A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

# TurfGrass TRENDS

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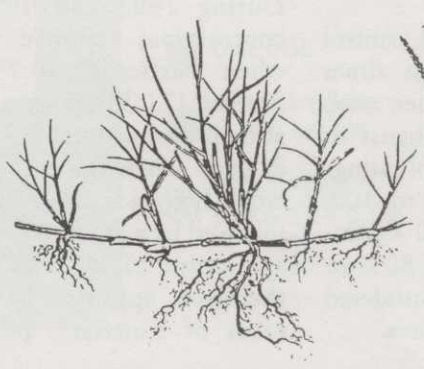
# Reduced Herbicide Application Rates:

## Crabgrass and Goosegrass Control in Bermudagrass

*by B. J. Johnson*

Effective cultural and chemical management practices are needed to maintain high quality turf on home lawns, golf courses, athletic fields, parks, and other turfgrass areas. A good weed control program begins with good management practices that encourage a dense, healthy turf (McCarty and Colvin, 1990). A thick, dense turf produces competition to emerging weed seedlings and minimizes the physical space available for weeds to become established. However, regardless of management practices, herbicides must be used to maintain optimum weed control.

Crabgrass (*Digitaria* spp.) and goosegrass [*Eleusine indica* (L.) Gaertn.] are problem summer annuals that actively grow in turfgrasses throughout the spring and summer. Preemergence herbicides – for convenience, referred to here as PRE herbicides – are toxic to crabgrass and goosegrass (Bhowmik and Bingham, 1990; Dernoeden and Krouse, 1991; Johnson and Murphy, 1987; 1989; 1993; Sawyer and Jagschitz, 1987; Watschke and Hamilton, 1990), but for consistent control the selection of the herbicide to be applied and its rate of application are important.



**Bermudagrass**

**(Figure taken from Roberts/Roberts, *THE LAWNSCAPE... Our Most Intimate Experience With Ecology.* Reprinted by permission of The Lawn Institute.)**

IN THIS ISSUE

# TurfGrass Trends





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The rate of application depends on the length of the growing season. PRE herbicides applied for crabgrass control in the southeastern United States must be effective for six to seven months. In contrast, in the northeastern United States, where the length of the growing season for this weed is only four to five months, the application rate of PRE herbicides and their required period of efficacy are less. For example, in Georgia, the normal use rate for pendimethalin (WDG) (various trade names) is 3.0 lb. ai/A[1], compared to 1.5 lb./A in the Northeast.

Because of increasing environmental concerns and the regulatory efforts they have engendered, it may become necessary to reduce herbicide usage for weed control in turf. In anticipation of this development, several programs utilizing lower herbicide rates for full-season weed control in turfgrasses have been evaluated at the University of Georgia.

Although turfgrass weed control research has been conducted in Georgia since the early 1970's, the reduced rate herbicide programs were initiated in 1991. Each treatment program was conducted over a two or three-year period. Treatments were applied to different weedy plots each year except in the multiyear program, where treatments were applied to the same plots for three consecutive years.

Turfgrass tolerance and weed control ratings were made at various times during the spring and summer, with final ratings made in late August to early September. Weed control ratings were based on a scale of 0 to 100, where 0 = no control, and 100 = complete control. On this scale, 80% or better control would be considered acceptable on most turfgrass sites.

## Sequential PRE and POST herbicide treatments

In this program, sequential applications of PRE and POST – i.e., postemergence – herbicides were applied for crabgrass and goosegrass control in common bermudagrass. The PRE herbicides (Ronstar®[2], pendimethalin, Barricade®, and Surflan®) were applied at reduced rates in late winter, prior to weed seed germination. The POST herbicides (MSMA (6.0 lb. gal) for crabgrass and Illoxan® (EC) and MSMA + metribuzin for goosegrass were applied in late spring or early summer, after the weeds had emerged.

## Crabgrass control

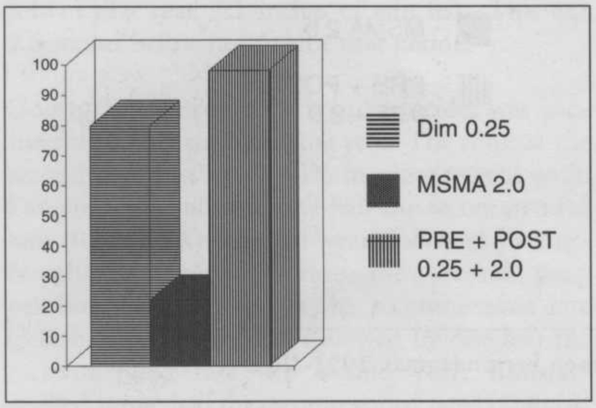
Reduced rate applications of PRE herbicides, followed by an application of MSMA, controlled crabgrass as effectively as did PRE herbicides applied alone at normal rates. The control was excellent (94%) in 1992 when Ronstar® was applied at one-third the recommended rate (1.0 lb./A) in late February, followed by MSMA at 2.0 lb./A in June. This was equal to the degree of control achieved with Ronstar® (applied alone at the normal rate of 3.0 lb./A. Pendimethalin at one-third the recommended rate (1.0 lb./A), followed by MSMA at 2.0 lb./A, controlled crabgrass in similar fashion.

