crotch may be in order. The young tree may still grow enough to re-establish its shape, but an old one may not. Older trees with a narrow crotch may be helped by bracing with cables.

**Safety and Clearance**

When pruning for safety or clearance around utility lines, consider the rate of tree growth in determining the amount to be removed from a tree. A slow growing tree will require less clearance than a fast growing tree. Maintain adequate clearance - not excessive clearance. When possible, utility lines should be located where they will not cause interference with trees and other ornamentals. When pruning for sight distance and clear zone, it may be necessary to remove the entire tree.

**Outdoor Advertising Signs**

Pruning and/or removal of trees and brush species to improve visibility of advertising signs can be done only by permit issued by the Region / Area Engineer. **Permits are not to be issued to increase visibility of advertising signs set up after the grace period allowed by law.** District Administrators should be sure that clearing permits issued for other purposes are not used to open up areas for sign visibility.

The practice of topping pine trees over ten feet in height should not be allowed. Hardwood trees may be top pruned, but the pruning should conform to the standards of the ISA for reducing tree height and reestablishing the crown. Trees that cannot be
handled as described above can be removed. Stump treatment or removal will be as required in any other clearing operation.

Trees with crowns extending above the sight-line from the roadway to the sign may be limbed to increase sign visibility. Care must be taken to ensure that sufficient crown area remains after limbing to maintain the health of the tree.

For more detailed information, see permits and regulations of the Maintenance Bureau.

**How to Remove a Tree Limb**

Limbs having a diameter of less than 1.5 inches can easily be removed using hand snips or loppers. The cut should be made at a crotch or back to the trace or "collar" of the branch if it is to be removed at the trunk. The "collar" is the wrinkled area at the base of a limb where active cell division is greatest and rapid healing will occur.

When removing limbs 1.5 inches or more in diameter, three steps should be followed to prevent damage to the trunk from bark stripping down the trunk from the weight of the limb. **Step 1** is to make a cut on the underside of the branch about 12 inches from the tree's trunk (Figure 6.3). This cut should go 1/4 to 1/3 of the way through the branch. Care should be taken to prevent pinching of the saw blade. The purpose of this cut is to go through the bark and outer woody layers of the limb. **Step 2** is to make a second cut on the upper side of the limb about 18 inches from the trunk. This cut will remove the limb without allowing the bark to strip back to the trunk causing damage. **Step 3** is to remove the 18-inch stub with an even, clean cut so that the entire "collar" remains. Pruning paint should **not** be applied to the wound following limb removal. Some paints may inhibit the healing process.
Figure 6.3. Three step removal of tree limbs: (1) first cut should be made on the underside of the limb about 12 inches from trunk; (2) second cut is on the upper side of the limb about 18 inches feet from the trunk; and (3) removal of the stub back to the "collar".

After a branch is cut off, the healing process begins. New wood (xylem) cells and new bark (phloem) cells grow from the outside of the wound toward the middle. The layers meet at the middle and unite to form a solid layer over the cut area. There is no connection between the old wood and the new wound-covering wood. If the cut surface is smooth and free of infection after a few years, a wound should be difficult to find.

When pruning, do not leave stubs since they usually die back resulting in decay that can be serious, especially if large branches on the main trunk are involved. Once
dieback starts, the disease may spread easily to perfectly healthy tissue. The problem is
the same if the branches are broken off rather than cut. Finish the pruning operation with
a cut almost flush with the tree trunk, but leaving the raised trace or "collar" area.

**Disposal of Cuttings**

All pruned wood and brush should be removed from the right-of-way and disposed
of or chipped and distributed over the site.

**PRUNING EQUIPMENT**

Pruning equipment generally consists of hand pruners, loppers, shears, pruning
saws, and pruning knives for cleanup. Hand pruners are generally used for cutting
branches 3/4\(\text{th}\) inch or smaller. Branches between 3/4\(\text{th}\) and 1.5 inches can easily be
removed with loppers. Branches larger than 1.5 inches will require a pruning saw. A
narrow bladed saw is useful to cut larger branches in tight places. Use shears only on
formally pruned hedges.

**SAFETY PROCEDURES**

The use of pruning equipment could be hazardous work and safety should be a
concern. The following principles should assist in safe pruning.

- safety equipment (hard hat, ear protection, etc.) in good repair and properly
  fitted (no loose fitting clothes)
- knowledge of equipment performance and features
- equipment well maintained and clean
- cutting edges sharp
- a comfortable, firm but relaxed control grip
- equipment within your control zone—**don't overextend**
- an eye on your surroundings and the area below
- electric wires in sight
- minimize unintentional nicks and accidental bark breaks
- eye protection on everyone in the area

OSHA standards in ANSI Z 133.1 may be used as a reference.
Figure 6.4. Examples of desirable tree modifications, preserving symmetry.
Figure 6.5. More good and bad examples of pruning for clearance.
FERTILIZATION

A timely fertilization program is essential for the establishment and growth of ornamental plants. A well-developed fertilization program generates optimal plant growth and allows better recovery from user activities.

Trees and shrubs should be fertilized with a granular or pelletized fertilizer twice annually. The first application should be made from mid-February to mid-March, with a fertilizer having a 2-1-1 ratio [2 parts nitrogen (N), 1 part phosphorus (P₂O₅), and 1 part potassium (K₂O)] and trace elements applied at a rate of 45 pounds of nitrogen per acre. A second application at a rate of 45 pounds of nitrogen per acre should be made using a fertilizer with a 1-1-1 ratio of N - P₂O₅ - K₂O and trace elements in mid-June to mid-July. Applying fertilizer after the first of August may predispose plants to freeze damage during the fall or early winter. Fertilizer quantities for ornamental plantings should be determined by the number of square feet in the growing area for shrub beds or the branch spread for individual trees or shrubs. Care should be taken to keep fertilizer off plant foliage or fertilizer pellets should be knocked off after application to prevent burning.

