Golf Course Weed Management

Arkansas lies in the turfgrass transition zone where turf managers sometimes come down with a condition known as "The Transition Zone Blues." These "blues" occur because June, July and August can be just too hot and humid for bentgrass greens. Then, after you recover from summer, a "blue norther" blows in during January or February and kills your bermudagrass fairways. However, winterkill on bermudagrass greens is most common. Unless covered, Tifgreen, Tifdwarf, TifEagle or Champion putting surfaces may be damaged when temperatures drop below 25 degrees F. Due to greater mowing height, bermudagrass tees and fairways have more cold tolerance. We will have weather cold enough to kill bermudagrass about every five years. Shade, high traffic, poor drainage, compaction and excessively low mowing predispose bermudagrass to winter damage. Winterkill will show up along the shaded side of a fairway or at a point where all the carts leave the path and the soil is very compacted. Zoysiagrass fairways and tees tend to have excellent cold tolerance but present some other maintenance challenges.

Bermudagrass and zoysiagrass are the most widely adapted and commonly used golf course grasses in the state. Tall fescue (sometimes used for roughs) can be grown over the entire state but performs better in north Arkansas. Centipedegrass, sometimes used for roughs, is best suited to the southern half of the state.

Most tees and fairways on Arkansas golf courses are bermudagrass (Common, Tifway, Tifsport) or zoysiagrass (Meyer, Cavalier, El Toro). Putting greens are hybrid bermudagrass (Tifdwarf, Tifgreen, TifEagle, Champion) or creeping bentgrass (SR 1020, Crenshaw, Penncross, L-93, the A's and G's and many others). Roughs range from tall fescue to bermudagrass, zoysiagrass, weeping lovegrass, centipedegrass and many native grasses. Perennial ryegrass and rough bluegrass are most often used for winter overseeding of bermudagrass turf.

Golf course weed control is complicated by a high level of foot and vehicular traffic resulting in turfgrass compaction and wear. This damage thins the turf opening it up for weed invasion. In addition, mowing heights on golf courses are lower than many other turf sites, which often results in turf with a limited root system. Turfgrass with a diminished root system has less recuperative potential and is slower to recover from herbicide injury.

Putting greens are the most sensitive to herbicides followed by tees, fairways and roughs. Weed management in bentgrass is more difficult because it is being grown on the edge of its range of adaptation and it is often barely hanging on during summer stress periods. Annual bluegrass is often the number one weed of bentgrass putting greens. Superintendents are left with the difficult problem of removing a cool-season grass from a cool-season grass. Another major problem on bentgrass greens is encroachment of bermudagrass and occasionally zoysiagrass from the collar. There is no easy cure for this problem or annual bluegrass.

Kyllinga, goosegrass and smooth crabgrass are fairly common on greens but much easier to control than *Poa* or bermudagrass encroachment.

Goosegrass, dallisgrass, crabgrass and sedges can be a problem on tees and high traffic parts of fairways. Virginia buttonweed, annual sedge, globe sedge, yellow and purple nutsedge and kyllingas favor low areas that remain wet during the growing season. Winter annuals such as annual bluegrass, henbit, chickweed, field madder, Carolina geranium, bittercress and shepherd's purse are common to fairways and roughs.

Turfgrass Weeds

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, *Poa annua*, 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 (three-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 Turfgrass References and Study Material."

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.

Herbicide Names

Herbicide labels contain three names: trade name, common name and chemical name. The nomenclature for Roundup Pro is **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 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 of many factors that include herbicide rate, environmental conditions, timing of application and the desirable species and variety being treated.

Nonselective. Nonselective herbicides control or suppress plants regardless of species. Glyphosate (Roundup), glufosinate (Finale) and diquat (Reward) are examples of nonselective 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 nonselective 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 nonselective. Glyphosate (Roundup) is an example of a nonselective 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 nonselective contact herbicides.

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.

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 aerification, 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 preemergence herbicides requires 0.25 to 0.5 inch of

Major Preemergence Crabgrass and Goosegrass Herbicides

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

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 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 degrees F. Alternating wet and dry conditions at the soil surface as well as light encourage crabgrass germination. Goosegrass germinates at soil temperatures of 60 to 65 degrees 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 a 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 of 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 dropped 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 0.5% granular formulation resulted in fewer particles per square foot compared to the more dilute 0.29% formulation. Note that the 0.29 G outperformed the 0.5 G. This was due to incomplete coverage by the 0.5 G. 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, and 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 preemergence 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 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 postemergence herbicides. Preemergence herbicides form the basis of most programs with postemergence 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 postemergence 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 degrees F. Postemergence herbicides applied at temperatures below 60 degrees 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 provide 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 postemergence herbicides. Applying herbicides such as MSMA, DSMA, 2,4-D, mecoprop, dichlorprop and dicamba at temperatures above 90 degrees 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 postemergence 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 postemergence 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 quarts/A (waiting for regrowth between each application) compared to applying one time at 6 quarts/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 + MCPP) 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 sulfonylurea 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 sulfonylurea 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 increases 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 retreatment 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 fluid ounce/A) and zoysiagrass (3 to 5 fluid ounce/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 or drain 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 or drain 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 herbicide 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 to 5 ounces/A) help to reduce turf injury.

Fenoxaprop (Acclaim Extra) at 13 to 39 fluid ounces/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.