During 1993 and 1994, crabgrass control was effective (above 86%) when Barricade® (0.75 lb./A) and Surflan® (2.0 lb./A) were applied alone at their normal rates. Control was just as good when the application rate of either herbicide was reduced by 67%, followed by a reduced (by 50%) rate of application of MSMA (1.0 lb./A). It therefore appears that application rates of Ronstar®, pendimethalin,

[1] All herbicide rates are presented as pounds active ingredient per acre.

[2] Trade names are included for the benefit of the reader and not imply any endorsement or preferential treatment.

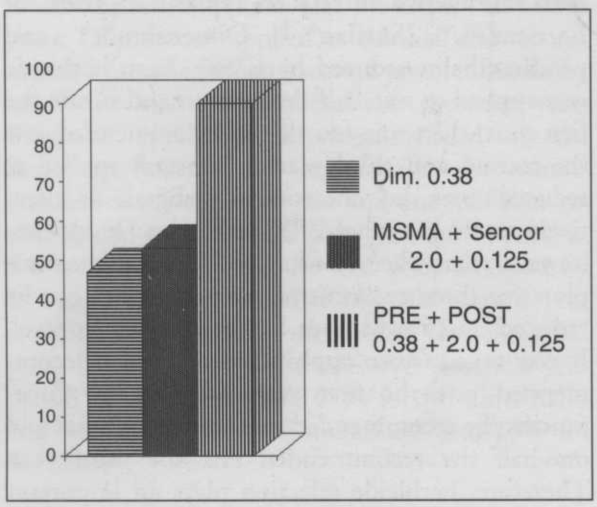
Barricade®, and Surflan® can be reduced without sacrificing crabgrass control if that PRE application is followed by a timely POST application of MSMA. In some instances, the PRE herbicides applied at reduced rates may even control crabgrass throughout the summer. When this occurs, POST applications of MSMA are not needed.




**Sequential PRE and POST herbicides in common bermudagrass. 1991. % Crabgrass control**

## Goosegrass control

Goosegrass in bermudagrass is more difficult to control with herbicides than is crabgrass (Johnson and Murphy; 1993). When applied alone at normal rates, Ronstar® controlled goosegrass more effectively (91%) than did pendimethalin (69%), Dimension® (69%), Barricade ® (71%), or Surflan® (77%) applied at normal rates. However, goosegrass




**Sequential PRE and POST herbicides in common bermudagrass (Average 1991-1992.) % Goosegrass control**

control was 80% or better when these PRE herbicides was applied at reduced (50 to 67%) rates then followed by a POST MSMA + metribuzin application (Johnson 1993a). MSMA + metribuzin was applied at the normal rate (2.0 + 0.125 lb./A) with all PRE herbicides except Surflan®, with which the MSMA + metribuzin application rate was 1.0 + 0.125 lb./A. It therefore appears that the use of sequential PRE and POST herbicide applications not only improved the consistency of goosegrass control, but also permitted a reduction in the PRE herbicide application rate. No apparent advantage in goosegrass control was achieved from sequential applications of PRE herbicides and POST Illoxan®, when compared with application of Illoxan® alone (Johnson 1993a).

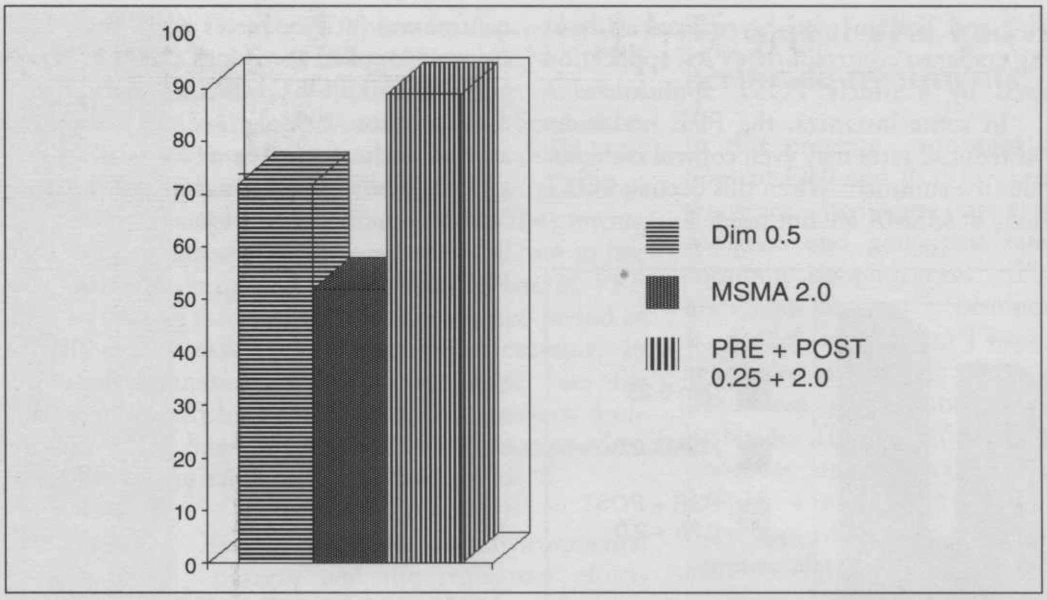
## Treatment with tank-mixtures of PRE and POST herbicides

In this study, PRE herbicides at reduced rates and POST herbicides at labeled rates were tank-mixed and applied to common bermudagrass in a single application in May, after crabgrass and goosegrass had emerged. For treatments of this nature to be effective, the POST herbicides must control already-emerged weeds, and the PRE herbicides must provide residual control through the remainder of the growing season.

