

Weed Control

Commercial Applicator – Classification 5

Training Manual



UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE

Cooperative Extension Service

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Preface

This manual provides information for the Arkansas commercial pesticide applicator wishing to become certified in Classification 5 – Weed Control and the noncommercial pesticide applicator wishing to become certified in Classification 9B – Ornamental Weed Control. To become a certified applicator in the desired category, a candidate must pass both a general standards exam and pass an examination based primarily on the material presented in this manual and (Circular 6) Arkansas Pest Control Law (Act 488 of 1975, as amended). Information covered in the general standards examination is contained in “A Guide for Private and Commercial Applicators: Applying Pesticides Correctly.” Refer to (Circular 6) Arkansas Pest Control Law (Act 488 of 1975, as amended) for specific requirements for Classifications 5 and 9B. The Arkansas State Plant Board administers the examinations. Up-to-date study materials can be obtained from the Arkansas State Plant Board, #1 Natural Resources Drive (P.O. Box 1069), Little Rock, AR 72203-1069, phone (501) 225-1598. Additional study information may be obtained from the University of Arkansas Cooperative Extension Service, the pesticide label, current publications on the subject, pesticide distributors and manufacturers.

Acknowledgments

Information accumulates from direct observations, scientific literature and anecdotes from others. Information from these sources blurs together quickly, and consequently, unique ideas are rare in society. Credit for sources of information on weed control must go to Land Grant University extension and research workers in the area of turf management and weed science who continually work to maintain and update weed management information. In addition, thanks go to pest control industry workers who hold training sessions nationally, regionally and locally where information is disseminated among the experienced and provided to the inexperienced, the Environmental Protection Agency whose personnel molded modern training and influenced the need for national uniformity in training requirements, and also, State regulatory personnel who cooperate with Universities and Industry and who strongly emphasized the importance of training.

The pesticide information presented in this publication was current with federal and state regulations at the time of printing. The user is responsible for determining that the intended use is consistent with the label of the product being used. Use pesticides safely. Read and follow label directions. The information given herein is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Cooperative Extension Service is implied.

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Selected Weed ID References

Weed Control Glossary

Ornamental Weed Control

Introduction

If there were no humans there wouldn't be any weeds. There are no weeds in nature. Good or bad, we decide which plants are weeds. Opinions as to what is a weed vary widely. Divergent viewpoints on this matter have given rise to the observation that one person's weed is another's wildflower. Typically, a weed is a plant growing where someone doesn't want it.

Weed control in ornamentals may be one of the most difficult challenges in pest management. Unlike turfgrass weed control, there is rarely an opportunity to control weeds in a planting of a single species. Landscape managers are likely to encounter woody trees and shrubs along with annual and perennial herbaceous species in the same bed. Multiplying these life cycle and growth habit possibilities by the hundreds of species and varieties available yields an endless number of combinations. Other challenges include little opportunity to use traditional approaches to weed control such as mowing, selective, broad-spectrum herbicides and cultivation. Landscape weed control is almost always labor intensive due to steep slopes and other design obstacles that make it impossible to use anything but hand-held equipment.

Weed Identification

To conduct an effective weed management program, the manager should be able to identify target weeds to genus and preferably to species. (For example: *Poa annua*. *Poa* is the genus name and *annua* is the species name for annual bluegrass.) Accurate weed identification is essential to selecting the appropriate control technique.

Weed identification should begin with classifying weeds by type. The five most common weed types are grasses, broadleaves, sedges, rushes and other non-grass monocots such as weeds in the lily family.

Grasses are monocotyledonous plants, which mean they have only one seed leaf (cotyledon) present when a grass seedling emerges from the soil. Grasses have joints (nodes) and hollow,

rounded stems. The true leaves (as opposed to seed or cotyledon leaves) have parallel veins and are several times longer than they are wide. Bermuda-grass, crabgrass, goosegrass and annual bluegrass are typical grass weeds found in ornamentals.

Broadleaf weeds are dicotyledonous, which means they have two cotyledons (seed leaves) at emergence and have net-like veins in their true leaves. Broadleaves often have colorful flowers compared to the inconspicuous flowers found on grasses. Chickweed, spurge, groundsel, henbit, lespedeza, clover, dandelion and dock are typical broadleaf weeds.

Sedges have solid, triangular stems (in most species) which bear leaves extending in three directions (3-ranked). Sedges lack ligules and auricles, and the leaf sheath is continuous around the stem. Yellow and purple nutsedge, annual sedge, green kyllinga, rice flatsedge and globe sedge are examples.

Rushes have round, solid stems and favor a moist habitat. Path rush is an example of the rush family. Path rush is often found on golf cart routes, sports fields and other compacted areas.

The **Lily** family also contains some important species such as wild garlic, false garlic, star-of-Bethlehem and grape hyacinth. These plants have parallel veins but are not grasses, sedges or rushes.

Weed Life Cycles

The previously listed weed classifications may be further divided into annuals, biennials and perennials. **Annuals** germinate from seed, grow, mature and die in less than 12 months. Annuals may be further classified as winter and summer annuals. **Winter annuals** germinate in the fall, grow during cool periods, mature in the spring and then die during the summer. **Summer annuals** germinate in the spring, grow actively during the summer and die in the fall. Crabgrass and goosegrass are examples of summer annual grasses. Prostrate knotweed is an example of a summer annual broadleaf, while

henbit and chickweed are representative of winter annual broadleaves.

Biennials reproduce from seed and complete their life cycle in two years. Biennials form rosettes and store foods in their fleshy roots the first year and then flower the second year. Many thistle species are biennials.

Perennial weeds live more than two years. Perennials may reproduce from seed or from vegetative structures such as roots, rhizomes, stolons, tubers or bulbs. The ability to reproduce vegetatively makes perennials more difficult to control. Some perennials such as dandelion, dock and wild garlic are actively growing during cool weather, while others like dallisgrass and nutsedge grow rapidly during the summer months. Perennials are further subdivided as simple perennials and creeping perennials. **Simple perennials**, such as dock and dandelion, overwinter by means of a vegetative structure such as a perennial root with a crown, but they reproduce almost entirely by seed. **Creeping perennials** can both overwinter and produce new independent plants from vegetative reproductive structures. Vegetative reproductive structures include creeping roots, stolons (bermudagrass), rhizomes (johnsongrass), tubers (nutsedge) and bulbs (wild garlic). Most perennials can also reproduce from seed.

If you are serious, a guide to weed identification is a very useful tool because weed identification is arguably the most important part of weed control. Some recommended publications may be found in the section "Selected Weed ID References."

Herbicides

Nomenclature

Herbicide labels contain three names: trade name, common name and chemical name. The nomenclature for Roundup would be as follows:

Trade Name: Roundup

Common Name: glyphosate

Chemical Name: N-(phosphonomethyl)glycine

The trade name is used by the chemical company to market the product and is often the most recognizable name. The common name is a generic name that is given to a specific chemical. Only one common name exists for each herbicide. It is useful to be familiar with common names when comparing products. The chemical name describes the chemistry of the herbicide. To make things confusing, the same or different chemical companies often sell the same herbicide under different trade names. For example, proflaminate is marketed by Syngenta for turf use as Barricade and for landscape use as Factor.

Herbicide Classification

Herbicides may be classified in many ways, but some of the most important groupings are selectivity, timing of application, chemistry and mode of action.

Selectivity

Selective. A selective herbicide controls or suppresses some plant species without seriously affecting the growth of another plant species. Selectivity may be due to differential absorption, translocation, morphological and/or physiological differences between ornamentals and weeds. Most ornamental herbicides are selective. Fusilade II is an example of a selective herbicide that controls many grass weeds without causing significant injury to broadleaf plants.

Non-selective. Non-selective herbicides control or suppress plants regardless of species. Glyphosate (Roundup Pro), glufosinate (Finale) and diquat (Reward) are examples of non-selective herbicides. These products are often used for trimming along sidewalks and fences and as preplant treatments when renovating or establishing ornamentals. It is important to note that the selectivity of some herbicides is based on rate. Increasing the rate of a selective herbicide such as Princep (simazine) will move it into the non-selective category.

Mode of Action

Mode of action refers to the sequence of events, which includes herbicide absorption, translocation to the site(s) of action, inhibition of a specific biochemical reaction, the degradation or breakdown of the herbicide in the plant, and the effect of the herbicide on plant growth and structure.

Herbicide Movement in Plants

Systemic (sometimes referred to as **translocated**) herbicides are extensively translocated in the vascular system of the plant. The vascular system consists of the xylem and phloem. The xylem transports water and various nutrients in solution, upward from the roots where they entered the plant, through the stems, and into leaves, flowers and fruits. The phloem conducts food materials from their principal sites of synthesis in leaves to other locations, such as fruits and developing roots and shoots, for storage and use. Systemic herbicides are slower acting than contact herbicides because they require from several days to a few weeks to move throughout the vascular system of a treated plant. Systemic herbicides may be selective or non-selective. Glyphosate (Roundup Pro) is an example of a non-selective systemic herbicide, while Vantage (sethoxydim) is an example of a selective systemic herbicide. Most of the systemic herbicides move in the xylem and phloem with the exception of the triazines (atrazine, simazine, Sencor), which are xylem mobile only.

Contact herbicides affect only the green plant tissue that comes in contact with the herbicide spray. Thus, thorough coverage of the weed foliage is needed to achieve optimum control. These herbicides are either not translocated, or only move to a limited extent, within the vascular system of plants. For this reason, underground vegetative reproductive structures such as roots, rhizomes and tubers are not affected. Multiple applications of contact herbicides are needed for long-term control because plants regrow from these unaffected plant parts. Contact herbicides are fast acting. Symptoms are

often visible within a few hours of application. Basagran T/O (bentazon) is a selective contact herbicide. Reward (diquat) is a non-selective contact herbicide.

Herbicide Families

Herbicides with similar chemistry are grouped into families. In general, herbicides in the same family exhibit similar absorption, translocation and mode of action. It is convenient to combine herbicide families that have similar sites of action into groups. For ornamental weed managers, the importance of knowing which herbicides have similar sites of action lies in developing weed control strategies that minimize the potential for developing herbicide-resistant weed populations.

Herbicide Resistance

A number of weed species that were once easily managed by certain herbicides have developed resistance. These weeds are no longer controlled by applications of previously effective herbicides.

Herbicide resistance probably develops through the selection of naturally occurring biotypes of weeds exposed to a family of herbicides over several years. A biotype is a population of plants within the same species that has specific traits in common. Resistant biotypes may have slight biochemical differences from their susceptible counterparts so they are no longer sensitive to certain herbicides. Resistant plants survive, go to seed and create new generations of herbicide-resistant weeds.

Dinitroaniline-resistant goosegrass and crabgrass have been documented in ornamentals. However, these plants are susceptible to other preemergence grass herbicides such as Ronstar.

Experience has shown that the potential for developing resistance is greatest when an herbicide has a single site of action. Development of johnsongrass resistant to the grass specific herbicides has already occurred in many areas in spite of their relatively short time in the market. We now have Illoxan-resistant ryegrass in the United States and several other countries.

Regardless of the mechanism for resistance, becoming familiar with the herbicide mode of action can help turf managers design programs that prevent the development and spread of herbicide-resistant weeds. Management programs for herbicide resistance should emphasize an integrated approach that stresses prevention. Dependence on a single strategy or herbicide family for managing weeds will surely increase the likelihood of additional herbicide resistance problems.

Some Strategies for Managing Resistance

1. Rotating herbicides having different modes of action. This is a problem in landscape weed control because there are a limited number of modes of action from which to choose.
2. Using tank mixtures of herbicides having different modes of action.
3. Avoiding sequential application of the same herbicides (over several years) or herbicides having the same mode of action.
4. Controlling weedy escapes in border areas and ditch banks.
5. Practicing good sanitation to prevent the spread of resistant weeds.
6. Integrating cultural, mechanical and chemical weed control methods.

Herbicide Formulations

The two big groups of herbicide formulations are dry and liquid. The amount of active ingredient in a dry formulation is designated as a percent of the weight. Active ingredient in liquid forms is listed in pounds per gallon. Within the dry formulations there are granular or pelletized herbicides that are spread directly on the target in dry form. These products usually contain very low percentage of active ingredient (0.1% to 2.0%) and are designated by the abbreviation **G** or **GR** (granule) or **P** (pellet). Other dry formulations are mixed with water and sprayed on the target. These products are designated as **SP** (soluble powder), **W** or **WP** (wettable powder), **WSP** (water soluble packet), **DF** (dry flowable), **SG** (soluble granule) or **WG, DG** or **WDG** (water dispersible granule). Liquid formulation designations include **L** or **F** (liquid suspension), **E** or **EC** (emulsifiable concentrate), **SC** (suspension concentrate), **SL** (soluble liquid), **ME** (microencapsulated) and **CS** (capsule suspension).

Some herbicide formulations may be incompatible. MSMA and 2,4-D amine will sometimes form sludge when mixed. Liquid nitrogen and 2,4-D amine will always form sludge when mixed. In addition to physical incompatibility, two herbicides may mix well but may be chemically incompatible resulting in a reduction in herbicidal activity. For example, mixing 2,4-D with Fusilade, Vantage or other grass-specific herbicides will result in

Ornamental Herbicides with the Same Mode of Action		
Dinitroanilines (Root Growth Inhibitors)	Lipid Inhibitors	ALS Inhibitors
Balan 2.5G (benefin) Biobarrier II (trifluralin) Biobarrier Root Control (trifluralin) Dimension 1 EC (dithiopyr) Barricade 65 WDG (prodiamine) Ornamental Weedgrass Control (pendimethalin) Pendulum 2G (pendimethalin) Pendulum 3.3 EC (pendimethalin) Pendulum WDG (pendimethalin) Pre-M 3.3 EC (pendimethalin) Pre-M 60 DG (pendimethalin) Treflan 5G (trifluralin) Surflan (oryzalin)	Acclaim Extra (fenoxaprop) Envoy (clethodim) Fusilade II (fluazifop) Ornamec 170 (fluazifop) Vantage (sethoxydim)	Image (imazaquin) Manage (halosulfuron)

decreased grass control. This is referred to as antagonism. The label will give instructions on what can and cannot be mixed with that herbicide. When tank mixing different formulations: (1) fill the tank 2/3 full of water, (2) start the agitation and keep it running and (3) add the respective formulations in this order: wettable powders > dry flowables > liquid suspensions > emulsifiable concentrates > soluble concentrates.

