Postemergent Annual Bluegrass Control in Dormant Nonoverseeded Bermudagrass Turf

Joe E. Toler¹

Department of Applied Economics and Statistics, F-148 Poole Agricultural Center, Clemson University, Clemson, SC 29634-0375

Thomas G. Willis, Alan G. Estes, and Lambert B. McCarty

Department of Horticulture, E-143 Poole Agricultural Center, Clemson University, Clemson, SC 29634-0319

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Abstract. Annual bluegrass (*Poa annua* L.) can be a troublesome weed to control in established turfgrass stands; it has developed herbicide resistance after repeated use of products with similar modes of action, and several new herbicides have been registered for use on turfgrasses. Four field studies were conducted near Clemson, S.C., from 2003 through 2005 to evaluate postemergence annual bluegrass control in dormant, nonoverseeded bermudagrass [*Cynodon dactylon* (L.) Pers.] turf using various herbicides applied in either December or February of each year and rated in the spring. Annual bluegrass control can be accomplished in dormant, nonoverseeded bermudagrass turf using a wide range of products applied in either December or February. Flazasulfuron, foramsulfuron, glufosinate, glufosinate + clethodim, glufosinate + glyphosate, glyphosate + clethodim, glyphosate + diquat, pronamide, rimsulfuron, and trifloxysulfuron provided 87% or greater annual bluegrass control regardless of application timing. Imazaquin and simazine controlled annual bluegrass greater than 85% when applied in December but less than 80% when applied in February. Glyphosate provided 93% annual bluegrass control when applied in February but only 72% control with December applications. No detrimental effects on bermudagrass spring greenup were observed for any herbicide treatment or application time. The availability of several effective herbicide options with differing modes of action provides turfgrass managers with the opportunity to use herbicide rotations that may prevent, or at least delay, the development of resistant annual bluegrass populations to these chemical products.

Golf course superintendents constantly battle annual bluegrass infestations in golf course putting greens, fairways, and roughs. The weapons used against annual bluegrass have included herbicides, growth regulators, management practices, and natural biologic controls (Dernoeden, 2000). Annual bluegrass is a severe and troublesome weed in established turfgrass stands because it reduces aesthetic appearance by producing unsightly seedheads at mowing heights as low as 6 mm, affects ball roll as a result of its upright growth habit that produces an uneven surface, and dies out quickly as a result of summer heat stress, leaving unsightly dead and bare patches (Bingham et al., 1969; Hall and Carey, 1992).

Many biotypes of annual bluegrass are true winter annuals that germinate in early fall, remain in a vegetative state throughout

the winter, flower and become a prolific seed producer in the spring, and then succumb to heat stress as summer temperatures rise (Vargas and Turgeon, 2004). These biotypes typically have an upright growth habit and can predominate on golf courses in areas where moist, compact conditions are present (McCarty, 2005). A dormancy period followed by chilling is usually required to maximize germination of upright annual bluegrass seed (Lush, 1989; Wu et al., 1987). Beard et al. (1978) reported consistently high annual bluegrass germination rates (>80%) across a wide temperature range (7 to 29 °C), but determined that alternating day/night temperatures were necessary to achieve highest germination. Bogart (1972) found that annual bluegrass seedhead production occurred only after soil temperatures surpassed 15 °C. When seedheads are produced, a contaminated fairway can appear white in color with seeds easily tracked onto putting greens. The profuse seed production of annual bluegrass contributes to the soil seedbank in which dormant seed can remain viable for 6 years or longer (Roberts and Feast, 1973), ensuring its survival and proliferation.

A major concern is that annual bluegrass resistance to commonly used herbicides is increasing. There have been reports of annual bluegrass resistance to the triazine (Barros and Dyer, 1988; Darmency and Gasquez, 1981) and dinitroaniline (Isgrigg et al., 2002; Lowe et al., 2001) herbicide families after years of continued use. Hutto et al. (2004) noted 31 of 71 golf courses tested in Mississippi contained simazine-resistant annual bluegrass. Gressel and Segal (1978) warned that selection pressure exerted by exclusive use of a single herbicide family over time can contribute to resistance development.