MULCH

Maintaining mulched areas around ornamental plantings provides a number of advantages including: moisture conservation, soil insulation preventing temperature extremes, reduction of weed competition, prevention of soil crusting and/or erosion, prevention of mechanical injury from maintenance equipment, and aesthetics. Material used as mulch should be decomposed or partially decomposed organic material such as wood chips or pine bark. Applied mulch should not impede aeration of the soil and the penetration of water, nor deplete the soil of nitrogen. Mulch material should be free of excess amounts of large leaves and sticks that would prevent proper dressing of the mulch surface and should also be free of harmful chemicals and detrimental amounts of soil or other foreign matter that would promote early compaction, matting, or deterioration of the mulch.

Mulch should be applied to a settled depth of 3 inches around all trees and ornamental plantings. Mulch should be placed around trees to a radius of about three feet. Free-standing shrubs should receive mulch to cover an area out to the drip line of the shrub. Shrubs planted closer than 6 feet on center in a row are to receive continuous
mulching for the entire shrub run and cover any area between shrubs and out to the drip line of the largest shrub row specimen.

**WATERING**

Water, too much or too little, is the number one reason for plant mortality in the landscape. Maintaining the proper moisture content in the soil is essential for optimizing plant-growth. Plants continually transpire water to the atmosphere, and if water is not replenished, growth is seriously limited and the plant may die. Too much water can be equally detrimental by depleting the roots' oxygen supply and eventually killing the plant.

One of the most important factors in water availability and irrigation requirements is soil type. Soil type determines the water-holding capacity of a soil and ultimately how often plant materials should be watered. Other factors which should be considered in determining irrigation requirements include plant species, temperature, exposure (sun or shade), site slope, and rainfall.

Generally, trees, shrubs, and groundcovers should be watered weekly throughout the growing season unless adequate rainfall has occurred that week. The soil should be moistened to a minimum depth of 6 inches during each irrigation event. Heavy irrigation applied less frequently promotes a deep root system that should withstand drought better than a shallow root system promoted by frequent, light irrigations. During extended periods of dry weather in the winter months, supplemental irrigation should also be applied to shrubs, groundcovers, and new plantings.

**PEST CONTROL**

When an insect or disease problem has been observed, the Maintenance Bureau of ALDOT should be notified and the problem discussed before treatment.

To combat the encroachment of weeds and grasses into shrub beds, a selective herbicide should be used. Once again, discuss the problem with the Maintenance Bureau personnel before treatment.

Pesticides should be applied by individuals in possession of a current Commercial Applicator Permit (appropriate category) as issued by the Alabama Department of Agriculture & Industries or under the supervision of a “Permitted” applicator.
CHAPTER 6: WILDFLOWERS

INTRODUCTION

Wildflowers are beautiful to view when in bloom, especially where large populations exist, such as woodland displays of dogwood, redbud, and native azalea in the spring. Meadow species of wildflowers are most noticeable when bright colored blooms appear on long stems so more color and less foliage is visible. Where wildflowers abound and contribute greatly to the beauty of the highway, delayed mowing in spring and fall (to encourage seed maturation), and limited treatment with herbicides encourage the development of many native species of wildflowers without any other inducement. After a period of time, many of the noxious weed species will be controlled, permitting even greater areas to return to wildflowers and other native vegetation.

The Alabama Department of Transportation has many challenges in developing suitable strategies for roadside wildflower development. Minimal disturbance, leaving existing vegetation where possible, is desirable if the vegetation is compatible with adjacent land use. However, in most cases, grading for highway construction makes replanting with other vegetation necessary. In many cases, upper levels of the soil profile have been completely removed making the re-establishment of vegetation a real challenge. Revegetation must take place as soon as possible to control erosion and heal the wounds of construction. Some areas are best protected as forestland, while other areas do best with turf, or other low-growing vegetation; but many areas of the rights-of-way are suited to the development of wildflower communities.

The Alabama Department of Transportation is committed to preserving existing wildflower colonies, where feasible, and to planting or otherwise promoting a variety of wildflower species on highway roadsides of the state.
HISTORICAL BRIEF

The use of wildflowers in the landscape has increased since Lady Bird Johnson first promoted them in the late 1960's and early 1970's. Interest in using wildflowers for highway landscaping surfaced during this same period with a cooperative program called "Operation Wildflower", a joint effort of the Federal Highway Administration and the Federated Garden Clubs of America.

Early efforts were not very successful in Alabama, due to a number of factors, including a generally poor understanding of the phenomenon of natural plant succession in roadside situations, the large amounts of unwanted and hard to control noxious weeds present, the lack of seeds of "native" Alabama wildflower species, and improper planting methods.

In the mid 1980's Alabama Department of Transportation managers began exploring ways in which to integrate wildflowers and native plants into the statewide vegetation management program. After surveying the efforts in other southeastern states, a cooperative research grant between the Federal Highway Administration and the Alabama Department of Transportation was used to establish guidelines that would develop the use and preservation of wildflower species that are both compatible with Alabama's highway vegetation management programs and add color to the state's roadsides.