Crabgrass control was 80% or higher when one-half rates of either Dimension® (0.25 lb./A) or pendimethalin (1.5 lb./A) were tank-mixed with MSMA at the normal rate (2.0 lb./A). This represented a degree of control higher than that achieved with either Dimension® or MSMA applied alone at normal rates. However, tank-mixes of the PRE herbicides with MSMA + metribuzin did not effectively control goosegrass ( below 53%). In general, tank-mixtures of PRE and POST herbicides were not as effective as sequential applications of PRE and POST herbicides in controlling either crabgrass and/or goosegrass.

## Multiyear PRE herbicide treatments

Five PRE herbicides (Barricade®, Surflan®, Dimension®, pendimethalin, and Ronstar®) were applied to the same plots at various rates annually over a three-year period for crabgrass and goosegrass control in common bermudagrass.




**Tank-mixed PRE and POST herbicides in common bermudagrass. 1991-1992 (Average 2-3 Exp.) % Crabgrass control**

## Crabgrass control

All PRE herbicides controlled 90% or more of the crabgrass during the first year when applied at normal rates. When the rates of application were reduced by one-half the recommended rate the first year, control was 85% in plots treated with Dimension® (0.25 lb./A) and pendimethalin (1.5 lb./A), 75% in plots treated with Barricade® (0.38 lb./A) and Surflan® (1.0 lb./A), and 64% in plots treated with Ronstar® (1.5 lb./A). This reinforces the previous finding that PRE herbicides applied alone at reduced rates may not control crabgrass consistently during the first year of use (Johnson and Murphy 1987; 1989; 1993). Therefore, if reduced PRE herbicide application rates do not result in consistent crabgrass control in bermudagrass, MSMA can be applied subsequently. It should also be emphasized that MSMA can be applied safely to bermudagrass and most of the cool-season grasses, but not to zoysiagrass (*Zoysia* spp.), centipedegrass [*Eremochloa ophiuroides* (Munro) Hack.], St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze], or bahiagrass (*Paspalum notatum* Flugge).

Crabgrass control ranged from 83 to 92% during the second year of the study when Barricade®, Surflan®, pendimethalin, and Dimension® were applied at one-half the recommended rate the first year, and one-fourth the recommended rate the second year. However, for Ronstar® to maintain similar control, it was necessary to apply the normal recommended rate the first year, followed by one-half the recommended rate the second year.

With PRE herbicides applied to the same plots for crabgrass control for three consecutive years, acceptable control (88 to 93%) was maintained with cumulative three-year application rates for Barricade®, Surflan®, Dimension®, and pendimethalin reduced by 67%. Each herbicide was applied at one-half the recommended rate the first year, then one-fourth the recommended rate the second and third years. Ronstar® applied at reduced rates did not control crabgrass as effectively as did the other PRE herbicides. It appears, however, that when Ronstar® is applied to the same plots for three consecutive years, the rates can be reduced by 25% without loss of adequate control. It was necessary to apply Ronstar® at the recommended rate the first year, followed by three-fourths the recommended rate the second year, and one-half the recommended rate the third year. Therefore, herbicide selection plays an important role in maintaining an optimum level of crabgrass control utilizing application rates below those recommended.

## Goosegrass control

None of the PRE herbicides controlled goosegrass effectively (better than 80%) in common bermudagrass during the first year. The poor control was probably related to rainfall. No irrigation water was applied at this test site. From May through July of that year, 7.1 inches of rain fell. This was 9.8 inches below normal for that period.

Goosegrass control with these herbicides was consistently higher the following year. The control the second year was above 80% in plots treated with: Dimension® applied at one-half the recommended rate (0.38 lb./A) the first year, followed by one-fourth recommended rate the second year; pendimethalin applied at the recommended rate (3.0 lb./A) the first year, followed by one-half the recommended rate the second year; Ronstar® applied at one-half the recommended rate (1.5 lb./A) both years; and Barricade® applied at the recommended rate (0.75 lb./A) the first year, followed by three-fourths the recommended rate the second year. Surflan® did not control goosegrass effectively at any rate.

Goosegrass control during the third year was effective when PRE herbicides were applied to the same plots for three consecutive years. To maintain better than 86% control during the third year, application rates for the herbicides were: pendimethalin and Ronstar® applied at one-half the recommended rate the first year, followed by one-fourth the recommended rate the second and third years; Dimension® applied at one-half the recommended rate the first and second years, followed by one-fourth the recommended rate the third year; Barricade® applied at the recommended rate the first year, followed by three-fourths the recommended rate the second year and one-half the recommended rate the third year; Surflan® applied at the recommended rate the first year, followed by one-half the recommended rate the second year and one-fourth the recommended rate the third year. In this program, the rates over the three-year period can be reduced by 67% for pendimethalin and Ronstar®, 58% for Dimension®, and 25% for Barricade®.

These results indicate that application of herbicides at recommended rates may not be needed each year to maintain acceptable crabgrass and goosegrass control in bermudagrass turf. When herbicides are applied to turfgrasses not previously treated, however, the rates cannot be reduced as much during the initial year as during subsequent years. Care should also be taken to select the herbicide and rate of application needed to perform best against whichever weed species are posing problems.