Considerable research has focused on selectively controlling or suppressing annual bluegrass in cool-season turfgrasses with herbicides (Dernoeden and Turner, 1988; Johnson et al., 1989; Park et al., 2002) or plant growth regulators (Isgrigg et al., 1998; Johnson and Murphy, 1995; Neylan et al., 1997; Woosley et al., 2003); however, current peer-reviewed research on controlling annual bluegrass in dormant, nonoverseeded bermudagrass is lacking. Bispyribac-sodium is a recently introduced herbicide that targets the acetolactate synthase (ALS) enzyme and has been used to control annual bluegrass in creeping bentgrass fairways (Lycan and Hart, 2006; Park et al., 2002). Most other recently introduced herbicides registered for use on turfgrasses are in the sulfonylurea (SU) family and also inhibit ALS enzyme activity (Tranel and Wright, 2002).

Increases in annual bluegrass resistance to some commonly used herbicides and the recent introduction of several new herbicides that may offer new options for postemergent annual bluegrass control in turfgrasses prompted this investigation. The objectives of the research were to 1) evaluate annual bluegrass control in dormant, nonoverseeded bermudagrass turf using various herbicides and herbicide combinations, 2) examine effects of these herbicides on bermudagrass greenup the next spring, and 3) compare annual bluegrass control when herbicides are applied in December versus February.

Materials and Methods

Four studies were conducted from Dec. 2003 through Feb. 2005 to evaluate postemergent control of annual bluegrass in dormant, nonoverseeded bermudagrass turf. Studies 1 and 2 were conducted on a common bermudagrass golf course driving range in Anderson, S.C. Studies 3 and 4 were conducted on a hybrid bermudagrass (*Cynodon transvaalensis* × *Cynodon dactylon* 'Tifway') golf course fairway in Easley, S.C. Soil was a Cecil sandy loam (clayey, kaolinitic, thermic Typic Kanhapludults) with a soil pH of 5.4 and 5.6, respectively, for the Anderson and Easley locations. Each study was performed separately at different locations on the two golf courses.

Herbicide treatments and rates are listed in Table 1. The treatments were applied with a CO₂-pressurized backpack sprayer

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¹To whom reprint requests should be addressed; e-mail bmccarty@clemson.edu.

Table 1. Herbicide treatments and rates applied in annual bluegrass control studies conducted near Clemson, S.C., from 2003 to 2005.

Herbicide	Rate
Atrazine	2.24 kg·ha ⁻¹
Bispyribac-sodium	0.15 kg·ha ⁻¹
Diquat + NIS	0.56 kg·ha ⁻¹ + 0.5% v/v
Flazasulfuron + NIS	0.053 kg·ha ⁻¹ + 0.5% v/v
Foramsulfuron + NIS	0.028 kg·ha ⁻¹ + 0.5% v/v
Glufosinate + NIS	1.68 kg·ha ⁻¹ + 0.5% v/v
Glufosinate + clethodim + NIS	1.68 kg·ha ⁻¹ + 0.28 kg·ha ⁻¹ + 0.5% v/v
Glufosinate + glyphosate + NIS	1.68 kg·ha ⁻¹ + 0.56 kg·ha ⁻¹ + 0.5% v/v
Glyphosate + NIS	0.56 kg·ha ⁻¹ + 0.5% v/v
Glyphosate + clethodim + NIS	0.56 kg·ha ⁻¹ + 0.28 kg·ha ⁻¹ + 0.5% v/v
Glyphosate + diquat + NIS	0.56 kg·ha ⁻¹ + 0.56 kg·ha ⁻¹ + 0.5% v/v
Imazaquin	0.56 kg·ha ⁻¹
Metsulfuron + NIS	0.028 kg·ha ⁻¹ + 0.5% v/v
Pronamide	1.68 kg·ha ⁻¹
Rimsulfuron + NIS	0.035 kg·ha ⁻¹ + 0.5% v/v
Simazine	2.24 kg·ha ⁻¹
Sulfosulfuron + NIS	0.023 kg·ha ⁻¹ + 0.5% v/v
Trifloxysulfuron + NIS	0.034 kg·ha ⁻¹ + 0.5% v/v

NIS = nonionic surfactant.

calibrated at 187 L·ha⁻¹ using 8003 flat-fan nozzles. Two × 3 meter plots were used for each of the four studies, and plots were blocked at the initiation of each study to provide similar annual bluegrass densities within each block.