Herbicide Spray Additives and Their Uses

Adjuvant: Any additive used with an herbicide that enhances the performance or handling of the herbicide.

Compatibility agent: A material that allows the mixing or improves the suspension of two or more formulations when applied together as a tank mix. Compatibility agents are used most frequently when a liquid fertilizer is the carrier solution for an herbicide.

Crop oil concentrate: Oil-based material that enhances herbicide penetration through the leaf cuticle.

Defoamer: A material that eliminates or suppresses foam in the spray tank so that pumps and nozzles can operate correctly.

Drift control agent: A material used in liquid spray mixtures to reduce spray drift.

Fertilizer: Certain fertilizers added to the spray tank can enhance penetration of the herbicide into the leaf. Ammonium sulfate and 10-34-0 are commonly used as additive in some parts of the country. Ammonium sulfate is sometimes mixed with glyphosate to treat weeds under marginal conditions such as drought stress. 10-34-0 has been used as an herbicide additive for velvetleaf control in the upper Midwest.

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

Wetting agent: A material that reduces interfacial tensions between water droplets and the leaf cuticle.

Timing of Application

Herbicides are also classified by when the chemical is applied relative to turfgrass and/or weed seed germination. The majority of herbicides may be classified into one of three timing categories: preplant, preemergence or postemergence. However, several herbicides have pre and postemergence activity. Examples include imazaquin (Image), simazine (Princep) and pronamide (Kerb).

Preemergence Herbicides

Preemergence herbicides are the foundation of an ornamental weed management program. Preemergence herbicides are applied to the site before weed seed germination. After being activated by rainfall or irrigation, these herbicides form an herbicide barrier at or just below the soil surface. When the roots or shoots of germinating seeds come in contact with the herbicide barrier, their growth is inhibited. Most preemergence herbicides are cell division inhibitors affecting the emerging root and shoot, which are sites of rapid cell division. Weeds that have already emerged (visible) are not consistently controlled because their growing point has escaped contact with the herbicide. The primary target of preemergence herbicides is annual grass, but some small-seeded annual broadleaves will be controlled.

A variety of factors affect the performance of preemergence herbicides. These include timing of application in relation to weed seed germination, soil type, environmental conditions (primarily temperature and rainfall), target weed species and biotype, and cultural practices that follow application. Soil organic matter and clay content have the greatest influence on the activity of preemergence herbicides.

Ideally, preemergence herbicides should be applied just before weed seed germination begins. Applying too early may result in reduced control or no control due to leaching and/or normal herbicide degradation. Preemergence herbicides must be in place and activated before the onset of weed seed germination. Activation of preemergence herbicides requires 0.25 to 0.5 inch of rainfall or overhead irrigation. For optimum performance, rainfall or

irrigation should occur within 24 hours of application. Water moves the herbicides into the upper layer of the soil. Failure to incorporate herbicides will result in loss through processes such as breakdown by sunlight and escape into the atmosphere as a gas. The critical period between application and activation by rainfall or irrigation varies with herbicide, rate and environmental conditions. However, it is safe to assume that sooner is better and, if irrigation is available, water-in pre-emergence herbicides immediately after application.

In warm weather, herbicides begin to degrade soon after application, eventually reaching a level at which weed emergence and growth can occur. Preemergence herbicides will degrade to the point of ineffectiveness from one to four months after application. For this reason, repeat or sequential applications are needed for full season control.

A typical cycle of preemergence herbicide applications would include an initial application in late winter to early spring to control summer annuals followed by second application in late summer to early fall to control winter annuals. In some parts of the country such as the humid South, an application in late May or early June may be needed because the spring application will have dissipated by that time.

Postemergence Herbicides

Postemergence herbicides are intended for use on weeds that have emerged and are visible. Postemergence herbicides are applied directly to emerged weeds. In contrast to preemergence herbicides, most postemergence herbicides have little or no soil activity. It is possible to conduct a total postemergence weed control program in ornamentals provided multiple applications are used throughout the year. Disadvantages of total post-emergence weed control include the need for frequent applications and the possibility of temporary ornamental injury. Most weed control professionals use a combination of preemergence and postemergence herbicides. Preemergence herbicides form the basis of most programs with post-emergence herbicides used to control weeds that escape the preemergence treatments. Established perennial weeds, both grasses and broadleaves, must be controlled with postemergence herbicides.

General guidelines for best results with postemergence applications are small weeds, adequate soil moisture and air temperatures between 60° and 90°F. Weeds that are small (two to four-leaf stages) and actively growing are much easier to control with postemergence herbicides. Control is improved at this stage because young weeds readily absorb and translocate herbicides.

Weeds that are stressed due to dry weather, heat or other environmental factors are more difficult to control with postemergence herbicides. Applying postemergence herbicides at temperatures above 90°F increases the risk of ornamental injury.

The resistance of postemergence herbicides to wash-off by rainfall or irrigation varies among products. Typically, a rain-free period of 6 to 24 hours is sufficient to avoid a reduction in effectiveness. Even if rain falls soon after application, some degree of control will be achieved.

Rather than a single rate, a range of post-emergence herbicide rates for a product usually is given. Repeat applications at moderate rates are generally more effective than a single application of the higher rate. The follow-up application is timed to be 7 to 14 days after the first or when regrowth appears.

Spot Spraying

Directed spot spraying with a hand-held, pump-up sprayer or lever-operated, backpack sprayer is one of the most commonly used methods of applying herbicides in and around landscape plantings. Lack of herbicide selectivity and the obstructions created by landscape plants often dictate the use of this approach. Spot spraying solutions are typically prepared by adding a certain amount of liquid herbicide per gallon of spray mix. These are usually given on a percent of total volume basis. For example, to make a 2% mixture of Roundup and water, add 2.66 oz of Roundup per gallon of water. This method is best for herbicides with little or no soil activity. Soil active herbicides should be carefully applied on a per unit area basis (per 1,000 sq ft or per acre).

Most pump-up sprayers do not have pressure gauges or pressure controls. The pressure in the tank will drop as the material is sprayed from the tank.

This pressure drop can be partly overcome by filling the tank only 2/3 full with spray solution, 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, do not overapply. The coverage should be similar to that resulting from a light rain. Just wet the foliage of the target weed and move on. Do not spray until runoff.

Use a funnel or some other shield attached just above the nozzle when applying non-selective herbicides such as Roundup, Reward or Finale. Solo sells an attachment for this purpose called a Drift Guard or you can improvise. A normal plastic funnel may be adapted, or cutting the top from a 2-liter soft drink bottle can make a cheap alternative. Attach it with duct tape or a hose clamp. Beware of dripping or tracking herbicide with your feet when moving from one location to another.

Principles of Herbicide Use

Before selecting any herbicide, determine whether or not the desirable landscape plants are tolerant of the chemical being considered. Consult the label to determine which herbicides may be safely used on the ornamentals in question. The majority of ornamental herbicide failures and mistakes are not from the weakness of the herbicide but from:

1. Choosing the wrong herbicide due to misidentification or lack of research into herbicide selection.
2. Applying at the wrong time.
3. Treating an ornamental species that is sensitive to the herbicide and will be damaged.
4. Poorly calibrated application equipment.
5. Failure to distribute the herbicide uniformly across the target area.
6. Using application equipment not suited to the job.

7. Inadequate spray tank agitation.
8. Treating the target weed at the wrong stage of growth (too large, too small).
9. Applying when environmental conditions are not conducive to good weed control (dry, hot, cold, windy, rainfall imminent).

Herbicide Selection Criteria

1. Does it control most of the weeds present?
2. Are the existing ornamentals listed on the label?
3. How close are susceptible ornamentals and other non-target species?
4. Is there potential for damage to future plantings due to residual herbicide remaining in the soil?
5. How will the herbicide be applied? Spread or sprayed?

Site Preparation

Because weed control in landscape plantings is difficult under the best conditions, it is nearly impossible to spend too much time on preplant weed control. There are always exceptions to this admonition, but many years of experience have taught me that people rarely expend excessive effort on preplant weed control in turfgrass and ornamentals. This may be all right on some sites, but if there are tough perennial weeds present, it is a mistake. Fumigation using methyl bromide, Basamid or soil solarization is an option for landscape beds. Solarization may not be practical because it must be done during the hottest part of the year and the covers must be left in place for six weeks.

Preplant Herbicide Application

One application of Roundup Pro or another labeled glyphosate product at least two weeks before planting is a cheaper but less effective alternative to soil fumigation. Complete control of some perennial weeds may require multiple applications

of Roundup. The treatments should be timed to the appearance of regrowth of the target weed. It should be noted that a full growing season of repeated Roundup treatments (usually 3 or 4) will control bermudagrass but not yellow or purple nutsedge.

Soil Fumigation

Soil fumigants are volatile liquids or gases that control a wide range of soilborne pests. Soil fumigants are also highly toxic and are expensive. Their use is often limited to high-value crops such as putting greens, propagation beds and ornamentals. A cover, usually plastic film, is placed over the treated area to trap the fumigant vapors in the soil. In addition to many weeds, fumigants also control diseases, nematodes and insects. Weed seeds that have hard, water-impermeable seedcoats such as mallow, sicklepod, white clover, redstem and morningglory are not controlled by fumigants. In addition, nutsedge control with fumigants is not dependable. Factors to consider before choosing a soil fumigant include expense, soil moisture level, soil temperature and time available before planting. There are three compounds available for soil fumigation in ornamentals: (1) methyl bromide, (2) metham or metam-sodium and (3) Basamid (dazomet).

Methyl bromide is a colorless, nearly odorless liquid or gas. At 38°F, the liquid becomes a gas and at 68°F is 3.2 times heavier than air. These properties require that a cover is used or methyl bromide will escape. Methyl bromide is extremely toxic (acute vapor toxicity is 200 ppm) due to inhalation hazard, and it is commonly combined with a warning agent such as chloropicrin (teargas) to warn the user of escaping gas.

Before using methyl bromide, the soil should be in a condition suitable for planting including seedbed preparation by tilling. Control will be only as deep as the soil is adequately tilled. Soil should be moist for adequate soil penetration and dispersion. Saturated soils or extremely dry soil will limit fumigant movement through the soil, thus reducing the level of weed control. Soil temperature at 4 inches should be a minimum of 66°F. Fumigation will not be effective if soil temperature is below 50°F. Before or during application, the site should be covered with plastic film with the edges properly

sealed to prevent gas leakage. The treated area should be covered for 24 to 48 hours. The cover should then be removed and the soil aerated for 24 to 72 hours before planting.

Metham or metam-sodium. Metham (methyl-dithiocarbamate) is a member of the thiocarbamate herbicide family. Metham is water-soluble and upon contact with the moist soil breaks down to form the highly toxic and volatile chemical methyl isothiocyanate. Metham should be applied to moist soil with a temperature of at least 60°F. It is most effective when used with a cover, but it may be used with a water and soil-seal method. With the water soil-seal method, the soil is cultivated and kept moist for a week before treatment. The material is applied, roto-tilled and watered in to the desired depth of control (usually 4 to 6 inches). Approximately seven days after treatment, the area should be cultivated to help release any residual gas. One to two weeks later (two to three weeks after initial application), the treated area may be planted. Disadvantages of metham use include the lowered effectiveness when used without a cover and the longer waiting period before planting. The oral LD₅₀ of metham is 820 mg/kg while the dermal LD₅₀ is 2,000 mg/kg.

Basamid (dazomet) has recently been introduced as a soil fumigant. Dazomet is a granular formulation and is not a restricted-use pesticide. Dazomet must be applied accurately and uniformly and then incorporated into the soil. Its use and effectiveness are very similar to metham. One of its main attractions is that, unlike methyl bromide, it can be handled without any special equipment. We have used Basamid in our research program on native soil with good success. While the label gives other options, use a plastic film to seal the site just as you would with methyl bromide. We consider Basamid to be about 80% as effective as methyl bromide.

Planters

When planting containers, it is a good idea to use sterile or weed-free potting soil whenever practical. Even if clean planting media is used, there will be some weed encroachment. The most practical method of weed control for a small

number of planters is the use of hand weeding and mulches. The key to successful hand weeding is frequent inspection. It is important to make regular weed removal rounds during the growing season before the number of weeds present becomes overwhelming. A single smooth pigweed may produce up to 200,000 seeds; a single annual bluegrass plant is capable of producing 2,000 seeds. The other option is the use of herbicides to control most of the weeds. Do not enter into herbicide use in planters lightly. Accurate application and careful herbicide selection is critical. There is a limited soil volume in containers, and this provides less herbicide buffering capacity compared to field plantings. As always, when using herbicides, it is a good idea to try new products and techniques on a small trial area before treating everything in the landscape. Not all ornamental herbicides are labeled for use in containers. Some are designated for field use only. Consult the label for use options. Ornamental Herbicide II and Rout herbicide are two of the most popular pre-emergence products for containers. Both products contain Goal (oxyfluorfen), which will cause contact burn of foliage if not washed off with irrigation water immediately after application. Ronstar (oxadiazon) also has the potential for foliar burn. Some of the other products registered for container use include Treflan, Ronstar and Devrinol.