## Turfgrass species response

The response of crabgrass to PRE herbicides varies among turfgrass species (Johnson 1993b). Programs to reduce herbicide rates for weed control will consequently vary with the turfgrass species being supported. Pendimethalin and Ronstar® applied at one-third the recommended rate in each of two applications (late February and late April) controlled crabgrass effectively (above 90%) in common bermudagrass. Ronstar® applied at one-third the recommended rate controlled crabgrass in tall fescue (96%), but pendimethalin did not (53%). Barricade® applied at one-fourth the recommended rate controlled crabgrass in common bermudagrass (89%), but one-half the recommended rate was required for similar control in tall fescue (82%). Dimension® applied at one-fifth the recommended rate in each of two applications controlled crabgrass in common bermudagrass (87%), but not in tall fescue, regardless of rate (control was below 65%).

The higher crabgrass control from pendimethalin and Dimension® in common bermudagrass, compared to that achieved in tall fescue, was probably related to differing levels of competition from the surrounding turfgrass during mid- to late summer. Canopy growth of tall fescue is upright. This allowed crabgrass to germinate and seedlings to emerge. In contrast, common bermudagrass grows actively during the summer and has a denser turf canopy than tall fescue. This probably suppressed crabgrass germination and seedling emergence. It is not known how other PRE herbicides applied at reduced rates will control crabgrass in tall fescue grown under severe stress conditions. In a preliminary study, Surflan® did not control crabgrass in tall fescue at any rate. It should be emphasized that herbicide performance on tall fescue would probably be better in geographical areas where heat stresses are not as severe.

## Turfgrass injury

The injury to common bermudagrass treated sequentially with PRE and POST herbicides was related to the application rates of the POST, not the PRE, herbicides (Johnson 1993a). The maximum turfgrass injury observed was about 35% with MSMA at 2.0 lb./A and 40% with MSMA + metribuzin at 2.0 + 0.125 lb./A. The symptoms of injury to common bermudagrass was moderate leaf discoloration with some plant necrosis. It should be noted that, in all instances, the turfgrass recovered fully within 2 to 3 weeks after the POST treatments.

Tank-mixes of MSMA + metribuzin, with either Dimension® or pendimethalin, injured common bermudagrass more than when either herbicide was applied alone (Johnson 1994). The injury at one week after treatment with MSMA + metribuzin was 26%, compared to 48% injury in plots treated with the tank-mixes. By two weeks after application, the injury from PRE plus POST tank-mixes was approximately 75% higher than that observed from MSMA + metribuzin alone. There were no differences in injury when MSMA + metribuzin was tank-mixed with Dimension® or pendimethalin, and turf treated with the tank-mixes required longer than four weeks to recover. There was no difference in turfgrass injury from tank-mixed herbicides, compared with POST treatment alone. The injury to turfgrass at one to two weeks after herbicide treatment averaged 40% where MSMA + metribuzin was applied alone or with PRE herbicide.

PRE herbicides applied at a reduced rate in one or two annual applications generally maintain a higher quality turf than that found in untreated plots. The lower turf quality in untreated plots probably resulted from weed competition.

**Dr. B. J. Johnson** is a Professor of Crop and Soil Sciences at the University of Georgia. Professor Johnson has been employed by the University of Georgia since 1954, with the exception of two years military leave and two years graduate school at Texas A&M. Although he has worked with several crops during this period, his interest since 1972 has been on weed control, fertilization, and plant growth regulators in cool- and warm-season turfgrasses. During the last five years his major research has focused on utilizing reduced herbicide rates for optimum weed control in turfgrasses. This is his first contribution to *TurfGrass TRENDS*.

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# Herbicide-Resistant Weeds in Turfgrasses

*by Tim R. Murphy*

Selective weed control in turfgrasses essentially began with the discovery in the mid-1940's that 2,4-D® would control dandelion in Kentucky bluegrass. Subsequently, numerous herbicides have been registered for use in turfgrasses. The use of herbicides, in combination with timely cultural management practices, has significantly contributed to the overall aesthetic quality of turfgrasses.

Soon after the advent of other pesticides, some species of insects and plant pathogens developed pesticide resistance, i.e., a pesticide that had previously controlled a species would no longer do so. This was not a new phenomenon. Resistance of San Jose scale to lime sulfur had been observed in 1908. By 1957, entomologists had reported that 76 insect species were resistant to certain insecticides. A 1980 survey showed that 428 species of insects and related arthropods exhibited resistance to commonly used insecticides (1).

Herbicide resistance was first reported in 1970, with the discovery in ornamental nurseries in Washington that simazine, a triazine herbicide, no longer controlled groundsel (*Senecio vulgaris*), a previously susceptible species (3). As of 1989, 53 weed species were considered to be resistant to various herbicide families (1).

Herbicide-resistance has been slower to develop, or to manifest itself, than insecticide- and fungicide-resistance. Some possible reasons for this include: a) weeds normally complete only one life cycle per year, b) weeds are not as mobile as insects and disease pathogens, c) crop rotations that utilize different herbicide families and mechanical cultivation are routinely practiced with most crops, and, d) certain resistant weeds are less ecologically fit than their herbicide-susceptible biotypes.

