Application of Glufosinate on Dormant Zoysiagrass (*Zoysia japonica*) Turf

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Abstract. Winter application of glyphosate on dormant zoysiagrasses (*Zoysia* spp.) is a common practice for control of fall-emerging weeds in the upper transition zone. However, repeated application can lead to selection of resistant weed populations. This study evaluated glufosinate, another non-selective herbicide, for weed control and safety on dormant zoysiagrass turf. Field plots were established on three sites during two growing seasons. At two application timings, glufosinate at rates of 0.84 or 1.68 kg·ha⁻¹ were compared with glyphosate at 0.56 kg·ha⁻¹ and a nontreated control. Application timings included 2 to 3 weeks or 2 to 3 days before zoysiagrass spring green-up. Regardless of rate, glufosinate was similar in effectiveness to glyphosate for control of annual bluegrass (*Poa annua* L.) and mouseear chickweed (*Cerastium vulgatum* L.). Application timing significantly affected phytotoxicity on zoysiagrass turf. For applications at 2 to 3 weeks before initiation of zoysiagrass green-up in spring, no negative impact on zoysiagrass was found. However, when applications were made within days of zoysiagrass resuming growth, both glufosinate and glyphosate reduced turf quality up to 40%. This study suggests that glufosinate can be an alternative to glyphosate for weed management on dormant zoysiagrass turf, but applications should be timed at least 2 weeks before initiation of spring growth.

Zoysiagrass (*Zoysia japonica* Steud.) is a popular turfgrass species used in golf course fairways in Missouri and surrounding states (Lyman et al., 2007). Throughout this region, zoysiagrass enters dormancy typically in November and resumes growth in late March or early April (Dunn and Diesburg, 2004). Weed established in dormant zoysiagrass reduces the aesthetic value as well as the playability during winter and spring months. Various pre- and post-emergent herbicides can be effective for control of winter weeds on zoysiagrass turf (Harrell et al., 2005; Johnson, 1980; Vargas and Turgeon, 2004). However, the main strategy adopted by golf course superintendents in this region is winter application of the non-selective herbicide glyphosate (Velsor et al., 1989), which is an economical and effective tool for control of a broad spectrum of weeds.

One of the concerns with winter applications of glyphosate in dormant warm-season turf is possible/potential delay of spring green-up (Johnson, 1977; Johnson and Burns, 1985; Johnson and Ware, 1978). Besides variation in zoysiagrass species and environmental conditions (Rimi et al., 2012; Velsor et al., 1989), application timing is a critical factor influencing herbicide safety on zoysiagrass turf. A 2-year study conducted in Missouri found that glyphosate at 2.24 kg·ha⁻¹ on ‘Meyer’ zoysiagrass (*Z. japonica*) applied on 1 Mar. had no impact on turf quality, but the same applications made on 1 Apr. caused significant injury in late April and May (Velsor et al., 1989). At both application dates, zoysiagrass turf was apparently dormant despite the presence of green tissue at the base of stems for 3 to 5 or 5 to 8 mm in length for March and April application dates, respectively (Velsor et al., 1989). This indicates that characterization of zoysiagrass as dormant is difficult, complicating identification of a safe window for application of non-selective herbicides. For golf course superintendents, applications closer to spring green-up are more desirable than earlier applications, because the limited residual activity of non-selective herbicides such as glyphosate allows continued emergence of winter annuals. Application before spring is more desirable also because there is limited demand for use of zoysiagrass turf in the winter months (Ryan Sears, personal

communication). Therefore, it is critical to determine the proper timing window toward the end of winter for both effective weed control and optimum zoysiagrass safety.

Another concern for winter application of glyphosate on dormant warm-season turf is selection of herbicide-resistant weeds. Since the first report of resistant rigid ryegrass (*Lolium rigidum* Gaudin) in 1996 (Powles et al., 1998), there are 24 species worldwide today with reported resistance to glyphosate (Heap, 2012). A common factor that links the selection of resistant species is repeated application. On turf, the first reported glyphosate-resistant annual bluegrass (*Poa annua* L.) was identified in 2011 from a golf course fairway in Missouri (Binkholder et al., 2011). After more than 10 years of glyphosate applications in dormant ‘Meyer’ zoysiagrass at rates up to 0.62 kg·ha⁻¹, a biotype of annual bluegrass survived glyphosate at 6.27 kg·ha⁻¹, which is eight times the labeled rate. Similarly, after winter application of glyphosate at 0.84 kg·ha⁻¹ for 20 years, a population of glyphosate-resistant annual bluegrass was identified from a bermudagrass [*Cynodon dactylon* (L.) Pers.] turf in Tennessee (Brosnan et al., 2012).