Annual Bluegrass (*Poa annua*)

Annual bluegrass can be mowed at a height of 1/8 inch and still produce seed. It thrives in compacted soils, grows well in wet soils and can produce over 2,000 seeds per plant. While weed scientists agree that the majority of annual bluegrass seeds germinate in the early fall, recent research at Auburn University has shown that a small percentage of annual bluegrass seed can germinate at the high air temperatures of summer, indicating its ability to germinate year round. Another problem with annual bluegrass control is that it exists as both an annual and perennial biotype. *Poa annua* var. annua is classified as the true annual biotype that dies in the late spring months, while *Poa annua* var. reptans is classified as a perennial that can survive high summer air temperatures under management regimes used to maintain creeping bentgrass putting greens. Syringing and fungicide use that ensures creeping bentgrass survival in the South also promotes the survival of the perennial biotype of annual bluegrass.

Research proves that both preemergence and postemergence herbicides can control annual bluegrass in most turfgrass sites. Application timing with preemergence herbicides is critical to achieving high levels of control. Annual bluegrass starts its primary period of germination in late summer and early fall when soil temperatures at the 4 inch level drop to the low- to mid-70 degree F ranges (or lower). Preemergence herbicide application should

be timed just prior to expected period of peak germination. Annual bluegrass often has a second germination flush in mid- to late winter. This is important for turf managers to recognize because fall herbicide applications normally do not provide season-long control, and repeat applications may be necessary.

Herbicide research repeatedly shows that the majority of preemergence herbicides labeled for use in turfgrasses will provide 80 to 90 percent control of annual bluegrass when applied according to label directions. Similarly, postemergence applications of atrazine, simazine and pronamide (Kerb) during November-February will provide high levels of annual bluegrass control in non-overseeded warm-season turfgrasses. In addition to bermudagrass, Kerb is now labeled for use in centipedegrass, zoysiagrass and St. Augustinegrass. For best results with Kerb, it should be applied during the cool winter months and watered in with 0.25 inch of irrigation water within 24 hours of application. Kerb is root-absorbed; thus, adequate water is necessary to move Kerb into the root zone and prevent volatilization. Kerb is highly phytotoxic to cool season turfgrasses and should not be applied to overseeded warm season turfgrasses or adjacent to cool season turfgrass sites.

Two new annual bluegrass control options are TranXit (rimsulfuron) and Revolver (foramsulfuron). These herbicides are for annual bluegrass control in overseeded and non-overseeded bermudagrass. TranXit and Revolver are sulfonylurea herbicides that have primarily postemergence activity on annual bluegrass. TranXit and Revolver are also labeled for use as a spring transition aid. Late spring applications of TranXit or Revovler at approximately the 50 percent green-up growth stage of bermudagrass will control perennial ryegrass with only slight injury to bermudagrass. Under no circumstances should TranXit or Revovler be applied to control annual bluegrass in desirable fall-seeded, cool-season turfgrasses or to creeping bentgrass.

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 percentages 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. 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 herbicide 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 mixed with that herbicide. When tank mixing different formulations: (1) fill the tank two-thirds 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. They 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.

Herbicide Management

Remember that herbicides can injure nontarget 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 nontarget plants are not present or not actively growing. For example, broadleaf herbicides are usually best applied in late fall to avoid vegetable 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, nontarget plants are also present at those times of year.

Use extreme care when applying nonselective 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 nonselective 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 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 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.

Examples of Turfgrass Herbicides Having the Same Mode of Action

ALS Inhibitors	Lipid Synthesis Inhibitors	Mitotic Inhibitors	Photosynthetic Inhibitors
Image	Illoxan	Balan	Princep
Manage	Vantage	Surflan	Aatrex
Manor	Acclaim	Barricade	Sencor
Corsair	Fusilade	Lesco Pre-M	
Revolver		Pendulum	
		XL	
		Team	
		Dimension	

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.

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 seed coats, 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 degrees F, the liquid turns into a gas and at 68 degrees 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 soil or extremely dry soil will limit fumigant movement, reducing the level of weed control. Soil temperature at 4 inches should be a minimum of 66 degrees F. Fumigation will not be effective if soil temperature is below 50 degrees 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 24 to 72 hours before planting.

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 degrees 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-and-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 LD_{50} of metham is 820 mg/kg while the dermal LD_{50} is 2000 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.

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 pounds/acre (2.3 to 9.2 pounds/1,000 square feet). 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 pounds/acre (4.6 pound/1,000 square feet) 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 pounds 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 pounds/1,000 square feet. 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.

Turfgrass IPM

Herbicides are not a substitute for a conscientiously applied cultural program. Cultural practices are at least 60 to 70 percent 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. Use weed-free mulch and topdressing materials.
2. Use weed-free seed, sprigs, plugs and sod.
3. Keep border areas such as fence lines, roughs and ditch banks weed-free.
4. Wash or blow 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 the sites 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

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. Tall fescue 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 *Poa annua* growth in bentgrass greens. Needs rainfall or irrigation for activation.

the fall survey with a spring assessment to observe spring germinating weeds. Put your survey data on paper.

PGRs are separated into two groups – Type I and Type II – based on how they inhibit growth. Type I inhibitors are primarily absorbed through 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, 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 square feet) are used for foliar-absorbed materials to minimize runoff from the leaf surface, while high volume applications (1 to 5 gallons per 1,000 square feet) 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 and indolebutyric acid that is foliar absorbed. Research suggests that this combination promotes root growth and vigor of certain plants growing under stressful conditions.