The Alabama Reunion in 1987 encouraged ALDOT to step up efforts in the area of landscaping with wildflowers. Since that effort began over 1000 acres have been planted across the state. To the extent possible in carrying out the objectives of the current overall vegetation management program, ALDOT will continue to develop local maintenance plans and execute them to encourage the growth and preservation of wildflowers and indigenous endangered plant species located on its rights-of-way.

NATURAL PLANT SUCCESSION

The tendency of vegetation to replace itself with different species from time to time is a natural, biological phenomenon known as plant succession. Plant succession is generally a slow process and thus cannot be readily observed unless one frequently visits the same area over a period of years.
There are two types of succession - primary and secondary. Primary succession involves the establishment of plants upon land surfaces that have not previously grown vegetation. For example: upon bare rocks, upon newly formed river islands, upon new ground provided by volcanic activity, natural filling in of lakes, and man-made construction activities. In natural situations, pioneer species such as mosses, lichens, and grasses will initially colonize the areas. Over time, the dominant vegetation types will change. Seeding and establishing grass on newly constructed highway cuts and fills is a method of speeding primary succession.

Secondary succession is the gradual change or replacement of vegetation in areas whose vegetation has been disturbed or removed. When vegetation is removed from land, a number of consequences follow, many of which are destructive. Shade-dependent plants die as intense light destroys their respiratory balance and warm, dry air reduces the humidity below their tolerance levels. Successional patterns vary from one region or habitat to another. But they will be influenced everywhere by the same ecological factors.

Plant communities are constantly changing in a sequential manner. The species that appear/disappear during this change over time can generally be predicted based on historical knowledge of the planting site. For most areas of Alabama, the sequence of successional species that will occur in a burned or logged area or in a cultivated area that is abandoned to nature is presented below.

<table>
<thead>
<tr>
<th>Years After Abandonment</th>
<th>Major Plant Species Present</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Crabgrass; Horseweed</td>
</tr>
<tr>
<td>2 - 4</td>
<td>Common Ragweed; Aster species; Goldenrod; Broomsgedge</td>
</tr>
<tr>
<td>5 - 10</td>
<td>Pioneer trees and perennial grasses; (loblolly pine and Broomsgedge)</td>
</tr>
<tr>
<td>10 - 200</td>
<td>Pines (loblolly and longleaf pine) with hardwood understory including sweetgum, dogwood and southern red oak</td>
</tr>
<tr>
<td>200+</td>
<td>Mature oak-hickory forest (with no further environmental change; fire for example)</td>
</tr>
</tbody>
</table>
In wildflower plantings, long-term weed management is a complex challenge that requires knowledge of the specific wildflowers and weeds, environmental conditions, and control methods. The ultimate objective in planting a naturalized wildflower area is to develop an attractive permanent planting that will provide flowers year after year with self-seeding annuals and perennials. However, wildflower plantings that are left unmanaged will eventually revert to the composition of plant species in the original plant community by succession.

The proper management of plant succession can be one of the most enduring assets of land use, whether it is for roadside development, forest, parkland or wildlife refuge. Plant succession as a continuing natural process is an important part of ALDOT’s vegetation management program. Selective spraying to encourage natural regeneration and succession outside designated mowing limits creates climax shrubs and groundcover communities.

**PLANNING THE PROGRAM**

The establishment and management of wildflower areas, like any other vegetation management practice, require extensive planning and attention to details from site selection to the routine maintenance procedures.

**Site Selection**

To be successful with any wildflower program, colorful wildflowers must be mass planted at high traffic locations. There must be a real commitment of time and effort to the program or it will not succeed. The costs and management requirements will be substantial, but the rewards of a well-designed and managed wildflower enhancement program can pay great dividends for ALDOT and the whole state.

Site selection is one of the most important factors in establishing stands of wildflowers. Some species require full sun, others partial shade, some require constantly moist soil and others well drained soil. Sites that are relatively weed free with existing stands of less competitive native grasses work best. On sloping sites, it may be necessary to seed a grass along with the wildflowers to maintain erosion control. Another alternative may be to use a fiber mat or other mulch to hold the soil and seed in place until germination and to control erosion. Wildflowers vary widely in their tolerance of soils and pH (acid/alkaline) conditions. Wildflowers often do best in soils of low fertility, because of less competition from other species. Except in situations of ornamental bed
plantings, the use of nitrogen-based fertilizers should be avoided. Nitrogen applications encourage the growth of weeds, thus increasing competition for the wildflowers. However, if a site is very infertile, it may be wise to consider the use of a low nitrogen fertilizer, such as 10-20-20.

In assessing a site for a wildflower planting, an inventory should be made of the plants growing on the site. Knowledge of the weeds present and past use of the land will help in predicting potential weed problems. Identifying the weeds present on site and in the surrounding area and the anticipated successional changes is the first step toward developing a weed management strategy. Some sites have a strong population of desirable native plants already established, making planting unnecessary. However, if a site is infested with difficult-to-control perennial weeds such as nutsedge (Cyperus spp.), it may be best to select another site for the wildflower planting, or weed pressure may be too great. If the site must be used, it may be advisable to spend a season controlling and removing as many perennial and reseeding annual weeds as possible before planting wildflowers. Weed species and populations in surrounding areas should also be considered in the site selection process. Seed dispersal mechanisms that allow wind and water to bring in seeds from outside the planting area will add to the site's weed population. After potential weed species and their sources have been identified, their growth habits and characteristics should be studied. Knowledge of these weeds is essential in determining methods of control.

There are three different situations that require different planning strategies: new plantings, existing wildflower areas, and endangered species areas.