Because winter application of non-selective herbicides for weed control on dormant warm-season turf is a common practice, alternative herbicides are desirable. Glufosinate, a non-selective, foliar-applied herbicide, can be used to control winter weeds in dormant bermudagrass turf (Tharp et al., 1999). Despite differences in toxicity for glyphosate (Carlson and Burnside, 1984) compared with glufosinate, most annual weed species, including barnyardgrass (*Echinochloa crusgalli* L.), fall panicum (*Panicum dichotomiflorum* L.), giant foxtail (*Setaria faberi* L.), and large crabgrass (*Digitaria sanguinalis* L.), responded similarly to glufosinate and glyphosate (Tharp et al., 1999). When applied on dormant bermudagrass turf, glufosinate at 1.68 kg·ha⁻¹ controlled annual bluegrass up to 93%, which was similar to the efficacy of 0.56 kg·ha⁻¹ glyphosate (Toler et al., 2007). Unlike glyphosate, which is translocated to the sink tissues including stolons and rhizomes in zoysiagrass, glufosinate is mainly directed to the apical-developing tissues (Grangeot et al., 2006). This characteristic could potentially improve the safety of glufosinate compared with glyphosate when applied to dormant zoysiagrass turf, especially when complete dormancy is difficult to determine.

Currently, the label for glufosinate does not include zoysiagrass for winter applications, and no report has documented the safety of glufosinate on dormant zoysiagrass. The objectives of this study were to: 1) evaluate the efficacy of glufosinate applied at two rates for control of winter weeds; and 2) determine the safety of glufosinate when applications were made within weeks or days before zoysiagrass breaking dormancy.

Material and Methods

Field plots were established at three distinct sites during two growing seasons. In

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2010, two studies were established at Columbia, MO, and Carbondale, IL. In 2011, one study was conducted at Columbia only. The soil was a Mexico silt loam (Udolic Ochraqulf) in Columbia and a Hosmer, fine-silty, mixed mesic Fragic Hapludalf at Carbondale. For each study, treatments included glufosinate at two rates, 0.84 or 1.68 kg·ha⁻¹, glyphosate at 0.56 kg·ha⁻¹, and a nontreated control. Treatments were applied at two different timings on dormant zoysiagrass; the first timing corresponded to 2 to 3 weeks before spring green-up, and the second timing was 2 to 3 d before spring green-up (Table 1). The initiation of green foliar tissue was considered the occurrence of spring green-up, and the timing of green-up was estimated based on historical records and scouting at each site. Soil temperatures at 10-cm depth were also recorded each time when treatments were applied (Toler et al., 2007). In Columbia, 2010 applications were made on 16 and 29 Mar., where soil temperatures at a 10-cm depth were 5.6 and 8.9 °C, respectively. In 2011, applications were made on 18 Mar. and 7 Apr. with corresponding soil temperatures at a 10-cm depth of 6.1 and 10.0 °C, respectively. At Carbondale, applications were made on 5 and 20 Mar. 2010, where soil temperatures at a 10-cm depth were 2.8 and 8.9 °C, respectively. The weather information was recorded by weather stations located at the research facilities where the experiments were conducted in both Columbia and Carbondale.

At Columbia, separate field plots measuring 1.5 × 3.0 m were established on mature 'Zenith' zoysiagrass (*Z. japonica*) turf in 2010 and 2011 at the Turfgrass Research Center on the University South Farm. At Carbondale, treatments were applied to mature 'Meyer' zoysiagrass on plots measuring 1.8 × 1.8 m in 2010 at the Turfgrass Research Facility. All treatments were applied with a CO₂ pressurized backpack sprayer calibrated to deliver 374 L·ha⁻¹ at a spray pressure of 276 kPa using TeeJet XR8004 flat fan nozzles (Spraying Systems Co., Wheaton, IL). During this experiment, plot areas were not irrigated. Mowing was delayed until zoysiagrass started to green-up, and then the plots were maintained at 2- and 5-cm heights at Columbia and Carbondale, respectively. All sites were not fertilized during the experimental period until zoysiagrass turf reached complete green-up in mid- to late June.