Treatments were applied on 14 Dec. 2003 and 21 Dec. 2004 for studies 1 and 3, respectively, and on 4 Feb. 2004 and 7 Feb. 2005 for studies 2 and 4, respectively. Atmospheric and soil temperatures at time of application are presented in Table 2. Annual bluegrass control was visually evaluated at several rating dates after herbicide application using a 0% to 100% rating scale with 0% = no control and 100% = complete control (80% was considered minimum acceptable control). Bermudagrass greenup was evaluated in the spring of 2004 and 2005 as a percentage of groundcover (0% to 100%).

The experimental design for each study was a randomized complete block with three replications. Results were transformed using an arcsine transformation before statistical analysis to achieve homogeneous variances. Annual bluegrass control and bermudagrass greenup data were statistically analyzed to evaluate main and interaction effects of treatments, application timings, and years (SAS Institute, Inc., 2005). The “multiple comparisons with the best (MCB)” procedure was used to select herbicide treatments into a subset such that the “best” treatment is included in the subset with $P = 0.05$ (Hsu, 1984). Linear contrasts were used to compare effectiveness of each herbicide treatment for December and February application dates using $\alpha = 0.05$. Analysis was performed on

results from the final spring rating date when annual bluegrass populations were greatest.

Results

No meaningful treatment-by-location, treatment-by-year, or application time-by-year interactions were detected ($P > 0.05$); therefore, results were combined across locations and years. However, application time-by-treatment interactions were noted ($P < 0.05$), so results are presented separately in Table 3 for December and February application times. Herbicide treatments included in the “best” subset for December applications provided greater than 85% annual bluegrass control, and herbicides in the “best” subset for February applications gave greater than 90% control.

The most encouraging result from these studies was that 10 of the herbicide treatments (rimsulfuron, trifloxysulfuron, flazasulfuron, glufosinate + clethodim, glufosinate, pronamide, foramsulfuron, glufosinate + glyphosate, glyphosate + diquat, and glyphosate + clethodim) were included in both “best” subsets and effectively controlled annual bluegrass (87% or greater) regardless of application time (Table 3). The other eight herbicide treatments (imazaquin, glyphosate, simazine, diquat, atrazine, bispyribac-sodium, sulfosulfuron, and metsulfuron) were either inconsistent (December versus February control was different) or ineffective (less than 80% control) on annual bluegrass in dormant bermudagrass turf.

Generally, postemergence herbicide applications to bermudagrass should be

avoided in early spring to prevent any delay in spring greenup. Fall applications of post-emergence herbicides may also delay spring greenup or cause permanent bermudagrass damage if applied before complete bermudagrass dormancy when green leaves and stolons are still present (Johnson, 1983). The herbicide application dates in this study were during complete bermudagrass dormancy, so no differences in bermudagrass spring greenup were observed for any of the herbicide treatments (data not shown).

Discussion

Postemergence herbicides are generally most effective when applied to immature, actively growing plants because herbicide absorption and translocation are maximized (Camacho and Moshier, 1991). This could help explain why December application of imazaquin and bispyribac-sodium provided greater control compared with February application (Table 3). Undoubtedly, these products did not provide sufficient residual activity to control annual bluegrass that germinated after the December application. A second application in February may be necessary to achieve acceptable control with these products.