When planning locations for new plantings, the locations should be visible to the traveling public for a considerable length of time and may vary from long, narrow areas to "block" type planting of irregular form depending upon site conditions. Annual "color" type plantings should be planned for areas of high traffic or special emphasis areas such as entrances into the State, rest areas, welcome centers, and scenic attractions.

Existing stands of planted or naturally occurring wildflowers require infrequent maintenance, but they must be managed in order to prevent encroachment of woody vegetation or undesirable weeds (natural succession).

In areas where endangered or threatened plant species are present on state right-of-way, appropriate planning and reporting should take place to ensure that the endangered or threatened species are preserved. (Known locations for endangered and threatened plant species are given below.)
Endangered or Threatened Species on Roadsides

Alabama Leather Flower (Clematis socialis): This is a perennial herbaceous plant with erect stems and rhizomateous growth habit. Leaves vary from scale-like at base to simple at mid-stem to dissected at top. Leaves are attached in opposite positions on the stems. Plant height is 8 to 12 inches; and flowering occurs in April and May. The flowers are solitary, bell-shaped, and blue-violet in color. St. Clair County, south of Ashville, along U.S. Highway 231, is one known location of Alabama leather flower. It is also reported to be present in Cherokee County, but the exact location of the few plants seen is not available.

Lyrate Bladder-Pod (Lesquerella lyrata): This annual plant is 4 to 12 inches in height and is covered with short hairs. The leaves are alternately arranged on the stem, and are ovate to elliptical in shape; the stem branches near the base. The flowers are on short stalks (3/8th to 5/8th inch) and have yellow petals, 1/8th to 1/2 inch in length. Seeds germinate in the fall, form rosettes during the winter, and flowers in March and April. Known locations of this plant include one in Franklin County near the intersection of Alabama Highway 24 and County Road 83 and another in Colbert County near Spring Valley on county routes.

Mohr's Barbara's-Button (Marshallia mohrii): This plant is an erect perennial that can grow up to 28 inches tall and has thick-rooted rhizomes. The stems are straight, branching only at flower heads. Basal leaves are 3 to 8 inches in length with smooth margins and blunt tips. It flowers in June with 2 to 10 branched heads about 1 inch broad and 5/8th inch tall. Flowers are disk-type with white petals and pale lavender anthers. Known locations of this plant include Alabama Highway 9, between Ellisville and Centre, and on U.S. Highway 411 east of Centre in Cherokee County. It has also been reported to be in Bibb and Etowah Counties, but this has not been confirmed.

Tennessee Yellow-Eyed Grass (Xyris tennesseensis): This perennial plant grows 28 to 40 inches in height with a clump-type of growth from fleshy bulbs. It has long, grass-like leaves that range in length from 6 to 18 inches. Flower heads are cone-shaped with individual, pale yellow flowers that open in late morning and fade away by mid-afternoon. Flowering occurs from August through September. Known locations of this plant include Franklin County on the west side of Alabama Highway 247, 3.6 miles south of the Colbert-Franklin County line, and about 11.2 miles northeast of Red Bay.
**Pitcher Plant (genus Sarracenia):** Pitcher plants resemble their namesake; they look like miniature pitchers. They are mostly found in boggy areas and are well adapted to acidic, nutrient-poor soils. These plants are somewhat unique in that they are carnivorous – they feed on insects which are trapped by specialized leaves (pitcher shaped structures). Known locations of these plants include US 45 / AL 17 in Mobile and Washington Counties just north of Citronelle.

**Selection of Wildflower Species**

The second consideration in the planning phase is the selection of the wildflower species. The species planted will affect weed management at the site. The objective in selecting a species of wildflowers is to develop a plant community that will 1) be attractive and compatible in terms of growing requirements, 2) flower over extended periods of time, 3) reseed the site for generations of new plants, and 4) remain at the flowering successional stage. In order to be successful in a particular location, the wildflower species must be compatible with and adaptable to growing conditions at the site. They must also be competitive with other species present, including weeds. Native species generally are most adaptable to local growing conditions and are usually the most competitive with native weeds that will be present.

In determining species that are to be included in a wildflower seed mix, consideration should be given to the germination times and growth characteristics of the species. Most wildflower mixes are a combination of annuals for color during the first year and reseeding annuals or perennials for flowers in the second and succeeding years. The objective in using a mix is to develop a wildflower community of compatible species. Species that germinate and emerge rapidly after planting will become better established, provide ground cover and, consequently, will help reduce the growth of weeds. Early establishment allows the wildflowers to develop better root systems and to capture available resources such as water and nutrients so they can successfully compete with weeds that germinate at later times. A careful selection of wildflower species will reduce future management problems and costs. In situations of high traffic or visibility, planting pure stands of single wildflower species may be desirable. Annual species with bright colorful flowers are usually selected to enhance the beauty of public areas.

Wildflower seeds are purchased through competitive bids or on a contract basis. Weed-free seed of acceptable purity and germination are required. All wildflowers are reviewed by the Alabama Department of Agriculture and Industries for their potential as a pest before they are selected for planting on Alabama highways. More than 40 species
of wildflowers have been planted with varying degrees of success.

Two "native" species occur regularly in turf areas. Showy primrose, *Oenothera speciosa*, and roadside verbena, *Verbena rigida*, are perennials that occur throughout Alabama. A major obstacle in promoting these species is the lack of commercially available seed of good germination. It does appear that showy primrose and roadside verbena produce abundant seed in Alabama. The problem is difficulties in efficient harvesting of seed.