Annual Flower Beds

In a perfect world, all annual beds would be fumigated before planting. If time and money allow, fumigation should be the first choice on high value annual beds. While under scrutiny at this time, methyl bromide is still available for soil fumigation. The other products available for this use are Vapam and Basamid. Methyl bromide remains the most effective of the three although its high level of toxicity restricts its use to professional applicators.

Short of fumigation, hand weeding, frequent cultivation, mulches, herbicides or a combination of all these methods are used for weed control in annuals. Cultivation has limitations as a weed control method in landscape beds. Cultivation may damage roots, spread perennial weeds and encourage germination of weed seeds by bringing them to the soil surface. Perennial weeds should be controlled before planting. Select annual species that

are compatible with effective herbicides. Use of landscape fabrics is not practical for annual beds due to the short-term nature of the planting. Organic mulches are the most practical. Preemergence herbicides may be applied to the soil before mulching or applied to the mulch and watered in after planting. Place transplants into weed-free soil. When using a preemergence herbicide in an annual bed, irrigate to settle the soil around the plants before applying the herbicide. A granular product such as Pendulum 2G is easy to apply and labeled for use on many popular bedding plants. Planting to encourage the rapid formation of a canopy will help shade weeds. Avoid small, odd-shaped flowerbeds. They are difficult to maintain and mow around. When mowing, blow clippings away from beds to prevent the introduction of weed seeds. Prepare the soil and apply the mulch before planting annuals. It is easier to install transplants through the mulch than to attempt to mulch around them after planting. Cultivation when changing plantings will suppress some weeds but may bring additional weed seeds to the soil surface. A preplant application of a non-selective herbicide between plantings will help reduce weed competition without disturbing the soil. Do not try to use non-selective herbicides such as Roundup Pro or Finale while annuals are present. It is too easy to make a mistake. Envoy, Fusilade II or Vantage may be used postemergence to selectively control weedy grasses after planting. No wide spectrum, selective, postemergence herbicide exists for broadleaf weeds and sedges.

Herbaceous Perennial Beds

The major differences in weed management for herbaceous perennial beds (as compared to annuals) are (1) preplant perennial weed control is more important because there won't be an opportunity for cultivation or renovation for several years and (2) geotextiles may be used in many instances. Mulches may be used over landscape fabrics and supplemented with preemergence herbicides and hand weeding. Apply preemergence herbicides soon after transplanting. Perennial weeds in herbaceous perennial beds may be controlled with carefully directed applications of Roundup. Do not allow the Roundup to contact the foliage of the desirable plants. Care must be taken when using Roundup in beds due to the many possibilities for getting

Roundup on non-target plants. Dripping spray wands, accidental wiping of foliage or tracking the herbicide onto turfgrass or onto another bedding plant are common Roundup use mistakes. While close planting will produce a rapid canopy to discourage weeds, perennials should be spaced to allow 3 to 5 years of growth. Open areas will make weed control more difficult but will eliminate the hassle of removing crowded plants to change the spacing.

Woody Groundcover Beds

After they are well established, woody groundcovers will crowd out most weeds. However, during establishment, weed control will be more difficult. The need to control perennial weeds before planting becomes increasingly important because injury free spot spraying with Roundup is almost impossible in a dense groundcover bed. Plan ahead and choose groundcovers that are tolerant of the herbicides that fit the weed spectrum present. Annual weeds may be controlled with a combination of mulch, pre-emergence herbicides and hand weeding. Envoy, Vantage and Fusilade II are excellent for post-emergence control of annual and perennial grasses. Use landscape fabrics where possible, but not where groundcovers are expected to root and spread.

Woody Tree and Shrub Beds

Beds made up exclusively of woody plants offer more weed control options due to greater herbicide tolerance. Depending on the growth habit of the species selected, the opportunity for directed applications of herbicides such as Roundup Pro or Finale is greatly enhanced. Care should be taken to avoid applying Roundup Pro to green bark or trees with fresh wounds from pruning, string trimmers, mowers, etc. Suckers and low-hanging branches should be removed well in advance of spraying to allow the wounds to heal. In situations where brownout is not objectionable, Finale may be used to prune suckers or contain low-growing creeping plants. Finale (glufosinate) does not translocate in most species. Mulches, landscape fabrics and herbicides may be readily combined to provide broad-spectrum weed control. A landscape fabric combined with a shallow layer of mulch or a deep mulch layer without landscape fabrics are two

reasonable approaches. Supplement these measures with a preemergence herbicide. Escaped weeds may be controlled with directed applications of non-selective herbicides. Hand weeding may be sufficient for scattered infestations. The greater range of control options available reduces the importance of preplant weed control. In some instances, dormant season application of Casoron (dichlobenil) may be useful for perennial weed control. Design plantings to provide a dense canopy that will shade weeds.

Mixed Plantings of Woody and Herbaceous Species

Consider planting the woody species first and then spending two years controlling perennials with non-selective herbicides. After the perennial weeds are under control, then plant the herbaceous species. Space the woody plants to provide plenty of shade to suppress weeds. Given the greater herbicide tolerance of woody plants, it may be necessary to develop separate weed management programs for different areas in the same planting.

Paved Areas

Before installing paving, regardless of the material used, perennial weeds such as nutsedge and bermudagrass should be controlled. Minimizing the number of cracks in the paving will reduce weed control problems in the future. When treating cracks in paving with Roundup or another non-selective herbicide, adding a non-staining, residual herbicide such as Factor will reduce the number of applications needed per season. Do not apply industrial vegetation management herbicides such as Hyvar (bromacil), Velpar (hexazinone), Tordon (picloram), Spike (tebuthiuron), Pramitol (prometone) and Arsenal (imazapyr) to control weeds in paved areas near ornamentals. Plants whose roots extend into the treated area may be killed or injured by these products. Remember that tree roots can grow under paving and pick up herbicides that were applied before the paving was installed. Large shade trees have roots that extend well beyond the drip line. An additional hazard associated with these herbicides is runoff onto sites with desirable vegetation. Every year desirable ornamental trees and shrubs are killed by the use of this category of herbicides. Roundup

Pro can be safely used to control most annual and perennial weeds growing under trees and shrubs. Grass encroachment onto paved areas can be reduced with the use of Roundup Pro. A neater edge can be accomplished with the use of Finale when edging creeping grasses. Finale is translocated very little thus leaving a uniform line of dead grass. Primo (trinexepac-ethyl) will also reduce the amount of edging needed when trying to control the growth of grasses that produce runners.

Spray Tips for Edging Paved Areas

Standard flat fan tips deliver a tapered pattern, which means that the application rate on the outside of the pattern is less than that in the center of the pattern. This is overcome in boom spraying applications by overlapping the spray patterns. When applying an edging spray with a single nozzle, use an even flat fan tip. These tips have an E designation such as 8003E on the tip. Typical nozzles such as 80° or 95° are often too wide for edging. A 4003E flat fan works very well for this purpose. It is not a commonly available tip and will have to be ordered. The narrower pattern produced by the 4003E makes it a good tip for spot spraying.

Mulches

Mulches prevent weed emergence by blocking light needed to stimulate germination. While very effective, mulches will not provide complete weed control. Hardwood and pine barks are two of the most popular materials. One common error made with using mulches is applying them too deep. Excessive mulching creates a constantly wet environment, which prevents oxygen penetration into the soil. Coarse bark mulch should be about 4 inches deep and fine-textured bark about 2 inches deep. Coarse mulches provide less water holding capacity and are less likely to have weeds growing in the mulch. Fine mulches hold water and provide a favorable environment for weed seed germination. Fine mulch has greater potential for tying up pre-emergence herbicides. Thin mulch layers make pre-emergence herbicides more effective. Biobarrier II, a landscape fabric that contains plastic nodules impregnated with Treflan, is an alternative to mulching and then applying a pre-emergence herbicide. Bark and other organic mulches need periodic

replenishment due to decomposition. Some perennial weeds such as nutsedge and field bindweed have sufficient root reserves to penetrate all mulches. Another problem often associated with organic mulches is weed seed germination on top of the mulch. Seeds that are readily carried by the wind such as groundsel, prickly lettuce and sow-thistle may be deposited on the mulch from remote sites. Avoid mulches that are contaminated with weed seed. Do not use foul-smelling mulches. They have gone anaerobic and may contain compounds that are toxic to plants.

Landscape Fabrics for Weed Control in Commercial and Home Landscapes

Jeffrey F. Derr, Weed Scientist, Virginia Tech

A number of fabrics are currently available for landscape weed control. They were developed in part as replacements for black plastic (solid polyethylene). We discourage the use of black plastic in landscapes due to plastic's lack of porosity. This lack of porosity restricts water and gas penetration through solid polyethylene. Carbon dioxide can accumulate under black plastic, which poses a problem since plant roots require oxygen for development. If black plastic is placed over dry soil, subsequent rainfall may not be able to reach plant roots. If placed over wet soil, the soil may not be able to dry out properly. Black plastic is still recommended for short-term weed control in areas such as vegetable gardens.

Because these fabrics do allow for water and gas exchange, they overcome the major problem of black plastic, namely its lack of porosity. Not only have we evaluated these fabrics for weed control, we have also recorded soil moisture and temperature under landscape fabrics, and have monitored the growth of landscape trees and shrubs.

These materials, also called geotextiles or weed barriers, are made of fibers that are woven (fiber runs in two directions) or nonwoven (in which fibers run in various directions and are attached at random spots using heat or glue). The fabrics are primarily composed of polypropylene, but some are made of polyester, polyethylene or a

combination of various materials. A few other weed barriers are made of solid polyethylene, in which small holes are punched through the material to allow for water penetration. Spun-bonded fabrics tend to be more expensive than woven ones, and while most fabrics are black, some are white, gray or brown.

We have attempted to evaluate all of the major brands of landscape fabrics currently being sold. In our research, solid black plastic has provided better weed control than any landscape fabric or other weed barrier. Weed shoots and weed roots were able to penetrate through holes present in the fabrics. Perennial weeds such as yellow nutsedge can penetrate all of the fabrics we have tested. The landscape fabrics are more effective in suppressing annual weeds. Not all fabrics are equal in their ability to control weeds. Dalen's Weed-X has provided the greatest suppression of weeds, with DeWitt Weed Barrier ranked second. Weed-X was also the best fabric for retarding weed root penetration.

Another important difference we noted among fabrics was their ability to withstand breakdown by sunlight. Some fabrics, such as Duon and Typar, broke down more quickly than fabrics such as Visqueen or DeWitt, probably due to differences in UV light stabilization. This can be important if the mulch shifts due to wind or rainfall, exposing the fabric to sun.

Advantages of Landscape Fabrics

1. Fabrics reduce the need for, or replace the use of, chemicals for weed control.
2. These products allow for water and gas exchange.
3. The rougher surface tends to hold mulch better than black plastic.
4. They provide long-term weed control if kept covered by mulch.
5. They improve weed control over mulch alone.

Disadvantages of Landscape Fabrics

1. They are more expensive than black plastic.
2. Installation is more difficult.

3. These materials will not control all weeds, especially perennial ones.
4. They may stimulate surface rooting of trees and shrubs.
5. Weed roots and shoots may grow through and become intertwined in the fabric.
6. The roots of ornamentals may grow through and into the fabric.
7. Seems to create a favorable environment for rodents.

Recommendations for Using Landscape Fabrics (Geotextiles)

1. Control perennial weeds prior to fabric installation.
2. Overlap fabric pieces; use U-shaped nails to peg down the fabric. The big staples that are used to hold big roll sod together work very well for this purpose. Another source of staples for this use is cutting the ends off wire coat hangers. Each hanger yields two staples.
3. Cut an X pattern for planting.
4. Do not leave soil from planting holes on top the fabric because it will provide a medium for seed germination.
5. Maintain shallow mulch layer to prevent photodegradation but do not use excess amounts because organic mulches such as pine bark become good growing media for weeds as they decompose.
6. Control weeds that germinate in the mulch layer when small.
7. Choose a fabric with a low ratio of open to closed space (fiber arrangement), such as Weed-X.
8. Landscape fabrics provide more effective weed control if used in combination with rock or other inorganic mulches rather than organic mulches.

9. Remember that yellow nutsedge will penetrate all mulches. Pennant applied under mulch will reduce yellow nutsedge emergence.
10. Compare the advantages and disadvantages of landscape fabrics to other weed control options for specific weed problems.

Weed IPM for Ornamentals

Weed prevention is avoiding the introduction of weeds into an uninfested area. One of the keys to making integrated pest management effective in controlling ornamentals weeds is not allowing weeds to become established. Some common sense steps to weed prevention include:

1. Using weed-free mulch.
2. Using weed-free plant materials. Container nursery stock and balled and burlapped material may contain weeds. While it may not be practical to return the plants, it will be possible to get a jump on controlling these weeds.
3. Keeping border areas weed-free and preventing weeds from producing seeds.
4. Washing equipment between uses.

Landscape weed control is not herbicides alone. Approach weed control as an integrated process that combines good cultural practices that will produce dense, vigorous landscape plants with intelligent selection and use of herbicides. To conduct an effective weed control program:

1. Provide proper cultural practices.
2. Have the ability to identify specific weeds.
3. Be familiar with the growth and reproductive characteristics of weeds. Scout for weeds and pay attention to perennial species because they have the greatest potential for creating future problems. The best time to identify perennials is during late summer or early fall. Note the location of various weed infestations. This information will allow you to be ready with the correct plan of attack come treatment time.

4. Have knowledge of the control measures available and have the ability to select and use them properly.

Too often weed control measures are a reaction to an immediate problem rather than part of a well-planned and coordinated program. Weed control professionals should spend at least as much time learning the conditions that lead to weed infestation as they do studying control options after weeds have become established.