Visual assessments of treatment effects included percent weed infestation and turf quality. Percent weed infestation for individual species and total weeds was evaluated using a 0% to 100% rating scale with 0 = no weeds and 100 = complete weed coverage. Percent weed cover for individual species, including annual bluegrass, mouseear chickweed (*Cerastium vulgatum* L.), dandelion (*Taraxacum officinale* L.), and white clover (*Trifolium repens* L.), was evaluated at 3 and 5 weeks after initial treatment (WAIT). To simplify the discussion, only results for annual bluegrass and mouseear chickweed are included in this report and discussed individually. Percent total weed cover was evaluated

every other week throughout the experiment at all three sites. Percent total weed covers were calculated as the area under percent weed curve (AUPWC), which represents the cumulative effect of weed infestation and is calculated by the equation:

$$\text{AUPWC} = \sum_{i=1}^{n-1} \{[(X_{i+1} + X_i)/2](t_{i+1} - t_i)\} \quad [1]$$

where X_i = percent weed coverage at the i^{th} observation, t_i = days after initial treatment at the i^{th} observation, and n = number of total observations (Campbell and Madden, 1990). A lower AUPWC value indicates less weed infestation during the study period for a given herbicide treatment. Turf quality was evaluated on a 1 to 9 scale where 1 represented total dead or dormant turf, 9 was the ideal turf quality with 100% green canopy, and 6 indicated minimally acceptable turf quality. Evaluations were initiated at the time of treatment application and continued until 100% green-up in nontreated plots was reached.

Treatments were arranged in a randomized complete block design with four replications at all sites. Analysis of variance was conducted using the PROC MIXED program in SAS 9.2 (SAS Institute, Cary, NC). There was a significant treatment-by-study interaction for all parameters. Therefore, data are presented separately for each study. Mean separation was conducted using Fisher's protected least significant difference at $P = 0.05$.

Results and Discussion

Glufosinate efficacy. Weed control efficacy varied among treatment application timings

and weed species. In Columbia, glufosinate applications in 2010 significantly reduced annual bluegrass cover regardless of application timing or rate (Table 1). No differences were found from application timing or rate for all glufosinate treatments at 5 WAIT, and the treated plots showed up to 89% annual bluegrass control (Table 1). Glyphosate-treated plots showed a similar effectiveness in annual bluegrass control compared with glufosinate, and annual bluegrass cover was similar for early and later application timings at 5 WAIT. Similarly, at 3 WAIT, mouseear chickweed percent cover was significantly reduced by glufosinate applications, regardless of application timing or rate (Table 1). Glyphosate was similar to glufosinate and no statistical differences were found in control of mouseear chickweed at 3 WAIT. These results support an earlier report in which glufosinate provided similar or greater control of annual bluegrass compared with glyphosate when applied in December or February on dormant bermudagrass turf (Toler et al., 2007). At 5 WAIT, mouseear chickweed plants were dead in all treated plots and present in only the nontreated control plots at a low level (Table 1). This was likely the result from the natural dynamics of the seasonal ending of the life cycle of mouseear chickweed (Watschke et al., 1995).

In 2011 at the Columbia site, annual bluegrass infestations in the nontreated control area were low with only 0.5% coverage observed in April (Table 2). The infestation of annual bluegrass in treated plots remained statistically similar compared with the nontreated control, except for glufosinate at 1.68 kg·ha⁻¹ applied on 7 Apr. Complete expression of glufosinate activity requires 10 to 14 d

Table 1. Treatment effect on annual bluegrass and mouseear chickweed percent cover (%) evaluated at 3 and 5 weeks after initial treatment (WAIT) in 2010 at Columbia, MO.