**Some Native and Introduced Wildflowers**

<table>
<thead>
<tr>
<th>Botanical Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Achillea millefolium</em></td>
<td>Yarrow</td>
</tr>
<tr>
<td><em>Ageratum coelestinum</em></td>
<td>Wild Ageratum</td>
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<tr>
<td><em>Asclepias tuberosa</em></td>
<td>Butterfly Weed</td>
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<tr>
<td><em>Aster novae-angiae</em></td>
<td>New England Aster</td>
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<tr>
<td><em>Aster patens</em></td>
<td>Late purple Aster</td>
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<tr>
<td><em>Castilleja coccinea</em></td>
<td>Indian Paintbrush</td>
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<tr>
<td><em>Centaurea cyanus</em></td>
<td>Blue Cornflower</td>
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<tr>
<td><em>Chrysanthemum leucanthemum</em></td>
<td>Oxeye Daisy</td>
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<tr>
<td><em>Coreopsis lanceolata</em></td>
<td>Lance-leaf Coreopsis</td>
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<tr>
<td><em>Coreopsis tinctoria</em></td>
<td>Plains Coreopsis</td>
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<td><em>Cosmos bipinnatus</em></td>
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<tr>
<td><em>Cosmos sulphureus</em></td>
<td>Yellow Cosmos</td>
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<tr>
<td><em>Delphinium ajacis</em></td>
<td>Rocket Larkspur</td>
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<tr>
<td><em>Dracopis amplexicaulis</em></td>
<td>Clasping Cornflower</td>
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<tr>
<td><em>Echinacea purpurea</em></td>
<td>Purple Coneflower</td>
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<td><em>Gaillardia pulchella</em></td>
<td>Indian Blanket</td>
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<td><em>Gypsophila paniculata</em></td>
<td>Baby's-Breath</td>
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<td><em>Liatris spicata</em></td>
<td>Blazing Star</td>
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<tr>
<td><em>Linaria spp.</em></td>
<td>Toadflax</td>
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<td><em>Linum rubrum</em></td>
<td>Red Flax</td>
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<tr>
<td><em>Monarda citriodora</em></td>
<td>Lemon Mint</td>
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<tr>
<td><em>Oenothera missouriensis</em></td>
<td>Missouri Primrose</td>
</tr>
<tr>
<td><em>Oenothera speciosa</em></td>
<td>Showy Primrose</td>
</tr>
<tr>
<td><em>Papaver rhoes</em></td>
<td>Corn Poppy</td>
</tr>
<tr>
<td><em>Penstemon smallii</em></td>
<td>Small's Beardtongue</td>
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Some Native and Introduced Wildflowers (continued)

<table>
<thead>
<tr>
<th>Botanical Names</th>
<th>Common Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phlox carolina</td>
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<tr>
<td>Phlox drummondii</td>
<td>Drummond Phlox</td>
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<tr>
<td>Ratibida colunaris</td>
<td>Mexican Hat</td>
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<tr>
<td>Ratibida pinnata</td>
<td>Prairie Coneflower</td>
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<tr>
<td>Rudbeckia hirta</td>
<td>Black-eyed Susan</td>
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<tr>
<td>Sabatia angularis</td>
<td>Rose Pink</td>
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<tr>
<td>Salvia lyrata</td>
<td>Lyre-leaved Sage</td>
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<td>Silene virginica</td>
<td>Catchfly</td>
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<td>Solidago nemoralis</td>
<td>Gray Goldenrod</td>
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<tr>
<td>Solidago speciosa</td>
<td>Showy Goldenrod</td>
</tr>
<tr>
<td>Verbena rigida</td>
<td>Roadside verbena</td>
</tr>
<tr>
<td>Verbena tenuisecta</td>
<td>Moss Verbena</td>
</tr>
<tr>
<td>Vernonia altissima</td>
<td>Tall Ironweed</td>
</tr>
</tbody>
</table>

SITE PREPARATION AND ESTABLISHMENT

Fall is the recommended planting time for many wildflowers. Generally, the soil is cool enough that winter annuals and some perennials will germinate and overwinter as small seedlings. In addition, the soil is cool enough to hold summer annual seed in a dormant state for early spring germination. Spring planting can be performed in small, localized beds with high visibility. Weed competition will quite often be greater at this time of year. The most effective weed management during site preparation is to kill as many weeds as possible; both viable weed seed and vegetative propagules, to prepare the site for wildflower planting. There are essentially two methods that are effective during site preparation: the use of a systemic herbicide and fumigation.

PREPARATION FOR PLANTING

Systemic Herbicides

Initial weed control with a systemic, non-residual herbicide, such as Accord® XRT II (glyphosate), is the approach most often used in establishing wildflowers. Accord® XRT II is often thought to control all plants; however, its activity on some plants, such as
common bermudagrass, varies depending on the time of year it is applied and the growth stage of the plant. Proper timing of the application is, therefore, very important to achieve maximum weed control results. The Accord® XRT II label contains details on application rates and timing for specific weeds.

To plant wildflowers in October or November, site preparation must begin in late summer (August/September). Total preparation time is approximately 4 to 6 weeks using the following method:

- Be sure the area is not recently mowed so grass and weeds will be the proper size at the time of spraying as specified on the glyphosate label. Apply Accord® XRT II at a 3% solution.
- Spray only when the plants are dry. Uniformly spray to wet but not to runoff.
- Allow at least 4 hours of drying time for maximum plant control with Accord® XRT II. The timing of this first application should coincide with active weed growth because the optimum susceptibility to glyphosate for perennial weeds is when they are actively growing or in the early flowering stage. In addition, they are most susceptible when they are not stressed.
- Ten to 14 days after the initial spray, when the grass and weeds are dying, till the site and prepare it for planting. This activity should be accomplished by mid-September for planting in early October.
- If weeds emerge, re-treat with Accord® XRT II 2 to 4 weeks after the final tilling and bed preparation. Tilling will bring new weed seed to the surface. The soil will be warm and if sufficient moisture is present, many annual weed seed may germinate. These seedlings will die within 7 to 10 days after treatment and the site will be ready for planting.