Herbicide Management

Remember that herbicides can injure non-target or desirable plants. When using any herbicide, research the characteristics of the product and manage the application carefully. Take steps to ensure that herbicides are directed to the target. Use them at the proper rate, at the right time and on a site that the label permits. Control each application so there is no off-target movement. Herbicide movement may result from drift of spray droplets, volatilization (movement as a gas) and contaminated surface runoff water or by tracking with feet or equipment. One way to avoid injury to desirable plants is to make treatments when the non-target plants are not present or not actively growing. For example, applying Roundup or preemergence herbicides in late winter before ornamentals break dormancy will reduce the chances of accidental injury. Always remember that some herbicides are mobile. Avoid applications during windy conditions. Always follow label directions, and heed label precautions. Volatile herbicide labels have restrictions to avoid vapor drift. Do not use these products during hot weather. Do not apply a volatile product during the heat of the day or in the morning of a day when very warm temperatures may occur.

Use extreme care when applying non-selective herbicides. Directed sprays are used to prevent contact with leaves or shoots of desirable plants. Droplets too small to be seen will readily move through the air and damage sensitive plants. Shielded sprays, where a cone surrounds a nozzle, can prevent the spray from hitting the foliage of a desired plant. A wiper (wick) application, where an herbicide solution is wiped on weed foliage only, is

another way to use non-selective herbicides safely around desired plants.

Be aware that some herbicides will leach vertically through the soil profile. They may injure or even kill sensitive trees and shrubs if their roots extend under the treated soil. Rainfall may move these products into the root zone, leading to injury. Atrazine and simazine are herbicides with potential for vertical and lateral movement.

When finished applying granular herbicides or fertilizers, sweep or blow them off hard surfaces such as parking lots, driveways, sidewalks and streets to prevent contamination of runoff water. Turf acts as a filter, but the materials left on impervious surfaces go directly into storm sewers or ditches and eventually into the water supply. Monitoring of rivers in the Atlanta area has shown a sharp increase in the levels of pesticides and fertilizers used in turfgrass management during the busy spring-early summer lawn care season.

Rules of Thumb for Weed Control in Ornamentals

1. When confronted with difficult-to-control perennial weeds, consider the herbicide tolerance of the ornamentals to be planted. Plant yellow nutsedge infested sites with ornamentals that tolerate Pennant or allow post-directed applications of Roundup, Manage or Basagran.
2. Make the minimum preplant weed control procedure one application of Roundup at least two weeks before planting. If possible, plan one year ahead. For tough perennials such as bermudagrass, it is best to spend an entire growing season making repeat applications to get complete control. Use a 2% solution of Roundup Pro (2 2/3 oz per gallon) or broadcast 3 quarts per acre.
3. Apply grass-specific herbicides such as Fusilade, Vantage and Envoy to seedling annual grasses (2 to 5 leaves) during good growing conditions. Mature grasses are much more difficult to control. Consult the label for the proper growth stage to treat perennial grasses. Grass specific herbicides only affect true grasses, not other monocots such as monkey grass, liriop, lilies and iris.
4. Apply and water-in preemergence herbicides with 0.25 to 0.5 inch of rainfall or irrigation as soon as possible after planting. Remember that weed seeds will often germinate within a few days of tillage or a burn-down herbicide application.
5. If possible, combine preemergence grass and broadleaf herbicides to broaden the spectrum of weed control. An example would be using a premix such as Snapshot or tank mixing Gallery and Surflan or Barricade or Pendulum.
6. Use a funnel or some other shield when applying non-selective herbicides such as Roundup or Finale. The top of a 2-liter soft drink bottle makes an acceptable funnel to attach to the end of a spray wand.
7. Do not allow weeds in landscape beds to produce seeds. The old saying, "One year's seeding – seven year's weeding," is pretty accurate.
8. Do not apply granular herbicides to ornamentals when the foliage is wet.
9. Delay irrigation following application of postemergence herbicides according to the label.
10. Repeat preemergence herbicide applications on an 8- to 12-week interval or two to four times per season depending on weed pressure and environmental conditions.
11. Bear in mind that there is no really good postemergence, selective herbicide available for broadleaf weed control over the top of ornamentals.
12. Use Roundup as a wipe-on if possible.
13. When spraying over the top of ornamentals with grass herbicides such as Vantage, Fusilade II and Envoy, use a nonionic surfactant rather than crop oil concentrate.

14. Avoid applying postemergence herbicides when temperatures are over 90°F.
15. Don't cultivate for 5-7 days before and after applying a translocated or systemic herbicide such as Roundup.
16. Do not tank mix Roundup with contact herbicides such as Reward or Finale. They destroy the plant tissue before the Roundup has a chance to translocate through the weed.
17. Nutsedge will not be eradicated by repeat applications of Roundup. It will come back. Roundup does not translocate to the nutsedge tubers. Roundup is more effective than Finale or Reward on nutsedge and other perennials.
18. Cover outdoor soil and mulch piles to prevent weed seed contamination.
19. Keep cultivation for weed control very shallow. Cultivation may bring new weed seeds to the surface, scatter root, rhizomes, tubers, etc., of perennial weeds or damage roots of ornamentals.
20. Cut woody sprouts in landscape beds with pruning shears and treat the cut end with undiluted Roundup or a 50% triclopyr + water solution to prevent resprouting.
21. Seal the soil around newly transplanted ornamentals with irrigation before applying soil-active herbicides.
22. Install edging that is wide enough for a mower wheel to ride. This will eliminate scalping and leaving an un-mowed band of grass.
23. Contact herbicides such as Finale will create a straighter line than a systemic herbicide such as Roundup when edging bermudagrass or other stoloniferous grasses. However, bermudagrass will recover faster from the Finale application. Cutting bermudagrass runners that have rooted in a bed before spraying them will prevent translocation back to the mother plant.
24. Use an even flat fan tip for edging to ensure uniform application across the spray pattern.
25. Use granular formulations of preemergence herbicides for greater crop safety.

Turfgrass Weed Control

Introduction

If there were no humans there wouldn't be any weeds. There are no weeds in nature. Good or bad, we decide which plants are weeds. Opinions as to what is a weed vary widely. Divergent viewpoints on this matter have given rise to the observation that one person's weed is another's wildflower.

Typically, a weed is a plant growing where someone doesn't want it. Violets may be desirable in an ornamental bed but are often considered a weed when growing in a lawn. Bermudagrass in a pure stand is a turfgrass but is considered a weed when growing in a zoysiagrass turf. Turfgrass weed control is usually concerned with maintaining the uniformity of the stand. But there are other reasons to control turfgrass weeds: competition with turfgrass, hard-to-mow plants, spiny plants and that clump of goosegrass that ruins your birdie putt on No. 17.

Sources of Turfgrass Weeds

Most turfgrass weeds result from seeds found in the soil. The number of weed seeds in the soil seed bank varies widely. Documented counts of viable seed from one square yard and a 10-inch depth range from a low of 250 to a high of 130,000. The old saying, "One year's seeding – seven year's weeding," is pretty accurate. Some seeds may remain inactive for several years and then emerge under favorable temperature, light and moisture conditions. These weeds generally germinate and mature when bare spots develop or if the soil is disturbed. Topsoils, manures and composts usually contain an abundance of weed seed. A new crop of weeds can be expected whenever these amendments are used.

Weed seeds may be transported from place to place by a variety of methods. Dandelion seeds are carried many miles by the wind. The tacky seeds of plantain are transported by clothing, equipment and animals. Ripe seedpods of yellow wood sorrel can explode and throw their seeds many feet. Moving weeds on sod is a common means of introducing weeds. Turfgrass managers should inspect sod prior to purchase to make sure it is free of problem weeds. Three difficult-to-control weeds that are commonly moved with sod are bermudagrass, Virginia buttonweed and nutsedge. The introduction of weeds from ornamental plantings is also common. Ornamental containers are an excellent way to transport weeds over long distances. Chamberbitter made its way to Arkansas in container ornamentals. Other species such as yellow nutsedge, oxalis and bittercress are commonly found in containers.

Reasons for Weed Invasion

Weed invasion is often the result of weakened turf rather than being the cause of it. Weed encroachment occurs in bare spots or areas of thin turf. There are a multitude of reasons for weak turfgrass including: (1) turf species not adapted to the environmental conditions; (2) damage from turfgrass pests such as insects, diseases, nematodes and animals; (3) environmental stresses such as excessive shade, drought, heat and cold; (4) poor turf management practices such as misuse of chemicals and fertilizer, improper mowing height, frequency and incorrect soil aeration; and (5) physical damage and compaction from concentrated traffic. Unless these fundamental causes of weed problems are corrected, weed invasion will continue. The presence of certain weed species may be an indicator of specific environmental conditions.

Weeds as Indicators of Specific Conditions

Condition	Indicator Weed(s)
Low pH	red sorrel
Soil compaction	goosegrass, knotweed, <i>Poa annua</i> , path rush
Low nitrogen	legumes: clover, lespedeza
Poor (sandy) soils	sandbur, poorjoe
Poor drainage	sedges, rushes
Surface moisture	algae
High pH	plantains
High nematode populations	prostrate spurge, knotweed
Low mowing	algae

Developing a Weed Control Program

There are several important considerations when developing a weed control program.

1. Know what kinds of turfgrass you have and the total area of each different type.
2. Identify the problem weeds and note what time of the year they occur.
3. Determine why the weeds invaded the turf area, and correct the conditions or cultural practices that caused the problem.
4. When an herbicide is needed:
 - Select a chemical that is effective for the weeds and safe for the turfgrass.
 - Follow all label directions.
 - Apply the herbicide at the correct time and rate.
 - Apply the herbicide uniformly over the turf area without skips or overlapping.
 - Repeat the herbicide application when specified on the label.
5. Follow a good turf management program along with the weed control program. An integrated approach that includes enhancing turfgrass competition, mechanical control and chemical control methods will be the most successful weed control program.

Weed Identification Is a Fundamental Skill

The importance of weed identification skills is obvious. It is impossible to look for control information until the weed has been identified. The ability to identify weeds is important from more than a control standpoint. Often, the first question a client is going to ask is, "What is that weed?" So, weed identification is also useful in establishing your credibility as a professional.

Weed identification should begin with classifying weeds by type. The four most common weed types are grasses, broadleaves, sedges and rushes.

Grasses are a monocotyledonous plant, which means they have only one seed cotyledon (leaf) present when a grass seedling emerges from the soil. Grasses have joints (nodes) and hollow, rounded stems. The true leaves (as opposed to seed or cotyledon leaves) have parallel veins and are several times longer than they are wide. Crabgrass, goosegrass, dallisgrass and annual bluegrass are typical grass weeds found in turf.

Broadleaf weeds are dicotyledonous, which means they have two cotyledons at emergence and have net-like veins in their true leaves. Broadleaves often have colorful flowers compared to the inconspicuous flowers found on grasses. Chickweed, henbit, lespedeza, clover, dandelion and dock are typical broadleaf weeds.

Sedges have solid, triangular stems (in most species) which bear leaves extending in three directions (3-ranked). Sedges lack ligules and auricles, and the leaf sheath is continuous around the stem. Yellow and purple nutsedge, rice flatsedge and globe sedge are examples.

Rushes have round, solid stems and favor a moist habitat. Path rush is an example of the rush family. Path rush is often found on golf cart routes, sports fields and other compacted areas.

Not all turfgrass weeds fall into these categories. Some turfgrass weeds are monocotyledonous plants but are not sedges or grasses. Some examples are wild garlic, false garlic and star-of-Bethlehem, which are members of the **lily family**.

Weed Life Cycles

The previously listed weed classifications may be further divided into annuals, biennials and perennials. **Annuals** germinate from seed, grow, mature and die in less than 12 months. Annuals may be further classified as winter and summer annuals. **Winter annuals** germinate in the fall, grow during cool periods, mature in the spring and then die during the summer. **Summer annuals** germinate in the spring, grow actively during the summer and die in the fall. Crabgrass and goosegrass are examples of summer annual grasses. Annual bluegrass is our most common winter annual grass weed in turf. Prostrate knotweed is an example of a summer annual broadleaf, while henbit and chickweed are representative of winter annual broadleaves.

Biennials reproduce from seed and complete their life cycle in two years. Biennials form rosettes and store food in their fleshy roots the first year and then flower the second year. Many thistle species in Arkansas are biennials.

Perennial weeds live more than two years. Perennials may reproduce from seed or from vegetative structures such as roots, rhizomes, stolons, tubers or bulbs. The ability to reproduce vegetatively makes perennials more difficult to control. Some perennials such as dandelion, dock and wild garlic are actively growing during cool weather, while others like dallisgrass and nutsedge grow rapidly during the summer months. Perennials

are further subdivided as simple perennials and creeping perennials. **Simple perennials**, such as dock and dandelion, overwinter by means of a vegetative structure such as a perennial root with a crown, but they reproduce almost entirely by seed. **Creeping perennials** can both overwinter and produce new independent plants from vegetative reproductive structures. Vegetative reproductive structures include creeping roots, stolons (bermudagrass), rhizomes (johnsongrass), tubers (nutsedge) and bulbs (wild garlic). Most perennials can also reproduce from seeds.

If you are serious about turfgrass weed control, a guide to weed identification is a very useful tool. Some recommended publications may be found in the section "Selected Weed ID References."

Principles of Herbicide Use

Before selecting any herbicide, determine whether or not the desirable turfgrass is tolerant of the chemical being considered. The majority of turfgrass herbicide failures result not from the weakness of the herbicide but from: (1) choosing the wrong herbicide, (2) applying at the wrong time, (3) treating a turfgrass species that is susceptible to the herbicide, (4) poor calibration, (5) lack of uniform application, (6) unsuitable application equipment, (7) insufficient agitation, (8) wrong growth stage of the target weed and (9) undesirable environmental conditions at the time of application.