Treatment	Rate (kg·ha ⁻¹)	Application date	Annual bluegrass percent cover (%)		Mouseear chickweed percent cover (%)	
			3 WAIT	5 WAIT	3 WAIT	5 WAIT
Control	—	—	3.8	7.5	2.3	0.5
Glufosinate	0.84	16 Mar.	1.0	2.0	0.3	0.0
Glufosinate	1.68	16 Mar.	0.3	0.8	0.5	0.0
Glyphosate	0.56	16 Mar.	0.5	0.0	1.3	0.0
Glufosinate	0.84	29 Mar.	0.8	3.5	0.3	0.0
Glufosinate	1.68	29 Mar.	2.3	1.5	0.3	0.0
Glyphosate	0.56	29 Mar.	2.8	0.8	0.8	0.0
LSD ($P = 0.05$)			1.4	3.4	1.2	NS ²

²NS represents nonsignificant using Fisher's protected least significant difference (LSD) ($P = 0.05$).

Table 2. Treatment effect on annual bluegrass and mouseear chickweed percent cover (%) evaluated at 3 and 5 week after initial treatment (WAIT) in 2011 at Columbia, MO.

Treatment	Rate (kg·ha ⁻¹)	Application date	Annual bluegrass percent cover (%)		Mouseear chickweed percent cover (%)	
			3 WAIT	5 WAIT	3 WAIT	5 WAIT
Control	—	—	0.5	0.5	1.3	0.5
Glufosinate	0.84	18 Mar.	0.5	0.8	0.5	0.3
Glufosinate	1.68	18 Mar.	1.8	2.3	0.8	0.3
Glyphosate	0.56	18 Mar.	0.5	0.8	2.8	0.5
Glufosinate	0.84	7 Apr.	1.0	0.3	0.0	0.0
Glufosinate	1.68	7 Apr.	3.5	2.0	0.0	0.0
Glyphosate	0.56	7 Apr.	0.3	0.0	0.8	0.0
LSD ($P = 0.05$)			1.4	NS ²	1.4	NS

²NS represents nonsignificant using Fisher's protected least significant difference (LSD) ($P = 0.05$).

(Grangeot et al., 2006), and the evaluation made at 3 WAIT occurred only 6 d after application. Therefore, the relatively higher (3.5%) annual bluegrass cover in the plots treated with glufosinate at 1.68 kg·ha⁻¹ may have been influenced by the short duration between application and evaluation. By 5 WAIT, annual bluegrass cover in these plots had declined by 57%, and no statistical differences were found among treatments (Table 2). Similarly, low mouseear chickweed cover was found in nontreated plots, and herbicides did not significantly reduce weed cover by 3 WAIT. Like in 2010, glyphosate resulted in statistically similar or lower efficacy than glufosinate for management of mouseear chickweed (Table 2).

At the Carbondale site, annual bluegrass coverage was much higher (16.8% vs. 3.8% in the nontreated control at 3 WAIT) compared with coverage at the Columbia sites (Table 3). Similar to the Columbia sites, efficacy on weed coverage varied among treatments and application timings. At 3 WAIT, all treatments significantly reduced annual bluegrass cover, except glyphosate applied at the late timing (20 Mar.). At 5 WAIT, glufosinate at 0.84 kg·ha⁻¹ for both timings resulted in numerically but not statistically lower annual bluegrass cover compared with the nontreated control. However, when applied at 1.68 kg·ha⁻¹, glufosinate significantly reduced annual bluegrass cover by 72% or 64%, respectively, for applications made on 5 or 20 Mar. Glyphosate at 0.56 kg·ha⁻¹ applied on 5 Mar. reduced annual bluegrass cover by 98% compared with only a 44% reduction in annual bluegrass cover after the 20 Mar. application. Coverage of mouseear chickweed in Carbondale was minimal (less than 1%), and hence no treatment effect was observed.

The cumulative effect of total weed infestation over the duration of the experiment is presented as AUPWC (Table 4). At the

Columbia sites, glufosinate and glyphosate applied in 2010 significantly reduced overall weed coverage by a range of 59% to 89% regardless of application timing. No statistical differences between the two rates of glufosinate were measured at either application date. Similarly, no significant difference between glufosinate and glyphosate was found, suggesting that weed control efficacy was similar at both timings. In 2011, overall low weed infestations were observed. The

plot area was not irrigated during this experiment, and limited precipitation in 2011 (60% reduction) compared with 2010 likely resulted in low weed infestations observed in this study. However, despite lower overall weed cover, glufosinate and glyphosate significantly reduced AUPWC by a range of 48% to 86% compared with the nontreated control. Like in 2010, no differences in AUPWC between glufosinate and glyphosate were found at either application date. These

Table 3. Treatment effect on annual bluegrass and mouseear chickweed percent cover (%) evaluated at 3 and 5 week after initial treatment (WAIT) in 2010 at Carbondale, IL.