**Fumigation**

A second technique for site preparation and establishment of wildflowers is the use of fumigation. Fumigants kill most weeds and dormant weed seed except those with hard seed coats such as Carolina geranium (*Geranium carolinianum*), white clover, and morning glories. Fumigation is a temporary weed control method and new weed seed will germinate as they are introduced into the area. The advantage of fumigation is that wildflowers become better established prior to weed emergence. Research has shown that fumigation can result in increased plant size over non-fumigated sites. Although increased size can benefit wildflower growth, the cost of fumigation is high and must be considered.
There are several fumigants available for use in wildflowers including methyl bromide, and Basamid Granular® (dazomet). Methyl bromide is a gas and for large areas requires the use of specialized equipment and a licensed applicator. Basamid Granular® is most effective in cool soil temperatures and remains in the soil for longer periods of time than methyl bromide. To ensure the soil is safe for planting, a soil bioassay should be conducted after any fumigation. However, because of the potential for prolonged soil activity with Basamid Granular®, a bioassay is essential when it is used. If the soil still contains the fumigant, wildflower seed will be killed.

If fumigation is to be used, planting sites should be tilled and prepared for planting in late summer to early fall (August/September). Fumigation requires adequate soil moisture and temperature for movement of the gas through the soil. Test planting should be made to determine when the soil is safe for planting wildflowers.

**PLANTING**

Planting times will vary according to the conditions and the seeds that are being planted. Planting should not be attempted when the ground is muddy or when soil or weather conditions prevent proper soil preparation and subsequent planting operations. There is a certain amount of risk associated with planting the seed in late fall. Rain and warm temperatures could cause some seed to germinate prematurely and be killed by a freeze.

At planting time, loosen the soil surface slightly to enhance seed contact. At this time the soil surface should be disturbed as little as possible because most annual weed seed that germinate are within the top one-fourth inch of soil. If the soil is deeply disturbed, additional weed seed that are capable of germinating and competing with the wildflowers will be moved to the soil surface.

Wildflower seed should be sown at recommended rates. At higher rates, more aggressive species may choke out slower-establishing species. On sites where one year of showy color is desired, use only annuals and sow at the recommended rate. Sowing at higher than recommended rates will waste seed and may actually decrease the amount of blooms.

The wildflower seed should be uniformly and evenly distributed over the planting area to give each seed adequate space and resources for germination and establishment. Uniform seed distribution allows maximum coverage of the soil by new seedlings and provides weed suppression. The amount and type seed planted per acre should conform to grower recommendations.
The size of the area to be seeded will determine the type of equipment best suited. On small areas seed may be sown by hand or with a small rotary seeder. Broadcast one half the required seed mixture in one direction over the entire site and the remainder perpendicular to the original seeding. When sowing small amounts of small seed, use sand or some other material as a spreader.

In large areas planted in the fall, mechanical seeders properly calibrated produce the desired results more efficiently and effectively. A specially designed wildflower seed drill has proved useful in planting seeds of varying sizes. This drill (seeder) allows the uniform planting of seeds that vary in size from species like toadflax that number more than 6,800,000 seeds per pound to lance-leaf coreopsis that number around 221,000 seeds per pound. The drill can be specifically calibrated for rate and planting depth by seed size which ensures that the seed will make direct positive contact with the soil at the depth recommended for the particular species being planted.

Insuring good seed-to-soil contact is essential for seed germination and survival. The soil also supports the seedling and supplies it with moisture until a root develops. Once the seed has been planted, it must be covered to maximum depth of 1/16th to 1/8th inch. This can be accomplished by lightly raking the seed in with a hand rake for small areas, or by using a light drag behind a tractor for larger areas. If a drill seeder is used, firm the soil after drilling with a cultipacker to insure proper seed/soil contact for germination. This step should not be overlooked.

Mulch should not be used in wildflower planting unless erosion is a potential problem. Mulch tends to lower seed germination and survival rates for seedlings of plants that thrive in full sun. For example, *Asclepias tuberosa* (butterfly weed) has the tendency to rot from the crown in wet conditions. It would be advisable not to mulch this species, as mulch would tend to keep the crown of the plant cool and moist. A good rule of thumb is to consider the conditions under which a species thrives in the wild. Plants found in fields and meadows typically have little or no natural mulch around them, while plants found in forests or shady areas generally have layers of natural mulch protecting them from the elements and keeping their roots shaded and moist. When mulching is desirable, a light, seed-free mulch, such as wheat straw should be used. The mulch should be lightly and evenly dispersed with no heavy clumps. Heavy, uneven, mulch reduces wildflower growth and development and results in areas with no plants.

In general, wildflower sites should receive no fertilizer. Some, like blazing star, will flop over when given too rich conditions. The practicality of wildflowers suitable for roadside conditions is that they thrive under roadside conditions: poor soil, poor drainage,
drought, air pollution and full sun. Native plants used in more formal landscaping can be fertilized or treated if and when they show specific nutrient deficiencies.

MAINTENANCE AND RENOVATION

The successful establishment of a wildflower area on an ideal site left unmanaged will soon deteriorate due to the forces of natural succession and/or competition from invading exotic species. When maintenance practices are performed in a timely and effective manner the area may remain an attractive addition to the roadside indefinitely.