A common misconception is that continued use of the same herbicide causes a mutation to occur that enables the weed to become resistant to the herbicide. However, herbicides do not cause mutations. Research has shown that individuals of resistant biotypes are naturally present at extremely low frequencies in most populations of a weed species. Continued use of the same herbicide over a period of years controls the susceptible biotypes, but allows the population of resistant biotypes to increase. The selection pressure exerted by the herbicide is analogous to a plant breeder selecting biotypes that are resistant (or more commonly tolerant) to various types of imposed selection stresses (drought, mowing height, diseases, insects, etc.). The end result of continued use of one herbicide for several consecutive years is a herbicide-resistant population of weeds. However, this statement is true only if resistant individuals are naturally present on the site.

In the mid-1980's, goosegrass (*Eleusine indica*) resistance to the dinitroaniline herbicide family (trifluralin, pendimethalin, oryzalin, benefin, others) was reported in South Carolina (2). Annual use of dinitroanilines in cotton for 8 to 10 consecutive years was a major factor contributing to the development of this case of resistance. Other herbicide families or herbicides in which resistance has been noted for other weed species include the triazines (atrazine, simazine, others), organic arsenicals (MSMA, DSMA), sulfonylureas (chlorsulfuron, sulfometuron, others), imidazolinones (imazaquin, others), diclofop, quizalofop, fluazifop and paraquat. Many of these herbicides are registered for use in various turfgrass species.

Prior to 1985, benefin was the only dinitroaniline herbicide registered for use on turfgrasses. However, in 1985 oryzalin, pendimethalin and trifluralin were registered for this use. Prodiamine, also a member of the dinitroaniline herbicide family, was labeled for use in turfgrasses in the early 1990's. At about this same time, dithiopyr, a member of the pyridine herbicide family, was also registered for annual weed control in turfgrasses.

In 1992, a golf course superintendent in middle Georgia indicated that various dinitroaniline herbicides were not controlling goosegrass in bermudagrass fairways. Herbicide records available back to 1985 revealed that dinitroaniline herbicides had been used on this golf course alone or in combination (with other herbicides) for seven consecutive years.

Experiments were conducted on a common bermudagrass fairway at this golf course in 1993 and 1994 to determine if dinitroaniline-resistant goosegrass was present. Oxadiazon (Ronstar® 2G), pendimethalin (several trade names), prodiamine (Barricade® 65 WDG), oryzalin (Surflan® 4AS) and dithiopyr (Dimension® 1EC) were applied at the maximum labeled rates to separate plots in either single or successive applications. In both 1993 and 1994, the initial herbicide application was in mid-February, and a second application was made approximately eight weeks later in mid-April. Goosegrass control was assessed at four and five months after the initial February application in 1993 and 1994, respectively. A control rating of less than 80% is not considered to be commercially acceptable.

A single application of oryzalin, prodiamine or pendimethalin at the maximum labeled rate did not control goosegrass (see Table 1). Subsequent applications of these herbicides at these same rates also did not provide control. The sequential application program is equivalent to a rate that is twice the labeled maximum. Additionally, dithiopyr did not control goosegrass as either a single or sequential application.

Pendimethalin, prodiamine, and oryzalin, being all members of the dinitroaniline herbicide family, have the same basic mode-of-action: inhibition of a specific phase of cell division (see Table 2). Dithiopyr, although belonging to the pyridine herbicide family, has a mode of action similar to the dinitroaniline herbicides. Because of their similar modes-of-action, rotating to dithiopyr proved not to be an effective strategy for controlling dinitroaniline-resistant goosegrass.

Single and sequential applications of oxadiazon provided 90% or better goosegrass control in 1993 and 1994 see (Table 1). Oxadiazon belongs to the oxadiazole herbicide family and has a mode-of-action totally different from the dinitroaniline herbicides and dithiopyr. Therefore, on sites where a dinitroaniline- or dithiopyr-resistant biotype of goosegrass is present, rotation to oxadiazon, or other herbicides that have a mode-of-action different from the dinitroanilines and dithiopyr should provide effective control.

Additional research conducted at this site showed that diclofop (Illoxan®) and MSMA + metribuzin (Sencor Turf®) effectively controlled dinitroaniline- and dithiopyr-resistant goosegrass. Herbicides in this group also have different modes-of-action from those of the dinitroanilines and dithiopyr.

Similar to what was observed in the development of pesticide resistance in cotton fields, exclusive use of dinitroaniline herbicides for a period of several years allowed the population of resistant goosegrass biotypes to flourish. Therefore, turfgrass managers should include a herbicide-resistant weed-avoidant control strategy in their weed management plan.

**Table 1. Goosegrass control with selected preemergence herbicides.**

| Goosegrass Control[2] | | | |
|---|---|---|---|
| Herbicide | Rate[1] lbs. ai/acre | 1993 % | 1994 % |
| Oryzalin | 3.0 | 0 | 30 |
| Oryzalin | 3.0 + 3.0 | 0 | 10 |
| Prodiamine | 0.75 | 27 | 53 |
| Prodiamine | 0.75 + 0.75 | 40 | 37 |
| Pendimethalin | 3.0 | 20 | 47 |
| Pendimethalin | 3.0 + 3.0 | 13 | 47 |
| Dithiopyr | 0.5 | 7 | 27 |
| Dithiopyr | 0.5 + 0.5 | 0 | 13 |
| Oxadiazon | 4.0 | 93 | 96 |
| Oxadiazon | 4.0 + 4.0 | 94 | 100 |
| No Herbicide | -- | 0 | 0 |
| LSD (0.05) | -- | 29 | 42 |

[1] Herbicides applied in single or sequential applications. Single applications were made in mid-February. Sequential applications were made in mid-February and mid-April.