Annual bluegrass typically undergoes a second germination flush when seeds are subjected to warm days and cool nights that often occur in the southeastern United States from mid-December through mid-January (McCarty, 1999). The fluctuation in day/night temperature can promote germination of annual bluegrass seeds present near the soil surface. However, cold temperatures can reduce annual bluegrass growth and development (Vargas and Turgeon, 2004), which may impact herbicide uptake and translocation by the target weed and reduce herbicide effectiveness and control. The annual bluegrass control provided in this study by the 10 herbicide treatments that were included in the “best” subset for each application time (Table 3) was not greatly affected by variation in environmental conditions.

The results for two herbicides, imazaquin and bispyribac-sodium, that provided more effective annual bluegrass control with December than February applications (Table 3) may be explained by differences in plant age and maturity at the two application times. By the February application, annual bluegrass plants could be more difficult to control with some herbicides because they have matured and are actively tillering. Glyphosate was the only herbicide achieving greater annual bluegrass control with February than with December application (Table 3). A plausible explanation is that this herbicide was more readily absorbed by annual bluegrass plants as a result of higher temperatures present during February compared with December applications (Table 2).

Sulfonylurea herbicides have been an important component of turfgrass weed management since the 1980s with the use of products such as metsulfuron and sulfometuron for broad-spectrum weed control in

Table 2. Atmospheric and soil temperatures at time of herbicide application.

Study	Application date	Temperature (°C)	
		Atmospheric	Soil at 4-inch depth
1	14 Dec. 2003	6	6
2	4 Feb. 2004	12	8
3	21 Dec. 2004	9	4
4	7 Feb. 2005	17	7

Table 3. Annual bluegrass control in dormant bermudagrass turf after December and February herbicide applications, 2003–2005.^z

Treatment ^y	Annual bluegrass control (%) ^x		December vs. February
	December	February	
Rimsulfuron + NIS	98*	99*	NS
Trifloxysulfuron + NIS	99*	97*	NS
Flazasulfuron + NIS	97*	97*	NS
Glufo + clethodim + NIS	94*	98*	NS
Glufo + NIS	90*	97*	NS
Pronamide	87*	99*	NS
Foramsulfuron + NIS	91*	95*	NS
Glufo + glyphosate + NIS	87*	97*	NS
Glyphosate + diquat	87*	97*	NS
Glyphosate + clethodim	89*	91*	NS
Imazaquin	91*	74	S
Glyphosate	72	93*	S
Simazine	86*	79	NS
Diquat + NIS	79	66	NS
Atrazine	61	70	NS
Bispyribac-sodium	74	39	S
Sulfosulfuron + NIS	59	52	NS
Metsulfuron + NIS	40	36	NS

^zRatings from late April when annual bluegrass pressure was greatest.

^yGlufo = glufosinate; NIS = nonionic surfactant added at 0.5% v/v.

^xMeans in a column followed by an asterisk were selected by the MCB procedure with $P = 0.95$ that the “best” treatment is selected.

^{ns}Nonsignificant ($P > 0.05$); S, significant ($P \leq 0.05$).

warm-season turfgrasses. This study demonstrates the effectiveness of several SU herbicides for postemergent annual bluegrass control in dormant nonoverseeded bermudagrass turf (Table 3) because four of the 10 “best” herbicide treatments for December and February applications were SU products (rimsulfuron, trifloxysulfuron, flazasulfuron, and foramsulfuron) that inhibit activity of the ALS enzyme. Fortunately, the modes of action of the remaining six “best” herbicide treatments that provided effective annual bluegrass control for both application times is different from the SU herbicides. The availability of several effective herbicides with differing modes of action would permit the use of herbicide rotations that may prevent, or at least delay, the development of resistant annual bluegrass populations.

Managing herbicide use is very important at a time when relatively few herbicides are being developed by chemical companies and when herbicide resistance is increasing. Herbicides that target the ALS enzyme are among the most widely used in the world but, unfortunately, are also the most notorious for selecting resistant populations (Tranel and Wright, 2002). With several effective herbicide options available for postemergent annual bluegrass control in dormant, nonoverseeded bermudagrass using either December or February applications, turfgrass managers should carefully consider using a rotation of herbicide products with different modes of action.

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