Management Practices

The third and final stage in wildflower management is long-term or permanent maintenance. Most wildflower plantings are not static but change annually and seasonally due to the mix of species. A good mix will provide flushes of seasonal flowering from spring to fall. Annual changes will occur based on the number of perennial plants and those species that have reseeding potential and the extent to which that potential is realized. Reseeding is essential for natural regeneration of annual plants in order to extend the life of the planting. Weed control techniques should be carefully selected in order to optimize wildflower reseeding potential at the site.

After a wildflower planting is established, there is no single approach or "magic formula" to manage encroaching weeds. The best approach for developing management programs is to: 1) anticipate weed problems, such as successional changes, before they occur; 2) identify weed seedlings quickly as they grow; and 3) take corrective weed control action as soon as possible. Management is further complicated by the fact that most wildflower plantings are a mix of species and few herbicides can be safely used for weed control. Similar plants, such as those in the same family, generally have similar tolerance to selective herbicides. For example, many popular wildflowers are in the Compositae (aster) family but so are many troublesome weeds. Therefore, a herbicide safe for the wildflowers will probably have no effect on the closely related weeds. With a mix of wildflowers from various families, it is unlikely that one herbicide will control all weeds without damaging some wildflowers. Therefore, weed management programs must be developed to use a combination of cultural, chemical and mechanical weed control techniques. An integrated weed management approach that incorporates multiple weed control techniques and is site specific will be the most effective for wildflowers. A range of weed control techniques is discussed below.
Competition

Seedlings that emerge first are often able to capture more space and resources and this gives them a competitive edge over later germinating seed. Young plants are the most susceptible to damage from competition. Therefore, if wildflowers are planted in a properly prepared, weed-free site, they will be quick to germinate and may establish ahead of weeds. Early development of the wildflower canopy in the spring will also help suppress annual weed growth. An even distribution of seedlings at this stage will allow maximum growth of the wildflowers. If the wildflowers are too thick, they will compete with themselves. This will cause die back and open areas within the site, which promotes weed establishment. In Alabama, horseweed can be expected to encroach in the first two years based on successional changes. It is difficult to control in wildflowers because it is a fall germinating member of the compositae family. Horseweed, however, can be suppressed with a good cover of fall wildflowers because it requires bare ground to germinate. Understanding weed and wildflower biology is essential in order to make maximum use of growth characteristics for weed suppression.

Mowing

Most wildflower plantings are maintained with an annual mowing. Mowing prevents development of pines and hardwood trees and arrests the successional development at the herbaceous plant stage. Areas with no shrub growth may need mowing only once every 1-3 years while brushy locations should be mowed once per year to keep out brushy growth. Mowing should be timed to meet three objectives: 1) to remove weeds before they flower and develop viable seed; 2) to disperse mature wildflower seed for reseeding within the site; and 3) to remove dead plant material and improve the appearance of the planting. Mowing is an important management tool and timing is essential to maximize weed control and wildflower reseeding. Mowing at the correct interval encourages wildflower establishment and discourages weeds, but mowing too frequently or at the wrong time discourages wildflower establishment.

Existing stands of planted or naturally occurring wildflowers require infrequent but timely maintenance in order to prevent their being overtaken by woody vegetation or undesirable weeds (natural succession). Once the wildflowers have finished blooming and set seed the entire area should be mowed (fall clean-up mowing). Mowing the area will help to scatter the seed for the following year's growth. Wildflower areas should be mowed to a height of 4 to 6 inches in September and October. Waiting longer than this
to mow generally results in very wet conditions which could cause more harm than good when you attempt to mow.

In areas with endangered or threatened plant species present on state right-of-way, appropriate management should take place to ensure that the endangered or threatened species are preserved. Unless otherwise noted, mowing should be performed only for safety purposes or to prevent woody vegetation from encroaching into the site.

**Hand Removal**

Hand removal is a viable alternative for weed control in small wildflower sites or "block" plantings. Any weeds that are pulled from the site before seeds mature and disperse will contribute to future weed control. One weed can produce thousands of seeds. Therefore, even on the smallest scale, the contribution of hand pulling should not be overlooked. Weeds should be controlled when they are immature and actively growing. Another option in this situation is the use of hand tools or "string-type" trimmers. Broadleaf weeds can be selectively cut with such tools.

**Chemical Control**

When planning any chemical control program, the user has the responsibility to determine the most effective herbicide to use, timing of the application and the proper rates. Herbicide labels must always be carefully read and followed for the best and most cost-effective results.

As discussed earlier, similar plant species have similar tolerance to herbicides. For this reason, herbicides are often classified as broadleaf and/or grass herbicides based on the weeds they control. Herbicide labels list the weeds that are controlled as well as tolerant, desirable species. In addition to the broadleaf and grass classification, herbicides are also categorized by their activity as either preemergence or postemergence herbicides. For the purposes of maintaining established wildflower plantings, preemergence herbicides should be applied to the soil prior to the emergence of the target weeds.

Preemergence products are applied uniformly to the soil to prevent germination and growth of the weeds controlled by the herbicide. In an established bed, these herbicides may be safe for existing plants. However, there may be some negative effects of preemergence herbicides regarding the reseeding potential of wildflowers. If the
preemergence herbicide were detrimental to the wildflower seeds, regeneration of new wildflower plants would be reduced. In a planting with a good, established wildflower population and a growing weed population, the use of a preemergence may be warranted to reduce the weeds, even though reseeding will be reduced for a period of time. These possibilities should be considered when making the decision to use preemergence herbicides.