[2] Control ratings were recorded four months after application in 1993 and five months after application in 1994.

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**Dr. Leslie MacDonald, Plant Pathologist, Ministry of Agriculture, Fisheries and Food, British Columbia.**

■

Table 2. Mode-of commonly used herbicides.

| Herbicide Family | Common Name | Brand Name[1] | Application Timing | Mode-of-Action |
|---|---|---|---|---|
| Aryloxyphenoxy propionate | Dielofop, Fluazifor-P, Quizalofop-P | Illoxan®, Fusilade II®, Assure II® | Postemergence | Inhibition of fatty acid synthesis. |
| Bipyridilium | Paraquat | Gramoxone Extra® | Postemergence | Cell membrane disruption through the formation of hydroxyl and lipid radicals. |
| Dinitroaniline | benefin, oryzalin, pendimethalin, prodiamine, trifluralin | Balan®, Surflan®, Pre-M®, others Barricade®, Treflan® | Preemergence | Inhibits cell division by binding to tubulin which prevents polymerization of microtubules at the growing end of the tubule. |
| Imidazolinone | Imazaquin | Image® | Postemergence | Inhibits the enzyme,acetolactase synthase, a key enzyme in the synthesis of the branched chain amino acids isoleucine, leucine and valine |
| Organic Arsenical | MSMA, DSMA | Bueno 6®, others DSMA 4®, others | Postemergence | Not well understood. Known to uncouple energy transfer during the production of ATP. |
| Pyridine | dithiopyr | Dimension® | Preemergence Postemergence | Inhibits cell division in the late prometaphase stage by binding to a microtubule associated protein. Does not bind to tubulin. |
| Sulfonylurea | chlorsulfuron, sulfometuron | Glean®, Tolar®, Oust® | Preeemergence, Postemergence | Inhibits the enzyme, acetolactase synthase, a key enzyme in the synthesis of the branched chain amino acids isoleucine, leucine and valine. |
| Triazine | atrazine, metribuzin simazine | Astrex®, others, Sencor 75 Turf® Princep®, others | Preemergence, Postmergence | Inhibits electron transport during the light-dependent phase of photosynthesis. Membrane disruption ensues due to formation of toxic lipid radicals. |

[1] Brand names are used only for information. Other products may be available with the same active ingredient.

Once resistance occurs, the only effective option for control in turfgrasses is to rotate to a herbicide that has a different mode-of-action than the herbicide previously used. Rotating to a different herbicide in the same chemical family is not effective, as members of the same family usually have the same mode-of-action. (Additionally, increasing the rate of the herbicide is not an effective option as true herbicide resistance is absolute and is not related to tolerance.) In the case of dinitroaniline-resistant goosegrass discussed above, rotation to oxadiazon, diclofop or MSMA + metribuzin effectively controlled this weed. This group of herbicides has a different mode-of-action than dinitroaniline herbicides and dithiopyr.

Dinitroaniline herbicides have been used widely for several years by turfgrass managers to control goosegrass, crabgrass (*Digitaria* spp.) and other annual weeds. While goosegrass resistance to this herbicide family and dithiopyr has been documented, there are no documented cases of crabgrass resistance to these herbicides. And goosegrass resistance has not become a widespread problem at this time.

No one can accurately predict whether resistant goosegrass will occur on every turfgrass site. If there are no resistant individuals in a given population of goosegrass, then the problem will not occur.

However, rather than take chances, a basic principle of pest control, i.e. pesticide rotation, should be practiced. By following this basic principle, turfgrass managers can continue to depend upon the effective, low-cost control that dinitroaniline herbicides have provided in the past.

Herbicide-resistant weeds are, nonetheless, a real phenomenon. Factors that contribute to their emergence include a) consistent use of herbicides with similar modes-of-action, b) lack of use of herbicides with different modes-of-action, and c) allowing herbicide-resistant weeds to reseed.

Most herbicide resistant weed populations take a long time to develop. In the case of dinitroaniline-resistant goosegrass in turfgrasses and cotton, dinitroaniline herbicides were used exclusively for periods of eight to ten years. Continued annual use of the same herbicide is one of the primary reasons why herbicide-resistant weeds are appearing more frequently in various crop systems, and why they have the potential to increase in turfgrasses. Other reasons include the development of herbicides that have a single-site/ narrow-spectrum mode-of-action, and use of herbicides that provide several months of residual weed control activity.

Herbicide resistant weeds have not been a major problem in turfgrasses. They can proliferate, however, unless turfgrass managers begin to employ herbicide-resistant weed management strategies. Specific management practices that discourage, or help to prevent, the development of herbicide-resistant weed populations are: a) sequential use of herbicides with differing modes-of-action (rotation), b) use of tank-mixes or combinations of herbicides that have different modes-of-action, c) controlling weeds that escape preemergence herbicide treatments with postemergence herbicides that have a different mode-of-action, and d) (where practical) preventing seed production by hand roguing.[3]

This examination of goosegrass resistance to the dinitroaniline herbicides and dithiopyr is not meant to suggest that it is time to push the "panic button." Nor does it indicate that these herbicides are no longer effective. The dinitroaniline herbicide family has provided and should continue to provide economical annual grass control in established turfgrasses. Their efficacy notwithstanding, herbicide-resistant weeds can become a problem in turfgrasses. There is a natural inclination to continue to use pesticides that have proved themselves effective in the past. Insecticide and fungicide rotation is now routine practice on turfgrass sites. If turfgrass managers are to hold herbicide-resistance in check, then herbicide rotation will have to become routine practice as well.