Herbicides

Herbicide Names

Herbicide labels contain three names: trade name, common name and chemical name. The nomenclature for Roundup Pro would be: **Trade Name:** Roundup Pro, **Common Name:** glyphosate **Chemical Name:** N-(phosphonomethyl)glycine. The trade name is used by the chemical company to market the product and is often the most recognizable name. The common name is a generic name that is given to a specific chemical. Only one common name exists for each herbicide. It is useful to be familiar with common names when comparing products. The chemical name describes the

chemistry of the herbicide. To make things confusing, the same or different chemical companies often sell the same herbicide under different trade names. For example, DuPont markets metsulfuron for pasture use as Cimarron and for forestry use as Escort. Metsulfuron is sold for use in turfgrass by Riverdale as Manor and by PBI Gordon as Blade.

Herbicide Terminology

Selective. A selective herbicide controls or suppresses some plant species without seriously affecting the growth of another plant species. Selectivity may be due to differential absorption, translocation, morphological and/or physiological differences between turfgrasses and weeds. Most turfgrass herbicides are selective. 2,4-D is an example of a selective herbicide that controls many broadleaf weeds without causing significant injury to grasses. Selective is a relative term that depends on many factors that include herbicide rate, environmental conditions, timing of application and the desirable species and variety being treated.

Non-selective. Non-selective herbicides control or suppress plants regardless of species. Glyphosate (Roundup), glufosinate (Finale) and diquat (Reward) are examples of non-selective herbicides. These products are often used for trimming along sidewalks and fences and as preplant treatments when renovating or establishing turfgrass. It is important to note that the selectivity of some herbicides is based on rate. Increasing the rate of a selective herbicide such as atrazine will move it into the non-selective category.

Mode of Action refers to the sequence of events that includes herbicide absorption, translocation to the site(s) of action, inhibition of a specific biochemical reaction, the degradation or breakdown of the herbicide in the plant and the effect of the herbicide on plant growth and structure.

Herbicide Movement in the Plant

Systemic (sometimes referred to as translocated) herbicides are extensively translocated in the vascular system of the plant. The vascular system consists of the xylem and phloem. The xylem transports water and various nutrients in solution, upward from the roots where they entered

the plant, through the stems, and into leaves, flowers and fruits. The phloem conducts food materials from their principal sites of synthesis in leaves to other locations, such as fruits and developing roots, for storage and use. Systemic herbicides are slower acting than contact herbicides because they require from several days to a few weeks to move throughout the vascular system of a treated plant. Systemic herbicides may be selective or non-selective. Glyphosate (Roundup) is an example of a non-selective systemic herbicide, while 2,4-D, dicamba (Vanquish), imazaquin (Image) and sethoxydim (Vantage) are examples of selective systemic herbicides.

Contact herbicides affect only the green plant tissue that comes in contact with the herbicide spray. Thus, thorough coverage of the weed foliage is needed to achieve optimum control. These herbicides are either not translocated or only move to a limited extent, within the vascular system of plants. For this reason, underground vegetative reproductive structures such as roots, rhizomes and tubers are not affected. Multiple applications of contact herbicides are needed for long-term control because plants regrow from these unaffected plant parts. Contact herbicides are fast acting. Symptoms are often visible within a few hours of application. Bromoxynil (Buctril) and bentazon (Basagran T/O) are selective contact herbicides. Diquat (Reward) and glufosinate (Finale) are non-selective contact herbicides.

Herbicide Resistance

A number of weed species that were once susceptible and easily managed by certain herbicides have developed resistance. These weeds are no longer controlled by applications of previously effective herbicides. Herbicide resistance probably develops through the selection of naturally occurring biotypes of weeds exposed to a family of herbicides over several years. A biotype is a population of plants within the same species that has specific traits in common. Resistant biotypes may have slight biochemical differences from their susceptible counterparts that eliminate sensitivity to certain herbicides. Resistant plants survive, go to seed and create new generations of herbicide-resistant weeds.

While most cases of resistance have appeared in agronomic crops, dinitroaniline-resistant goosegrass has been documented in

turfgrass. However, these plants are susceptible to other goosegrass herbicides such as Ronstar, Illoxan and MSMA + metribuzin. Experience has shown that the potential for developing resistance is greatest when an herbicide has a single site of action. Arkansas now has Illoxan- and Oust-resistant ryegrass. Australia has Roundup-resistant ryegrass. Other southern states have documented simazine tolerance in annual bluegrass.

Regardless of the mechanism for resistance, becoming familiar with the herbicide mode of action can help turf managers design programs that prevent the introduction and spread of herbicide-resistant weeds. Management programs for herbicide resistance should emphasize an integrated approach that stresses prevention. Dependence on a single strategy or herbicide family for managing weeds will surely increase the likelihood of additional herbicide resistance problems.

Some strategies for managing resistance include:

1. Rotating herbicides having different modes of action.
2. Using tank mixtures of herbicides having different modes of action.
3. Avoiding sequential application (year after year) of the same herbicides or herbicides having the same mode of action.
4. Controlling weedy escapes in border areas and ditch banks.
5. Practicing good sanitation to prevent the spread of resistant weeds.
6. Integrating cultural, mechanical and chemical weed control methods.

Herbicide Formulations

The two big groups of herbicide formulations are dry and liquid. The amount of active ingredient in a dry formulation is designated as a percent of the weight. The active ingredient in liquid forms is listed in pounds per gallon. Within the dry formulations there are granular or pelletized herbicides that are spread directly on the target in their dry form. These products usually contain very low percentage of active ingredient (0.1% to 2.0%) and are designated by the abbreviation **G** or **GR** (granule) or **P** (pellet). Other dry formulations are mixed with water and sprayed on the target. These products are designated as **SP** (soluble powder), **W** or **WP** (wetable powder), **WSP** (water soluble packet), **DF** (dry flowable), **SG** (soluble granule) or **WG**, **DG** or **WDG** (water dispersible granule). Liquid formulation designations include **L** or **F** (liquid suspension), **E** or **EC** (emulsifiable concentrate), **SC** (suspension concentrate), **SL** (soluble liquid), **ME** (micro-encapsulated) and **CS** (capsule suspension).

Some herbicide formulations may be incompatible. MSMA and 2,4-D amine will sometimes form sludge when mixed. Liquid nitrogen and 2,4-D amine will always form sludge when mixed. One way to avoid a big mess is to combine a small amount of each herbicide in a jar with water, shake and see what happens. In addition to physical incompatibility, two herbicides may mix well but may be chemically incompatible resulting in a reduction in herbicidal activity. For example, mixing 2,4-D with Fusilade, Vantage or other grass specific herbicides will result in decreased grass control. This is referred to as antagonism. The label will give instructions on what can and cannot be

Examples of Turfgrass Herbicides Having the Same Mode of Action			
ALS Inhibitors	Lipid Synthesis Inhibitors	Mitotic Inhibitors	Photosynthetic Inhibitors
Image Manage Manor Corsair Revolver	Illoxan Vantage Acclaim Fusilade	Balan Surflan Barricade Lesco Pre-M Pendulum XL Team Dimension	Princep Aatrex Sencor

mixed with that herbicide. When tank mixing different formulations: (1) fill the tank 2/3 full of water, (2) start the agitation and keep it running and (3) add the respective formulations in this order: wettable powders > dry flowables > liquid suspensions > emulsifiable concentrates > soluble concentrates.

Herbicide Spray Additives and Their Uses

Adjuvant: Any additive used with an herbicide that enhances the performance or handling of the herbicide.

Compatibility agent: A material that allows the mixing or improves the suspension of two or more formulations when applied together as a tank mix. Compatibility agents are used most frequently when a liquid fertilizer is the carrier solution for an herbicide.

Crop oil concentrate: Oil-based material that enhances herbicide penetration through the leaf cuticle.

Defoamer: A material that eliminates or suppresses foam in the spray tank so that pumps and nozzles can operate correctly.

Drift control agent: A material used in liquid spray mixtures to reduce spray drift.

Fertilizer: Certain fertilizers added to the spray tank can enhance penetration of the herbicide into the leaf.

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

Wetting agent: A material that reduces interfacial tensions between water droplets and the leaf cuticle.

Using Charcoal (Activated Carbon) to Deactivate Herbicides

Plan ahead. Have a supply of activated charcoal on hand. Timing is critical when dealing with herbicide accidents. The rate range for using activated charcoal is 100 to 400 lbs/a (2.3 to

9.2 lbs/1,000 sq ft). For herbicide spills it is necessary to incorporate the charcoal into the contaminated soil, preferably to a depth of 6 inches. To be effective, charcoal must come in contact with the herbicide. The rule of thumb is to apply 200 lbs/a (4.6 lb/1,000 sq ft) charcoal for each pound of herbicide active ingredient per acre. In case of a severe spill, it may be necessary to remove the contaminated soil.

Applying charcoal can be a huge mess. If possible, avoid trying to apply the dry form because it is easily moved by wind. Look for a liquid charcoal product such as **52 Pickup**. Use a sprinkling can for small areas. For larger applications a power sprayer is more convenient. Use tips with a large opening and remove the nozzle screens to avoid clogging. We use Spraying Systems 8008 or 8010 flat fans or a Boom Buster tip. If mixing dry charcoal with water, adding 0.5% nonionic surfactant will help the charcoal go into solution. Fill the tank half-full of water and start the agitation. Add the charcoal and the remainder of the water. The target dilution is 1 to 2 lbs of charcoal per gallon of water. Afterward, clean the sprayer, pump and lines thoroughly because charcoal is very abrasive.

To deactivate an herbicide that is still on the soil surface following an accidental application, apply charcoal slurry at 2 to 4 lbs/1,000 sq ft. Water the slurry into the soil. Use enough water to remove the charcoal from the grass blades. Raking the charcoal into the soil will improve results. The area may be seeded 24 hours after treatment. However, if the herbicide has been moved into the soil by rainfall or irrigation, surface application of charcoal will not be very effective. Charcoal will not leach into the soil.

Timing of Application

Herbicides are also classified by when the chemical is applied relative to turfgrass and/or weed seed germination. The majority of herbicides may be classified into one of three timing categories: preplant, preemergence or postemergence. However, atrazine (Aatrex), simazine (Princep), dithiopyr (Dimension) and pronamide (Kerb) are exceptions. They are used as preemergence and postemergence herbicides.

Preplant Herbicides

These herbicides are applied before turfgrass is established to make the site as weed-free as possible. Glyphosate (Roundup) is often used as a preplant herbicide. On high-value sites, such as putting greens, soil fumigants such as methyl bromide, metam-sodium or dazomet are used as preplant herbicides.

Preemergence Herbicides

Preemergence herbicides are the foundation of a turfgrass weed management program. Preemergence herbicides are applied to the site before weed seed germination. After being activated by rainfall or irrigation, these herbicides form an herbicide barrier at or just below the soil surface. When the roots or shoots of germinating seeds come in contact with the herbicide barrier, their growth is inhibited. Most preemergence herbicides are cell division inhibitors affecting the emerging root and shoot, which are sites of rapid cell division. Weeds that have already emerged (visible) are not consistently controlled because their growing point has escaped contact with the herbicide. The primary target of preemergence herbicides is annual grass, but some small-seeded annual broadleaves will be controlled.

Major Preemergence Crabgrass and Goosegrass Herbicides

A variety of factors affect the performance of preemergence herbicides. These include timing of application in relation to weed seed germination, soil type, environmental conditions (primarily temperature and rainfall), target weed species and biotype, and cultural factors (core aeration, for example) that follow application.

All of the products listed in the table below are characterized by long soil persistence, low water solubility and strong adsorption to organic matter. As a result, when they are applied to turfgrasses and activated by water, a very thin herbicide barrier is formed. As the weeds start to germinate, the young seedling comes into contact with the herbicide, absorbs the herbicide and the young seedling dies. It is therefore very important to apply the herbicide and water it in prior to seed germination if maximum results are to be obtained. Activation of pre-emergence herbicides requires 0.25 to 0.5 inch of rainfall or irrigation. For optimum performance, rainfall or irrigation should occur within 24 hours of application to move the herbicides into the upper layer of the soil. The critical period between application and activation by rainfall or irrigation varies with herbicide, rate and environmental conditions.

Ideally, preemergence herbicides should be applied just before weed seed germination begins. Applying too early may result in reduced control or no control due to leaching and/or normal herbicide degradation. However, there is a good deal of research that indicates preemergence summer annual grass control applications may be made as early as January. The reason this works is that

Trade Name(s)	Common Name	Family	Mode of Action
Barricade	Prodiamine	Dinitroaniline	Mitotic inhibitor
Pendulum, Pre-M	Pendimethalin	Dinitroaniline	Mitotic inhibitor
Surflan	Oryzalin	Dinitroaniline	Mitotic inhibitor
Team Pro	Trifluralin + benefin	Dinitroaniline	Mitotic inhibitor
XL	Oryzalin + benefin	Dinitroaniline	Mitotic inhibitor
Dimension	Dithiopyr	Pyridine	Mitotic inhibitor
Ronstar	Oxadiazon	Oxadiazole	Disrupts cell wall synthesis

during cool weather the rate of herbicide degradation is slow and most of the preemergence grass herbicides do not leach readily. Applying early (January-February) is often a must for lawn care companies because a period of several weeks is required to service all of their customers. Preemergence herbicides must be in place and activated before weed seed germination begins.