Treatment	Rate (kg·ha ⁻¹)	Application date	Annual bluegrass percent cover (%)		Mouseear chickweed percent cover (%)	
			3 WAIT	5 WAIT	3 WAIT	5 WAIT
Control	—	—	16.8	19.3	0.5	0.3
Glufosinate	0.84	5 Mar.	10.8	12.3	0.0	0.0
Glufosinate	1.68	5 Mar.	7.8	5.5	0.3	0.0
Glyphosate	0.56	5 Mar.	2.3	0.3	0.0	0.3
Glufosinate	0.84	20 Mar.	7.8	12.8	0.0	0.3
Glufosinate	1.68	20 Mar.	8.5	7.0	1.3	0.0
Glyphosate	0.56	20 Mar.	16.3	10.5	0.0	0.0
LSD (<i>P</i> = 0.05)			4.7	7.5	NS ^z	NS

^zNS represents nonsignificant using Fisher's protected least significant difference (LSD) (*P* = 0.05).

Table 4. Area under percent weed curve (AUPWC) influenced by treatment applied at Columbia, MO, in 2010 and 2011, and at Carbondale, IL, in 2010.

Treatment	Rate (kg·ha ⁻¹)	Application date		Application date		Application date	
		Columbia, 2010		Columbia, 2011		Carbondale, 2010	
Control	—	—	1099	—	560	—	1692
Glufosinate	0.84	16 Mar.	451	18 Mar.	220	5 Mar.	1294
Glufosinate	1.68	16 Mar.	221	18 Mar.	232	5 Mar.	937
Glyphosate	0.56	16 Mar.	226	18 Mar.	294	5 Mar.	1184
Glufosinate	0.84	29 Mar.	174	7 Apr.	78	20 Mar.	1208
Glufosinate	1.68	29 Mar.	120	7 Apr.	227	20 Mar.	1107
Glyphosate	0.56	29 Mar.	205	7 Apr.	269	20 Mar.	1752
LSD (<i>P</i> = 0.05)			588	195		NS ^y	

^zArea under percent weed curve was calculated by the equation: $AUPWC = \sum \{(X_{i+1} + X_i)/2\}(t_{i+1} - t_i)$, where X_i = percent total weed coverage at the i th observation, t_i = days after treatment at the i th observation, and n = number of total observations.

^yNS represents nonsignificant using Fisher's protected least significant difference (LSD) (*P* = 0.05).

Fig. 1. Zoysiagrass turf quality influenced by winter application of glufosinate at 0.84 or 1.68 kg·ha⁻¹ (designated as “low” or “high,” respectively), glyphosate at 0.56 kg·ha⁻¹, and a nontreated control. Applications were made at two dates, 16 and 29 Mar. 2010 (designated as “early” or “late,” respectively), at Columbia, MO. Turf quality was assessed on a 1 to 9 scale during the spring green-up, where 1 represents total dead or dormant turf, 9 is the ideal turf quality with 100% green canopy, and 6 indicates the minimally acceptable turf quality. The vertical bar indicates Fisher's Protected least significant difference (LSD) at *P* = 0.05 for comparisons of significant differences between treatments at a given evaluation date.

results agree with an earlier study that the efficacy of glufosinate and glyphosate is similar at recommended rates (Tharp et al., 1999). In Carbondale, although numerically the AUPWC for glufosinate- and glyphosate-treated plots was overall lower compared with the nontreated control, differences were not statistically significant. Variability in the incidence of annual bluegrass likely precluded treatment differentiation.

Glufosinate safety. The time period for zoysiagrass to initiate new growth and reach full green-up was ≈ 4 weeks at all sites (Figs. 1 to 3). In each situation, a short lag phase in turf quality was followed by an exponential increase. Although there did not appear to be an influence of glyphosate or glufosinate on the

initiation of green-up, application timing did impact the overall turf quality in spring months.