Postemergence herbicides are applied after the emergence of the actively growing weeds. Postemergence herbicides may be selective or non-selective in weed control. A selective postemergence herbicide controls certain weeds, but does not injure desirable wildflowers. A non-selective postemergence herbicide controls most (if not all) treated vegetation (both the desired and undesired). **There are no selective postemergence herbicides in ALDOT's program that can be used to control broadleaf weeds in mixed wildflower plantings.**

Grassy weeds in wildflower plantings can be controlled with Vantage® (sethoxydim) at the rate of 3.0 pints/acre without damaging most wildflowers. Vantage® must be applied when the grasses are immature and actively growing. This would usually be in May depending on the weather and the species of grass. By June, many species of grassy weeds go to seed and applying the herbicide at this time would prove futile. When using Vantage®, decline of grasses may not be seen for up to one month. This herbicide will also damage any native or ornamental grasses that may be included in the wildflower planting.

One way to circumvent damage to the wildflower planting is to use a non-selective postemergence herbicide such as Accord® XRT II (glyphosate) directed to the weeds while avoiding contact with wildflowers. The following application methods can be used for this purpose:

- **Spot spray** - a small sprayer with a hood over the nozzle is used that can be directed to individual or small groups of weeds so the spray will not contact desirable wildflowers.
- **Wipe-on** - an application device is used to wipe or wick the herbicide on weeds that are taller than the wildflowers. Equipment may be either a rope wick or roller type applicator. This technique may be particularly useful for reducing tall weeds such as horseweed. Inexpensive hand wicks or wipers are available.
• Clip-cut - Hand held clippers are sold that dispense a thin layer of herbicide onto the blade and can be used to selectively cut weeds. This method applies the herbicide to the cut surface of the stem so it is translocated into the weed to control the total plant.

Renovation

Wildflower plantings decline over time because many herbaceous perennial plants often have a limited life span. Decline may also be attributed to weed pressure, allelopathy, and site conditions. Renovation of an existing planting may be more cost effective than starting a new one.

New seeds can be planted into existing wildflower plantings that are relatively weed free. The soil should be disturbed as little as possible to prevent additional weed seed germination. This can be accomplished either by raking or using a slit or drill seeder. Renovation should be completed during the same time frames used for initial seeding.

ALLELOPATHY

Some plants produce chemical compounds that inhibit the growth of other nearby plants (allelopathy). Toxic substances may be released from the roots or leaves of such plants and by substances from plant residues on the surface that are leached into the soil with rainwater. Weeds are known to have allelopathic (detrimental) effects on some crops and vice versa. Some plants that are known or suspected to be allelopathic are bermudagrass (Cynodon dactylon), johnsongrass (Sorghum halepense), yellow nutsedge (Cyperus esculentus), purple nutsedge (Cyperus rotundus), pigweed (Amaranthus spp.) and sunflower (Helianthus spp.). Horseweed is known to be allelopathic to itself. This is most likely the reason it declines rapidly in the normal plant succession. However, even though it will decline over several years, if it is left in wildflower plantings, it will severely reduce the wildflower population and make the area unattractive at the same time.

Allelopathic effects will never become a total weed control method for wildflowers. However, differences in plant growth caused by this process can be effectively used in developing a weed management strategy.
SUMMARY

Weed management in wildflowers is a continuing challenge. As wildflowers become more popular, additional knowledge and experience will generate improved management techniques. The primary objective for wildflower plantings should be a naturalized planting with seasonal changes and interest rather than a weed-free groomed area. This can be achieved with properly applied management techniques. Wildflowers are a valuable natural and scenic resource that should be managed (preserved and enhanced) and above all enjoyed by everyone.
APPENDEX

CONVERSION RATES

Mass or Weight
1 pound = 16 ounces
1 pound = 0.4535924 kg (kilogram) = 453.5924 g (grams)
1 ounce = 0.0625 pounds = 28.349527 g (grams)
1 kg (kilogram) = 2.205 pounds

Volume
1 gallon = 128 fluid ounces = 3.785 L (liters) = 3785 ml (milliliters)
1 fluid ounce = 0.029573 L (liters) = 29.573 ml (milliliters)
1 L (liter) = 0.2642 gallons = 33.82 fluid ounces

Length or Distance
1 foot = 0.3048 m (meters)
1 m (meter) = 3.281 feet
1 mile = 5,280 feet = 1609 m (meters)

Surface or Area
1 acre = 4,047 m² (square meters) = 0.4047 ha (hectares)
1 acre = 43,560 square feet
1 square foot = 0.093 m² (square meters)
1 m² (square meter) = 10.76 square feet
1 ha (hectare) = 2.471 acres

Pressure
1 pound per square inch (psi) = 6.895 kPa (kilopascals)
1 kPa (kilopascal) = 0.146 pound per square inch (psi)
Application Rates
1 L/ha (liter per hectare) = 0.1069 gallons per acre = 13.68 fluid ounces per acre
1 gallon per acre = 9.354 L/ha (liters per hectare)
1 kg/ha (kilogram per hectare) = 0.8922 pounds per acre
1 pound per acre = 1.121 kg/ha (kilograms per hectare)

Concentrations
1 kg/L (kilogram per liter) = 8.33 pounds per gallon
1 pound per gallon = 0.1198 kg/L (kilograms per liter)
or 119.8 g/L (grams per liter)

Speed
1 mile per hour = 1.609 km/h (kilometers per hour) = 26.83 m/min (meters per minute)
1 mile per hour = 88 feet per minute

Flow Rates
1 gallon per minute = 3.785 L/min (liters per minute)
1 L/min (liter per minute) = 0.264 gallons per minute