Crabgrass germinates in the spring (late March-April) when soil temperature at the 4-inch depth reaches 53° to 58°F. Alternating wet and dry conditions at the soil surface as well as light encourages crabgrass germination. Goosegrass germinates at soil temperatures of 60° to 65°F. Goosegrass also requires light for germination and is very competitive in compacted, heavy traffic areas with thin turf. Because warmer temperatures are required, goosegrass typically germinates about two to four weeks later than crabgrass. Thus, when targeting goosegrass only, it is a mistake to apply preemergence herbicides at the crabgrass timing. Apply preemergence herbicides for goosegrass control two to three weeks later than the crabgrass application date.

Sequential or Repeat Applications

In warm weather, herbicides begin to degrade soon after application eventually reaching a level at which weed seed germination can occur. Preemergence herbicides will degrade to the point of ineffectiveness from 6 to 16 weeks after application. For this reason, repeat or sequential applications are needed for full season control.

Core Aerification and Preemergence Herbicides

For years it was assumed that core aerification would disrupt the herbicide barrier in the soil and result in weed seed germination. However, research has shown that core aerification of 'Tifgreen' and common bermudagrass did not stimulate crabgrass germination when done immediately before application and one, two, three or four months after treatment. An exception to this occurred with creeping bentgrass where greater amounts of

crabgrass occurred where cores were returned compared to sites not aerified or aerified with the cores removed.

The most common reason for disruptions in the herbicide barrier is due to lack of uniform herbicide application. Poor application of a spray or a granular product can lead to large untreated areas that result in weed outbreaks. Poorly formulated granular products may prevent uniform distribution of the herbicide. The two most common problems with granular herbicides are excessively large particle size or a lack of uniform particle size. Big particles result in fewer particles per square foot and thus less coverage. A mixture of many particle sizes will prevent uniform distribution because heavy particles will behave differently than light particles when they drop on the spreader rotor. The data in the table below illustrates this point. Two experimental formulations of Barricade were compared to the spray formulation. The most concentrated granular product, the 0.5% granular formulation, resulted in fewer particles per square foot compared to the more dilute 0.29% formulation. Note that the 0.29G outperformed the 0.5G. This was due to incomplete coverage by the 0.5G. Remember that most of the preemergence herbicides are largely immobile in the soil.

Preemergence Control of Smooth Crabgrass with Various Barricade Formulations

Barricade Formulation	Rate: lbs ai/ac	% Control
Barricade 65 WDG	0.75	98
Barricade 0.5 G	0.75	81
Barricade 0.29 G	0.75	91
LSD 0.05		9.3
Applied March 4, 1996, rated September 26, 1996.		

Other Preemergence Considerations

The majority of preemergence herbicides (dinitroanilines often referred to as DNAs) used in turfgrass weed control are mitotic inhibitors that interfere with cell division. These materials are intended for use on established stands of grass. Plan ahead when using preemergence herbicides, and do not treat areas where new turfgrass is to be established. The same precaution applies to established turf that is to be overseeded. Examples include tall fescue lawns that are to be overseeded in the fall and warm-season grasses that are to be overseeded with a cool-season grass. The waiting period before planting is typically two to four months. There are exceptions to this rule when the objective is *Poa annua* control in overseeded ryegrass. Planting too soon following a preemergence treatment may result in reduced germination of seeds or root inhibition of sod, sprigs or plugs. Dimension is in a different herbicide family (Pyridines) but has the same root-inhibiting mode of action as the dinitroanilines.

In heavily trafficked areas, bare spots or thin stands, it is often wise to skip applications of pre-emergence herbicides that are mitotic inhibitors until the grass has recovered. Ronstar (oxadiazon), which is not a mitotic inhibitor, is a good choice for preemergence control of annual grasses on high traffic sites such as par 3 tees. This is why Ronstar is the preemergence herbicide of choice for weed control when sprigging. In tolerant grasses, MSMA is a postemergence alternative for these situations. The disadvantage is temporary turfgrass injury from MSMA.

Preemergence Herbicide Use

Recommended dates of application for control of crabgrass and other summer annual grasses are February 15 - March 5 for southern Arkansas and March 1 - 20 in northern Arkansas. Goosegrass usually germinates about two weeks later than crabgrass. Apply preemergence herbicides for annual bluegrass control on September 1. Herbicides such as atrazine (Aatrex) and simazine (Princep) may be applied in November or December because they will control small annual bluegrass postemergence.

A good window to shoot for when using simazine for winter weed control is the period between Thanksgiving and Christmas. Preemergence herbicides should be watered-in immediately after application. Herbicide-only formulations have been the standard for many years, but the practice of impregnating herbicides on dry fertilizer granules is becoming increasingly popular. Common sense suggests that choosing a fertilizer carrier with relatively uniform particle size will improve the uniformity of herbicide distribution. Another factor to consider when using herbicide + fertilizer products for summer annual grass control is that warm-season grasses are dormant at the time of the first application so much of the fertilizer will be wasted. These products are better used for the second application in May or June when warm-season grasses can use nitrogen fertilizer. When using fertilizer/herbicide combinations, consider whether or not the herbicide/nutrient ratio is right for the turfgrass and the environmental conditions.

Postemergence Herbicides

Postemergence herbicides are intended for use on weeds that have germinated and are visible. They are applied directly to emerged weeds. In contrast to preemergence herbicides, most postemergence herbicides have little or no soil activity. It is possible to conduct a total postemergence weed control program in turfgrass provided multiple applications are used throughout the year. The primary advantage of total postemergence control is that it is possible to wait and see if weeds emerge and thus whether it is necessary to treat. Disadvantages of total postemergence weed control include the need for frequent applications and, in some cases, temporary turfgrass injury. Most turfgrass managers use a combination of preemergence and post-emergence herbicides. Preemergence herbicides form the basis of most programs with post-emergence herbicides used to control weeds that escape the preemergence treatments. Established perennial weeds, both grasses and broadleaves (dallisgrass, nutsedge, Virginia buttonweed, white clover, plantain) must be controlled with post-emergence herbicides. Some postemergence herbicides may be used on newly established grasses.

General guidelines for postemergence applications are small weeds, good soil moisture and air temperatures between 60° and 90°F. Postemergence herbicides applied at temperatures below 60°F are often effective; however, more time is required for the herbicide to kill the weeds. Annual weeds that are small (two- to four-leaf stage) and actively growing are much easier to control with postemergence herbicides. Control is improved at this stage because young weeds readily absorb and translocate herbicides. Early weed control accompanied by fertilization also provides an opportunity for stoloniferous turfgrasses (bermudagrass, centipedegrass, St. Augustinegrass, zoysiagrass) to fill in the bare areas left by removing the weeds.

Weeds that are stressed due to dry weather, heat or other environmental factors (dust-covered leaves) are more difficult to control with post-emergence herbicides. Applying herbicides such as MSMA, DSMA, 2,4-D, mecoprop, dichlorprop and dicamba at temperatures above 90°F increases the risk of turfgrass injury.

The resistance of postemergence herbicides to wash-off by rainfall or irrigation varies among products. Typically, a rain-free period of 6 to 24 hours is sufficient to avoid a reduction in effectiveness. Even if rain falls soon after application, some degree of reduced control will be achieved.

Mowing can affect performance of post-emergence herbicides. Avoid mowing one to two days before application to allow development of greater leaf area to intercept the spray. Delay mowing one to two days after spraying to provide time for the herbicide to be absorbed and translocated.

Follow the label when using surfactants and crop oil concentrates with postemergence herbicides. Do not add surfactants that are not required because the result may be increased turfgrass injury. In situations where there is good soil moisture, warm temperatures and high humidity, the benefits of surfactants may not be obvious.

However, under marginal environmental conditions, failure to use the proper additive may result in reduced weed control.

Rather than a single rate, a range of post-emergence herbicide rates for a product usually is given. Repeat applications of a moderate rate are generally more effective than a single application of the higher rate. The follow-up application is timed to be 7 to 14 days after the first or when regrowth appears. For example, for bermudagrass control it is much more effective to apply Roundup three times at 2 qts/a (waiting for regrowth between each application) compared to applying one time at 6 qts/a.

If possible, avoid using postemergence herbicides during the spring green-up or transition period of warm-season turfgrasses. It is preferable to treat either completely dormant or actively growing grasses. Applying products such as Confront and to a lesser extent Trimec will cause yellowing and stunting of bermudagrass and zoysiagrass that is in transition.

Broadleaf Weed Control

Phenoxy (2,4-D, dichlorprop, MCPA, mecoprop) and benzoic acid (dicamba) herbicides have traditionally been the backbone of broadleaf weed control programs in turfgrass. These are selective, postemergence, foliar-applied herbicides. Rarely applied alone, these materials are typically used in two- and three-way combinations to broaden the spectrum of control. For perennials and tough annuals, repeat applications of these combination products 10 to 14 days apart are often needed for acceptable weed control. Overseeded ryegrass needs to be mowed three to four times before treatment with three-way phenoxy herbicides.

Over the last few years, some alternatives to the phenoxy herbicides for broadleaf weed control have been labeled for use in turfgrass. Triclopyr (Turflon II, Turflon Ester, others) and clopyralid (Lontrel) are now commonly used alone and in combination for postemergence broadleaf weed control. Triclopyr is a good alternative to try when the traditional three-way products (2,4-D + dicamba + MCPA) do not provide control. Triclopyr and clopyralid belong to the carboxylic or picolinic acid family of herbicides and produce symptoms very similar to the phenoxy herbicides. Clopyralid

has very good turf safety on cool- and warm-season grasses but has a narrow range of control limited to the sunflower (Asteraceae) and legume (Fabaceae) families. Clopyralid is excellent on white clover and other legumes, thistles and other members of the Asteraceae. Confront (triclopyr + clopyralid) has a broader spectrum and is useful on hard-to-control broadleaves. Care must be taken to avoid overdosing when using triclopyr on warm-season grasses. In fact, Turflon Ester (triclopyr ester) is labeled for suppression of bermudagrass in cool-season turfgrasses.

Metsulfuron (Manor, Blade) is a member of the sulfonyleurea family of herbicides. It is an effective product for controlling many species of broadleaf weeds in bermudagrass, zoysiagrass, St. Augustinegrass and centipedegrass. Chlorsulfuron (Corsair) is also a member of the sulfonyleurea family of herbicides. Corsair controls some broadleaf weeds but does not have the broad control spectrum of metsulfuron.

Grass Control in Bermudagrass and Zoysiagrass

The organic arsenicals (MSMA, DSMA, CMA) have been the standard for postemergence grass weed control in tolerant turfgrass species for many years. Two to four applications spaced 7 to 10 days apart are generally needed for satisfactory control. The rate and number of applications generally increase as weeds mature. Control is also reduced if rainfall or irrigation occurs within 24 hours of treatment.

Alternatives to MSMA have appeared in the marketplace over the past few years. The following section describes postemergence grass herbicides suitable for use on various turfgrass species.

MSMA has been the primary herbicide for postemergence control of crabgrass. Repeat applications with a short time interval between applications are required for control of mature crabgrass. MSMA is not effective for goosegrass or tufted lovegrass control. Dallisgrass control requires five applications of MSMA at weekly intervals. This treatment

is limited to use on bermudagrass. Tank mixing low rates of Sencor (metribuzin) with MSMA improves goosegrass control in bermudagrass. Adding metribuzin to MSMA also increases bermudagrass injury, but the bermudagrass will recover quickly under good growing conditions. Do not use Sencor on zoysiagrass. MSMA + metribuzin should be limited to established, actively growing bermudagrass that is being maintained at a mowing height of 0.5 inch or greater.

Drive (quinclorac) is an effective herbicide for control of crabgrass, barnyardgrass and broadleaf signalgrass in bermudagrass and zoysiagrass. Do not use Drive on centipedegrass or St. Augustinegrass. Drive also controls some broadleaf weeds such as white clover and dandelion. It may be tank mixed with MSMA to improve the spectrum of control. Drive will not control goosegrass. Drive is much safer for crabgrass control in cool-season grasses than MSMA.

Diclofop (Illoxan) has shown excellent goosegrass control under the right conditions. Illoxan causes little turfgrass injury, and re-treatment is usually not needed. This herbicide is more effective on younger, lower-mowed goosegrass (0.5 inch less mowing height). It is a slow-acting herbicide usually requiring two to three weeks for control. Illoxan has little effect on other turfgrass weeds. Treated areas should not be overseeded with ryegrass for six weeks following application. Do not tank mix Illoxan with other pesticides.

Fenoxaprop (Acclaim Extra) will control crabgrass in zoysiagrass and tall fescue. The crabgrass should be treated while it is very small (less than 4 leaf). Acclaim Extra may also be used for bermudagrass suppression in zoysiagrass and tall fescue. Three to four applications of Acclaim Extra per year over a two-year period are needed to provide significant bermudagrass suppression. Eradicating bermudagrass from zoysiagrass with Acclaim Extra requires a long-term effort.

Sethoxydim (Vantage) is approved for use in centipedegrass. Apply Vantage to centipedegrass to

control annual grasses and suppress bermudagrass and bahiagrass. Do not make more than two applications per season. Clethodim (Envoy, Select) is also safe to use on centipedegrass but is not currently labeled in Arkansas.

Fluazifop (Fusilade II) may be used on tall fescue (3 to 6 fl oz/a) and zoysiagrass (3 to 5 fl oz/a) to suppress bermudagrass and control annual grass weeds. Eradicating bermudagrass from zoysiagrass with Fusilade II is a difficult proposition that requires persistence.

Ethofumesate (Prograss) has been approved for bermudagrass suppression in St. Augustinegrass. Research indicates that tank mixing with atrazine and using multiple applications will improve the level of control.