**Dr. Tim R. Murphy** received his Ph.D. degree in Agronomy-Weed Science from Clemson University in 1985. Since that time he has been employed with the University of Georgia Cooperative Extension Service as an Extension Weed Scientist. He is currently responsible for directing the Extension weed science educational effort in turfgrasses, aquatic sites, small grains, soybeans and canola. He conducts several evaluations each year aimed at developing control programs for problem weeds in turfgrasses and is also responsible for developing the Cooperative Extension Service weed control recommendations for a wide range of commodities in Georgia. He was recently the coordinating author for *Weeds of Southern Turfgrasses*, a book containing 437 color photographs of 193 weed species that are found in cool- and warm-season turfgrasses in the southern United States. Copies of this publication may be purchased through C.M. Hinton, Publications Distribution Center, IFAS Building 664, University of Florida, Gainsville, FL 32611. This is his first contribution to *TurfGrass TRENDS.*

**References Cited**

1. Lebaron, H. M. and J. Gressel. 1982. Introduction. Chapter 1. pp. 1-30. In H. M. LeBaron and J. Gressel (Eds.) *Herbicide Resistance in Plants.* John Wiley and Sons, New York.

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[3] For additional insights on increasing the effectiveness of weed-control management practices see: Lambert B. McCarty, "Winter Weed Control in Southern Turf - Early Detection, Recognition and Action are Key," *TurfGrass TRENDS*, 4-11 (NOV 95), pp. 9-13.

# Conducting a Bioassay for Herbicide Residues

*by Joseph C. Neal*

## What is a bioassay?

A bioassay is a technique for determining if herbicide (or other chemical) residues are present in soil or water in high enough concentrations to adversely affect plant growth. This is a simple and direct method to determine if it is safe to seed or plant into areas previously treated with herbicides or into soil with an unknown history of herbicide use.

In its simplest form, a bioassay uses susceptible plants to identify if the herbicide is present in concentrations high enough to inhibit germination and/or growth. However, scientists sometimes use sensitive bioassays to estimate herbicide concentrations in soil and water, and identify unknown herbicide residues from the symptoms of injury.

## When is a bioassay warranted?

When newly seeded or established plants show seemingly unexplained symptoms of injury, stress, or decline. Also, when seeding or planting into areas previously treated with residual herbicides, such as those applied for crabgrass control in turf. Top soil from abandoned farmland can often contain herbicide residues, particularly atrazine, which can injure many plants. Additionally, if you suspect that another product may have been contaminated with a herbicide, both the product and treated soil can be tested.

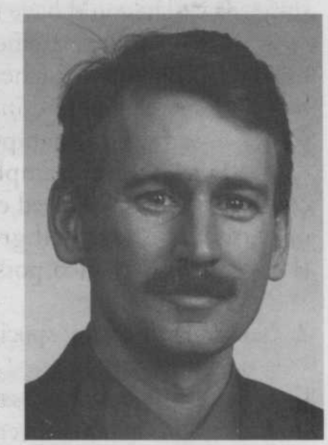

**Table 1. Some recommended bioassay species for herbicides and the expected injury symptoms.**

| Herbicides | Recommended Test Species | Expected Symptoms |
|---|---|---|
| Acetanalides (Dual®, Lasso®, Pennant®) | Oat, ryegrass | Stunting, malformed leaves. |
| Amitrol | Oat, cucumber, tomato | White (not yellow) leaves. |
| Dinitroanilines (Balan®, Treflan®, pendimethalin, others) | Oat, ryegrass, cucumber | Stunting, swollen and shortened roots. |
| Isoxaben (Gallery®) | Cucumber | Swollen roots, stunted plants |
| | Mustard, chinese cabbage | Reduced emergence. If plants emerge, roots are swollen and stunted. |
| Oxadiazon (Ronstar®) | Oat, ryegrass, tomato | Stunted shoot growth, roots less affected. Foliage necrotic where contacted by herbicide treated soil. |
| Sulfonylureas and imidazolinones (Glean®, Oust®, Lesco TFC®, Pursuit®, Arsenal®, others) | Tomato, cucumber, spinach | Stunting and general yellowing of the new growth. |
| Triazines | Oats | Stunting, yellow leaves. |
| (Atrazine, simazine, others) | Cucumber, tomato | Stunting, interveinal yellowing of new leaves (starting with about the third true leaf). |
| Synthetic auxins (Banvel®, MCPP®, 2,4-D®, Turflon®, Picloram®, others) | Cucumber, tomato | Malformed, twisted shoot growth. |

## How to conduct a bioassay.

1. Collect representative soil samples.

a. Sample from areas suspected of having her bicide residues as well as areas which are known to be free of herbicides. You will use the herbicide-free soil for comparison.

b. Take separate samples from high spots, low spots, and different soils. Also sample areas where sprayer overlap could have resulted in an over-dose.

c. Take soil cores. Remove the thatch and keep only the upper two inches of soil. Most residual herbicides will be bound in the upper two inches of soil. On sandy soils, sample to four inches.

d. Take several samples from an area and combine them. You need enough soil to fill several pots in which you will grow the bioassay plants (I suggest 3- to 4-inch pots).