Tranxit (rimsulfuron) may be used on zoysiagrass and bermudagrass for control of cool-season grasses such as annual bluegrass, rough bluegrass, perennial ryegrass and tall fescue. It is not for use on residential lawns. Tranxit may be used on bermudagrass that has begun to green up. Do not apply to slopes that drain onto cool-season grasses such as bentgrass greens or ryegrass overseedings.

Revolver (foramsulfuron) may be used on zoysiagrass and bermudagrass for control of cool-season grasses such as annual bluegrass, rough bluegrass, perennial ryegrass and tall fescue. Use only on sod farms and golf courses. Revolver provides some control of goosegrass and dallisgrass, but the research data is insufficient at this time. Revolver may be used on bermudagrass that has begun to green up. Do not apply to slopes draining onto cool-season grasses such as bentgrass greens or ryegrass overseedings.

Kerb (pronamide) is used for annual bluegrass control in bermudagrass and for aiding in transition of bermudagrass overseeded with ryegrass. It has both pre and postemergence activity but works very slow taking up to six weeks for control. Kerb should be watered in after application. Manor (metsulfuron) is also used for ryegrass to bermudagrass transition. Do not apply Kerb or Manor to slopes draining onto cool-season grasses such as bentgrass greens or ryegrass overseedings.

Roundup Pro (glyphosate) at one pint per acre is a cheap and effective way to control annual bluegrass in completely dormant bermudagrass.

Grass Control in Cool-Season Turfgrasses

Postemergence grass control in cool-season grasses with organic arsenicals such as DSMA or MSMA is risky due to the high probability of unacceptable levels of injury. These products can be very damaging to cool-season grasses such as tall fescue, especially during hot weather.

Drive (quinclorac) is an effective herbicide for control of crabgrass, barnyardgrass and broadleaf signalgrass in tall fescue, Kentucky bluegrass, perennial ryegrass and bentgrass fairways. Drive also controls some broadleaf weeds such as white clover and dandelion. Drive has become one of the dominant postemergence grass herbicides in cool-season grasses.

Fluazifop (Fusilade II) may be used on tall fescue to control annual grassy weeds and suppress bermudagrass. Apply when weeds are small and before the onset of hot weather stress.

Sethoxydim (Vantage) at 2.4 pints per acre controls many annual grasses in fine fescue. Spring applications are most effective when weeds are small and the weather is cool.

Corsair (chlorsulfuron) controls tall fescue selectively in Kentucky bluegrass and fine fescues. Low rates (1-5 oz/a) help to reduce turf injury.

Fenoxaprop (Acclaim Extra) at 13 to 39 fl oz/a may be used on Kentucky bluegrass, fine fescues, tall fescue, annual bluegrass, perennial ryegrass and bentgrass fairways to control most annual grass weeds and to suppress bermudagrass encroachment. Apply in the spring when the turf is not under stress. Acclaim Extra may be tank mixed with Turflon Ester for improved suppression of bermudagrass in tall fescue.

Soil Fumigation

Soil fumigants are volatile liquids or gases that control a wide range of soilborne pests. Soil fumigants are also highly toxic and are expensive. Their use is limited to high-value crops such as fruits, vegetables, tobacco, ornamentals and turfgrass. A cover, usually plastic film, is placed over the treated area to trap the fumigant vapors in the soil. In addition to many weeds, fumigants also control diseases, nematodes and insects. Weed seeds that have hard, water-impermeable seedcoats such as sicklepod, white clover, redstem and morningglory are not controlled by fumigants. Factors to consider before choosing a soil fumigant include expense, soil moisture level, soil temperature and time available before planting. There are three compounds available for soil fumigation in turf: (1) methyl bromide, (2) metham or metam-sodium and (3) dazomet (Basamid).

Methyl bromide is a colorless, nearly odorless liquid or gas. At 38°F, the liquid turns into a gas and at 68°F is 3.2 times heavier than air. These properties require that a cover be used or methyl bromide will escape. Methyl bromide is extremely toxic (acute vapor toxicity is 200 ppm) due to inhalation hazard, and it is commonly combined with a warning agent such as chloropicrin (teargas) to warn the user of escaping gas.

Before using methyl bromide, the soil should be in a condition suitable for planting including seedbed preparation by tilling. Control will be only as deep as the soil is adequately tilled. Soil should be moist for adequate soil penetration and dispersion. Saturated soils or extremely dry soil will limit fumigant movement through the soil, thus reducing the level of weed control. Soil temperature at 4 inches should be a minimum of 66°F. Fumigation will not be effective if soil temperature is below

50°F. Before or during application, the site should be covered with plastic film with the edges properly sealed to prevent gas leakage. The treated area should be covered for 24 to 48 hours. The cover should then be removed and the soil aerated for 24 to 72 hours before planting.

Metham or metam-sodium. Metham (methyl-dithiocarbamate) is a member of the thiocarbamate herbicide family. Metham is water-soluble and upon contact with the moist soil breaks down to form the highly toxic and volatile chemical methyl isothiocyanate. Metham should be applied to moist soil with a temperature of at least 60°F. It is most effective when used with a cover, but it may be used with a water and soil-seal method. With the water soil-seal method, the soil is cultivated and kept moist for a week before treatment. The material is applied, roto-tilled and watered in to the desired depth of control (usually 4 to 6 inches). Approximately seven days after treatment, the area should be cultivated to help release any residual gas. One to two weeks later (two to three weeks after initial application), the treated area may be planted. Disadvantages of metham use include the lowered effectiveness when used without a cover and the longer waiting period before planting. The oral LD50 of metham is 820 mg/kg while the dermal LD50 is 2,000 mg/kg.

Dazomet (Basamid) has recently been introduced as a soil fumigant. Dazomet is a granular formulation and is not a restricted-use pesticide. Dazomet must be applied accurately and uniformly and then incorporated into the soil. Its use and effectiveness are very similar to metham.

Turfgrass Growth Regulators

Trade Name	Common Name	Site of Uptake	Seedhead Suppression	Mode of Action	Comments
Cutless	flurprimidol	roots	incomplete	inhibits gibberellic acid synthesis	Occasionally used in a tank mix with Prograss for suppression of bermudagrass encroachment into bentgrass greens. Needs rainfall or irrigation for activation.
Embark	mefluidide	foliage	yes	cell division inhibitor	Used for seedhead inhibition in tall fescue and other grasses.
Primo	trinexepac-ethyl	foliage	no	inhibits gibberellic acid synthesis	Used on bermudagrass and zoysiagrass fairways to reduce clippings and improve turf density. Also used on bentgrass and bermudagrass putting greens.
Proxy	ethephon	foliage	no	promotes ethylene production which restricts growth	Primarily for cool-season grasses. Not much research data available.
Roll Out	cytokinins, gibberellic acid and indolebutyric acid	foliage	no	encourages cell division and elongation	Not tested in Arkansas. Label uses include fall color retention for bermudagrass.
Royal Slo-Gro	maleic hydrazide	foliage	yes	cell division inhibitor	Occasionally used to inhibit tall fescue seedheads in utility turf.
RyZup	gibberellic acid	foliage	no	encourages cell division and elongation	Not tested in Arkansas. Label uses include fall color retention for bermudagrass.
Trimmit, TGR	paclobutrazol	roots	no	inhibits gibberellic acid synthesis	Use to suppress <i>Poa annua</i> growth in bentgrass greens. Needs rainfall or irrigation for activation.

PGRs are separated into two groups: Type I and Type II, based on how they inhibit growth. Type I inhibitors are primarily absorbed through the foliage and inhibit cell division and differentiation in meristematic regions. They are inhibitors of vegetative growth and interfere with seedhead development. Their growth inhibition is rapid, occurring within 4 to 10 days, and lasts 3 to 4 weeks, depending on application rate. Embark (mefluidide) is an example of a Type I inhibitor that inhibits cell division in growth and development.

Type II inhibitors are generally root absorbed and suppress growth through interference with gibberellic acid synthesis, a hormone responsible for cell elongation. Type II PGRs are slower to produce growth suppression, but their duration is usually from 4 to 7 weeks, again, depending on application rate. Type II PGRs have little effect on

seedhead development and result in miniature plants. Trimmit, Scotts TGR (paclobutrazol) and Cutless (flurprimidol) are root-absorbed Type II PGRS. Primo (trinexepac-ethyl) is a foliar-absorbed Type II PGR that is systemically translocated to the site of activity.

Proxy 2L (ethephon) is a PGR with best activity on cool-season grasses. It promotes ethylene production in plants, which is a regulatory hormone that restricts plant growth. Root-absorbed PGRs are activated by irrigation or rainfall after application and are less likely to cause leaf burn due to overlaps in application. Foliar-absorbed materials such as Primo and Embark require uniform and complete coverage for uniform response and must be leaf absorbed before irrigation or rainfall occurs. Usually low application volumes (0.5 to 1 gallon per 1,000 sq ft) are used for foliar-absorbed

materials to minimize runoff from the leaf surface while high-volume applications (1 to 5 gallons per 1,000 sq ft) are used for root-absorbed materials.

An available plant growth promoter is RyzUp from Abbott Laboratories. RyzUp is gibberellic acid, which encourages cell division and elongation. RyzUp helps initiate or maintain growth and prevent color changes during periods of cold stress and light frosts on bermudagrass such as Tifdwarf and Tifgreen. Bermudagrass greens may experience an early light frost before the overseeding has become established. RyzUp helps the turfgrass recover from this discoloration. PGRIV from MicroFlo and Roll Out from Griffin are combinations of gibberellic acid, indolebutyric acid that is foliar absorbed. Research suggests that this combination promotes root growth and vigor of certain plants growing under stressful conditions.

Turfgrass IPM

Herbicides are not a substitute for a conscientiously applied cultural program. Cultural practices are at least 60%-70% of turfgrass weed control. The best means of preventing weed encroachment is a dense, vigorously growing turf. By choosing the right grass for the site and following proven fertilization, mowing and irrigation practices, weeds will be less competitive with the turf. Before deciding to use any weed control program, first determine why the turf is thin and weeds are invading. Correct the factors causing unhealthy turf before implementing an herbicide program. Weed prevention is avoiding the introduction of weeds into an uninfested area. One of the keys to making integrated pest management effective in controlling turfgrass weeds is not allowing weeds to become established. Some common sense steps to weed prevention include:

1. Using weed-free mulch and top dressing materials.
2. Using weed-free seed, sprigs, plugs and sod.
3. Keeping border areas such as fence lines, roughs and ditch banks weed-free.
4. Washing or blowing equipment between uses, especially when moving a mower or other piece of equipment from a weedy area to a weed-free area.

Have a Plan

Too often weed control measures are a reaction to crisis rather than part of a well-planned and coordinated effort. Turfgrass professionals should spend at least as much time learning the conditions that lead to weed infestation as they do studying control strategies after weeds have become established.

A big part of having a plan is scouting and mapping the weeds. As you travel through the sites that you maintain, collect information that will allow you to be ready with the correct herbicides and plan of attack come treatment time. Late summer or early fall is a good time to make weed surveys. Follow the fall survey with a spring assessment to observe spring-germinating weeds. Put your survey data on paper.

Herbicide Management

Remember that herbicides can injure non-target or desirable plants. When using any herbicide, manage the application carefully. Take steps to ensure that herbicides are directed to the target. Use them at the proper rate, at the right time and on a site that the label permits. Control each application so there is no off-target movement. Off-target movement may result from drift of actual spray droplets, volatilization and surface runoff water or by tracking with feet or equipment. One way to avoid injury to desirable plants is to apply when the non-target plants are not present or not actively growing. For example, broadleaf herbicides are usually best applied in late fall to avoid vegetables and ornamentals while controlling perennial broadleaf weeds in turfgrass. In most cases, these products will effectively control perennial weeds in late spring or early summer, too. However, numerous sensitive non-target plants are also present at those times of year.

Use extreme care when applying non-selective herbicides. Directed sprays are used to prevent contact with leaves, shoots or green stems/bark of desirable plants. Droplets too small to be seen will readily move through the air and damage sensitive plants. Shielded sprays, where a cone surrounds a nozzle, will help prevent the spray from contacting the foliage of a non-target plant. A wiper (wick) application, where an herbicide solution is wiped on weed foliage only, is another way to use non-selective herbicides safely around desired plants.

Be aware that some herbicides will leach vertically through the soil profile. They may injure or even kill sensitive trees and shrubs if their roots extend under the treated soil. Shallow-rooted plants or those with surface roots are especially vulnerable. Rainfall may move these products into the root zone, leading to injury. Atrazine, simazine, metribuzin and dicamba are turfgrass herbicides with potential for vertical and lateral movement. Manor, Tranxit, Revolver, Corsair and Kerb are herbicides that may move with runoff water under certain conditions. It is also possible to cause injury to a bentgrass green if traffic crosses the treated area and moves onto the green before the spray dries. Heavy rainfall shortly after application may cause off-site movement of these products, especially if the soil is already saturated.

When finished applying granular herbicides or fertilizers, sweep or blow them off hard surfaces such as parking lots, driveways, sidewalks and streets to prevent contamination of runoff water. Turf acts as a filter, but the materials left on impervious surfaces go directly into storm sewers or ditches and eventually into the water supply. Monitoring of rivers in the Atlanta area has shown a spike in turf pesticide and fertilizer levels during the busy spring-early summer season.

Herbicide Use Tips

1. Avoid use of ester formulations of 2,4-D, dichlorprop, triclopyr and other growth regulator herbicides during the hot months. These formulations are more likely to volatilize and damage non-target plants through vapor drift. To reduce drift, use a nozzle that produces coarse droplets (showerhead also known as a Chem-Lawn Gun), and avoid spraying when the wind speed is over 5 mph.
2. Avoid applying postemergence herbicides during the spring green-up or fall transition period of warm-season grasses. While the injury is usually temporary, it is preferable to spray while the grass is completely dormant or fully green and actively growing. If the weed infestation is severe, the benefits of weed control may outweigh the herbicide injury caused by treating during the transition periods. Compared to the growth regulators, Manor (metsulfuron) is a safer postemergence broadleaf herbicide to use on bermudagrass during the spring transition period.
3. Avoid applying excess amounts of dicamba, atrazine, simazine or metribuzin over the root zone of shallow-rooted trees, shrubs and other ornamentals. They are mobile, soil-active herbicides that, under the right conditions (sandy soil and a heavy rainfall immediately after application), will be taken up by the roots of ornamentals.
4. Do not make a dormant application of Roundup, Reward or Finale to any turfgrass species except bermudagrass. The bermudagrass should be completely dormant. Even if there is only 10 to 20 percent bermudagrass green-up, injury will be severe. Remember that zoysiagrass never goes completely dormant in Arkansas.
5. Be aware that different turfgrass species and varieties differ in their herbicide tolerance. MSMA can be used safely on bermudagrass but will severely injure St. Augustine, centipedegrass and carpetgrass. In general, the *Zoysia japonica* derived zoysiagrasses (Meyer, El Toro, Crowne, Palisades, Empire, etc.) are more herbicide tolerant than the fine-textured *Zoysia matrella* derived grasses (Emerald, Cavalier, Zorro, etc.).
6. Grasses growing in shade are more susceptible to herbicide injury. Use reduced herbicide rates or do not treat.
7. Areas on golf courses that drain onto sites (putting greens, tees) where cool-season grasses (rough, bluegrass, ryegrass and bentgrass) are planted should not be treated with Manor, Tranxit, Revolver, Kerb, Sencor, simazine or atrazine for winter weed control. Runoff water containing these herbicide residues may damage cool-season grasses. Heavy rainfall immediately after applying simazine or atrazine to a golf course fairway may result in injury due to accumulation of excess herbicide in low areas due to movement with runoff water.
8. Do your own weed control experiments. Often, control information does not exist for many species that do not occur frequently. Simple control studies may be conducted by treating infested sites with recommended rates of labeled herbicides. It is important to include an untreated area within the experimental site for comparison.

Selected Weed ID References

Color Atlas of Turfgrass Weeds. Ann Arbor Press, 310 North Main Street, P.O. Box 320, Chelsea, MI 48118.

Weed Identification Guide. Southern Weed Science Society, 1508 W. University Avenue, Champaign, IL 61821. \$97 (Includes over 300 high-quality color photos).

Weeds of Arkansas Lawns, Turf, Roadsides and Recreation Areas (MP 169). Business Office, Cooperative Extension Service, University of Arkansas, P.O. Box 391, Little Rock, AR 72203. \$5 per copy – make check payable to Cooperative Extension Service, University of Arkansas.

Weeds of Southern Turfgrass (SP 79). Publications, P.O. Box 110011, University of Florida, Gainesville, FL 32611-0011. \$8 per copy – make check payable to the University of Florida.

Weeds of the Northeast. Comstock Publishing Associates, Cornell University Press, Sage House, 512 East State Street, Ithaca, NY 14850.

Weed Control Glossary

Absorption: The process by which an herbicide passes from one system into another, e.g., from the soil solution into a plant root cell or from the leaf surface into the leaf cells.

Acid equivalent (ae): The theoretical yield of parent acid from a pesticide active ingredient that has been formulated as a derivative. For example, Roundup Pro contains 4 lbs per gallon of the isopropylamine salt form of glyphosate but 3 lbs per gallon of the parent acid.

Acid soil: Soil with a pH value less than 7.0.

Activation: The process by which a surface-applied herbicide is moved into the soil where it can be absorbed by emerging seedlings. This is normally accomplished by rainfall, irrigation or tillage. Activation does not imply any chemical change in the active ingredient.

Active ingredient (ai): The chemical in an herbicide formulation primarily responsible for its phytotoxicity and which is identified as the active ingredient on the product label.

Adjuvant: Any substance in an herbicide formulation or added to the spray tank to modify herbicidal activity or application characteristics.

Adsorption: The process by which an herbicide associates with a surface, e.g., a soil colloidal surface.

Alkaline soil: Soil with a pH greater than 7.0.

Allelopathy: The adverse effect on the growth of plants or microorganisms caused by the action of chemicals produced by other living or decaying plants.

Antagonism: An interaction of two or more chemicals such that the effect when combined is less than the predicted effect based on the activity of each chemical applied separately.

Band treatment: Applied to a linear restricted strip on or along crop rows rather than continuous over the field area.

Bioassay: Quantitative or qualitative determination of herbicide by use of sensitive indicator plants or other biological organisms.

Biological control of weeds: Control or suppression of weeds by the action of one or more organisms, through natural means, or by manipulation of the weed, organism or environment.

Biotype: A population within a species that has a distinct genetic variation.

Boot or Booting: A growth stage of grasses (including cereal crops) when the upper leaf sheath swells due to the growth of the developing spike or panicle.

Broadcast treatment: Applied as a continuous sheet over the entire field.

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

Chemical name: The systematic Name of a chemical compound according to the rules of nomenclature of the International Union of Pure and Applied Chemistry (IUPAC), Chemical Abstracts Service or other organization.

Chlorosis: Yellowing of normally green tissue due to chlorophyll destruction or failure of chlorophyll formation.

Common name: A generic name for a chemical compound. Glyphosate is the common name for Roundup.

Compatibility: The characteristic of a substance, especially a pesticide, of being mixable in a formulation or in the spray tank for application in the same carrier without undesirably altering the characteristics or effects of the individual components.

Competition: The active acquisition of limited resources by an organism that results in a reduced supply and consequently reduced growth of other organisms in a common environment.

Concentration: For herbicides, the quantity of active ingredient or parent compound equivalent expressed as weight per unit volume (such as lbs per gallon for liquids). Dry herbicide concentrations are expressed as percent by weight.

Contact herbicide: An herbicide that causes injury to only the plant tissue to which it is applied, or an herbicide that is not appreciably translocated within plants.

Dicot: Abbreviated term for dicotyledon; preferred in scientific literature over broad leaf to describe plants.

Dicotyledon (dicot): A member of the Dicotyledoneae; one of two classes of angiosperms usually characterized by having two seed leaves (cotyledons), leaves with net venation and root systems with tap roots.

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

Directed application: Precise application to a specific area or plant organ such as to a row or bed or to the leaves or stems of plants.

Dispersible granule: A dry granular formulation that will separate or disperse to form a suspension when added to water.

Dormancy: The state of inhibited seed germination or growth of a plant organ when in an environment normally conducive to growth.

Ecotype: A population within a species that has developed a distinct morphological or physiological characteristic (e.g., herbicide resistance) in response to a specific environment and that persists when individuals are moved to a different environment.

Emergence: The event in seedling establishment when a shoot becomes visible by pushing through the soil surface.

Emulsifiable concentrate (EC): A single-phase liquid formulation that forms an emulsion when added to water.

Encapsulated formulation: Herbicide enclosed in capsule or beads of material to control the rate of release of active ingredient and thereby extend the period of activity.

Epinasty: That state in which more rapid growth on the upper part of a plant organ or part (especially leaf) causes it to bend downward.

Flowable: A two-phase formulation containing solid herbicide suspended in liquid and that forms a suspension when added to water.

Formulation: (1) A pesticide preparation supplied by a manufacturer for practical use. (2) The process, carried out by manufacturers, of preparing pesticides for practical use.

Granular: A dry formulation consisting of discrete particles generally $<10 \text{ mm}^3$ and designed to be applied without a liquid carrier.

Head or Heading: A growth stage of grasses (including cereal crops) when the spike or panicle is emerging or has emerged from the sheath.

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

Herbicide: A chemical substance or cultured biological organism used to kill or suppress the growth of plants.

Herbicide resistance: The trait or quality of a population of plants within a species or plant

cells in tissue culture of having a tolerance for a particular herbicide that is substantially greater than the average for the species and that has developed because of selection for naturally occurring tolerance by exposure to the herbicide through several reproductive cycles.

Incorporate: To mix or blend an herbicide into the soil.

Interference: For plants; the total adverse effect that plants exert on each other when growing in a common ecosystem. The term includes competition, allelopathy, biotic interference and other detrimental modifications in the community or environment.

Label: The directions for using a pesticide approved as a result of the registration process.

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

Leaching: (1) The removal of materials in solution from the soil. (2) The downward movement of material(s) into a soil profile with soil water (material may or may not be in true solution and may or may not move from soil).

Monocot: Abbreviated term for monocotyledon; preferred in scientific literature over grass to describe plants.

Monocotyledon (monocot): A member of Monocotyledoneae; one of two classes of angiosperms, usually characterized by the following: one seed leaf (cotyledon), leaves with parallel venation, root systems arising adventitiously and usually diffuse (fibrous).

Non-selective herbicide: An herbicide that is generally toxic to all plants treated. Some selective herbicides may become non-selective if used at very high rates.

Non-target species: A species not intentionally affected by a pesticide.

Overtop application: A broadcast or banded application applied over the canopy of crops such as by airplane or a raised spray boom of ground equipment.

Pelleted formulation: A dry formulation consisting of discrete particles usually larger than 10 cubic millimeters and designed to be applied without a liquid carrier.

Persistent herbicide: A herbicide that, when applied at the recommended rate, will harm susceptible crops planted in normal rotation after harvesting the treated crop, or that interferes with regrowth of native vegetation in

non-crop sites for an extended period of time.
See residual herbicides.

Pesticide interaction: The action or influence of one pesticide upon another and the combined effect of the pesticide(s) on the pest(s) or crop system.

Phloem: The living tissue in plants that functions primarily to transport metabolic compounds from the site of synthesis or storage to the site of use.

Phytotoxic: Injurious or lethal to plants.

Plant growth regulator: A substance used for controlling or modifying plant growth processes without severe phytotoxicity.

Postemergence (POST): (1) Applied after emergence of the specified weed or crop. (2) Ability to control established weeds.

Preemergence (PRE): (1) Applied to the soil before emergence of the specified weed or crop. (2) Ability to control weeds before or soon after they emerge.

Preplant application: Applied before planting or transplanting a crop, either as a foliar application to control existing vegetation or as a soil application.

Preplant incorporated (PPI): Applied and blended into the soil before seeding or transplanting, usually by tillage.

Rate: For herbicides, the quantity of active ingredient expressed as weight per unit area of treated surface or per unit volume of the treated environment for aquatic applications.

Registration: The process designated by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and carried out by the Environmental Protection Agency (EPA) by which a pesticide is legally approved for use in the U.S.

Residual herbicide: An herbicide that persists in the soil and injures or kills germinating weed seedlings for a relatively short period of time after application. See persistent herbicide.

Residue: That quantity of an herbicide or metabolite remaining: in or on the soil, plant parts, animal tissues, whole organisms and surfaces.

Resistance: Ability to withstand exposure to a potentially harmful agent without being injured. (There is no general agreement as to the distinction between herbicide tolerance and herbicide resistance in plants.)

Safener: A substance that reduces toxicity of herbicides to crop plants by a physiological mechanism.

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

Soluble concentrate (SC): A liquid formulation that forms a solution when added to water.

Soluble granule (SG): A dry granular formulation that forms a solution when added to water.

Soluble powder: A dry formulation that forms a solution when added to water.

Solution: A homogeneous or single-phase mixture of two or more substances.

Spot treatment: An herbicide applied to restricted area(s) of a whole unit; i.e., treatment of spots or patches of weeds within a larger field.

Spray drift: Movement of airborne spray from the intended area of application.

Surfactant: A material that improves the emulsifying, dispersing, spreading, wetting or other properties of a liquid by modifying its surface characteristics.

Susceptibility: The sensitivity to or degree to which a plant is injured by a herbicide treatment.

Suspension: A mixture containing finely divided particles dispersed in a solid, liquid or gas.

Systemic: Synonymous with translocated herbicide, but more correctly used to describe the property of insecticides or fungicides that are absorbed into a plant (through roots or leaves) and translocated to other tissue.

Tank-mix combination: Mixing of two or more pesticides or agricultural chemicals in the spray tank at the time of application.

Tiller or Tillering: A growth stage of grasses when additional shoots are developing from the crown.

Tolerance: (1) Ability to continue normal growth or function when exposed to a potentially harmful agent (there is no general agreement as to the distinction between herbicide tolerance and herbicide resistance in plants). (2) The concentration of a pesticide residue that is allowed in or on raw agricultural commodities as established by the Environmental Protection Agency.

Toxicity: The quality or potential of a substance to cause injury, illness or other undesirable effects.

Toxicology: The study of the principles or mechanisms of toxicity.

Trade name: A trademark or other designation by which a commercial product is identified.

Translocated herbicide: An herbicide that is moved within the plant. Translocated herbicides may be either phloem mobile or xylem mobile. However, the term frequently is used in a more restrictive sense to refer to herbicides that are applied to the foliage and move downward through the phloem to underground parts.

Vapor drift: The movement of pesticides as vapor from the area of application after the spray droplets have landed on the target.

Weed: Any plant that is objectionable or interferes with the activities or welfare of man.

Weed control: The process of reducing weed growth and/or infestation to an acceptable level.

Weed eradication: The elimination of all vegetative plant parts and viable seeds of a weed from a site.

Wettable powder (WP): A finely divided dry formulation that can be readily suspended in water.

Wetting agent: (1) a substance that serves to reduce the interfacial tensions and causes spray solutions or suspensions to make better contact with treated surfaces (see surfactant). (2) A substance in a wettable powder formulation that causes it to wet readily when added to water.

Xylem: The non-living tissue in plants that functions primarily to conduct water and mineral nutrients from roots to the shoot.

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