2. Select the bioassay species.

In general, the best bioassay species is the one you intend to grow. However, crop plants and turfgrasses sometimes do not grow well indoors in pots, nor do they respond rapidly or decisively enough to be reliable bioassay species. Therefore, it is often advisable to select particular species known to perform well in bioassays such as ryegrass, oats, cucumber, and tomato. Table 1 provides a list of recommended bioassay species for different herbicide residues.

3. Seed and grow for about three weeks.

Seed the bioassay species in both "clean" and "contaminated" soil. Place the pots in a greenhouse or on a sunny window sill and keep them watered (do not waterlog). Watch the plants for about three weeks.

4. Evaluate plant growth.

a. Oats in "clean" soil should be about four inches tall when you evaluate the plants. Cucumbers and other broadleaf indicator plants should have three true leaves (not counting the seed leaves).

b. Examine overall growth, as well as the leaves, and roots. Look for stunting, yellowing (or other discoloration), abnormal leaf or stem growth, and root swelling or stunting.

## What to do if herbicide residues are present?

There are basically three options:

1. Leave the soil fallow (or stockpile top soil) for one growing season before planting (in turfgrass areas this is generally not feasible);

2. Plant another species which is tolerant of the herbicide, such as selecting a different turfgrass species or installing a woody ground cover bed; or

3. Incorporate (rototill) activated carbon into the soil to a depth of six inches. The recommended amount to detoxify herbicide residues is 100 lb. activated carbon per acre for every pound of herbicide active ingredient (AI) per acre suspected to be present. After incorporating activated carbon, run the bioassay again to confirm detoxification.

If option three is chosen, be aware that activated carbon does not detoxify all herbicide residues. You may, therefore, wish to run a small test in pots to determine whether the activated carbon will effectively detoxify the herbicide residues. Mix 1/2 ounce (dry measure) of activated carbon in 1 quart of water. Add 1 fluid ounce of this to each 4 inch pot of soil. [This will approximate an application of 600 lb. activated carbon per acre.] Dump the soil in a bag and mix well; then return the soil to the pot and run the bioassay. If the plants grow well, proceed with the application of activated carbon to the field. If the plants are still stunted, contact your local Cooperative Extension office for assistance.

A bioassay is a simple, inexpensive, and accurate way to determine if herbicide residues are present in high enough concentrations to affect seedling emergence or plant growth. By conducting a bioassay on new top soil or in new seedings previously treated with a herbicide, you may avoid wasted time and seed, thus saving you time and money in the long run.

**Dr. Joseph C. Neal** is an Associate Professor of Weed Science in the Department of Floriculture and Ornamental Horticulture at Cornell University. He has degrees in Horticulture from the University of Georgia and Clemson University and in Horticulture Weed Science form North Carolina State University. Dr. Neal is currently researching the biological control of weeds; he also conducts research and extension programs in weed management for nursery and floriculture crops, turfgrass and landscape horticulture. His most recent contribution to *TurfGrass TRENDS* appeared in the July 1995 issue.

# Letter From the Publisher

Dear Readers:

You may have noticed some of the changes we made last year. Instead of the usual 16 pages, we now, if the subject warrants it, bring you 20 or even 24 pages of research reviews and updates.

In the December issue we included a 1995 pull-out article index, along with abstracts from January to December, in order to help you more easily locate the articles you need. This index will also help our new readers to order issues they might have missed.

You asked us to continue living up to our name and write about TRENDS in the turfgrass research community. You wanted us to continue providing you with in-depth review articles about the latest university research, as well as with practical application tips for you, the turf manager. You also asked us to leave out the things you get from other publications.

Our goal is to help you to stay abreast of the competition by providing you with continuing education. We will also keep you informed about trends and changes in the Environmental Protection Agency.

Our advisory board, which consists of lawncare professionals, golf course superintendents, sports facility greenkeepers, sod producers, and educators, provides the guidance our authors need to ensure that their articles focus on, and present solutions for, problems that affect you, the turfgrass manager.

While our editorial board has set the schedule for the upcoming year, we are always open to your suggestions for topics, changes or additions. We are here to serve you as best as we can and will make every effort to bring you the tools you need to stay ahead.

In response to a request to help you organize your visit to the many turf conferences and shows being held during the winter months, we are, in this issue, bringing you handy checklist and daily planner forms. We hope they will help you to organize your visit before you get to the registration desk. Since our authors are speakers at many of the conferences, take a little time to talk to them; they always welcome comments on their articles.

To help turf management schools with their shrinking budgets, we have established a favorable multiple and bulk subscription rate for educators and students. Please call us for details.

Take advantage of the half-price introductory offer for a three month subscription and introduce a colleague to *TurfGrass TRENDS*. It might be the most useful tool you have ever given a friend.

Wishing you a happy, healthy, and pest-free New Year.

Maria L. Haber

Maria L. Haber

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| Car Rental: | Telephone: | | Confirmation# |
| Hotel: | Address: | | Confirmation# |
| Telephone# | Fax# | | Deposit Sent: |
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| Packing List Prepared | | Emergency Contact: | |
| Miscellaneous: | ___Weather report | ___Local Maps | ___Restaurant/Event Guides |
| Presentation Materials Prepared: | | Materials Shipped: | |
| ___Brochures | ___Business Cards | ___Promotionals | ___Gifts: |
| Presentation Needs: | | Location: | |
| Equipment Needed: | | Local Contacts: | |

| **Calendar Preparation** | | | |
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