In 2010, zoysiagrass in Columbia started to break dormancy in early April and reached 100% green coverage, indicated by the turf quality rating of 9, by early May (Fig. 1). From mid-April until the beginning of May, chemical applications at the early timing (16 Mar.) appeared to reduce zoysiagrass turf quality by 10% to 21%. However, applications on 29 Mar. had a more pronounced influence, reducing turf quality by 15% to 33%. The reduction in turf quality was transient, and no differences were measured by mid-May.

The pattern of zoysiagrass turf quality changes was similar in 2011 compared with 2010, but initiation of turf growth occurred

over a longer period of time (Fig. 2). For the 18 Mar. herbicide applications, reductions in zoysiagrass turf quality were small, ranging from 0% to 20% over the course of the experiment. However, between 14 Apr. and 29 May, turf quality was significantly reduced by the later application (7 Apr.) of glyphosate (2% to 37%) and the higher rate of glufosinate (11% to 25%). The soil temperature at a 10-cm depth was 10.0 °C on 7 Apr. at the second timing. According to Beard (1973), zoysiagrass resumes growth when soil temperatures reached 10 °C. Although zoysiagrass appeared to be dormant on 7 Apr., some level of metabolic activity (Velsor et al., 1989) may have resulted in limited herbicide activity. By late May, zoysiagrass approached

Fig. 2. Zoysiagrass turf quality influenced by winter application of glufosinate at 0.84 or 1.68 kg·ha⁻¹ (designated as “low” or “high,” respectively), glyphosate at 0.56 kg·ha⁻¹, and a nontreated control. Applications were made at two dates, 18 Mar. and 7 Apr. 2011 (designated as “early” or “late,” respectively), at Columbia, MO. Turf quality was assessed on a 1 to 9 scale during the spring green-up, where 1 represents total dead or dormant turf, 9 is the ideal turf quality with 100% green canopy, and 6 indicates the minimally acceptable turf quality. The vertical bar indicates Fisher’s protected least significant difference (LSD) at $P = 0.05$ for comparisons of significant differences between treatments at a given evaluation date.

Fig. 3. Zoysiagrass turf quality influenced by winter application of glufosinate at 0.84 or 1.68 kg·ha⁻¹ (designated as “low” or “high,” respectively), glyphosate at 0.56 kg·ha⁻¹, and a nontreated control. Applications were made at two dates, 5 and 20 Mar. 2010 (designated as “early” or “late,” respectively), at Carbondale, IL. Turf quality was assessed on a 1 to 9 scale during the spring green-up, where 1 represents total dead or dormant turf, 9 is the ideal turf quality with 100% green canopy, and 6 indicates the minimally acceptable turf quality. The vertical bar indicates Fisher’s protected least significant difference (LSD) at $P = 0.05$ for comparisons of significant differences between treatments at a given evaluation date.

full recovery and no treatment effect was detected.

At the Carbondale location, zoysiagrass resumed growth over a longer time period than the Columbia experiments in May 2010 (Fig. 3). Herbicide application timing significantly impacted zoysiagrass turf quality during green-up. None of the applications at the earlier timing (5 Mar.) delayed zoysiagrass development. Our results agree with Toler et al. (2007) who reported that neither glufosinate at 1.68 kg·ha⁻¹ nor glyphosate at 0.56 kg·ha⁻¹ delayed bermudagrass spring green-up when applications were made at soil temperatures below 10 °C. However, for applications at the later timing (20 Mar.), turf green-up was delayed and therefore turf quality was reduced up to 39% (Fig. 3). Glyphosate appeared more influential than glufosinate and reduced zoysiagrass turf quality by 18% to 39% compared with the nontreated control. In comparison, glufosinate applied at the 20 Mar. timing reduced zoysiagrass turf quality by 4% to 28% regardless of rate. Soil temperatures on 20 Mar. were 8.9 °C, close to the temperature (10 °C) reported to trigger spring green-up (Beard, 1973). It was likely that despite the apparently dormant appearance, the zoysiagrass plants were metabolically active at this stage and were therefore more vulnerable to herbicides applied (Velsor et al., 1989).

Glufosinate and glyphosate exhibited similar efficacy on annual bluegrass and mouseear chickweed in dormant zoysiagrass turf. However, the timing of applications was important to zoysiagrass safety. When applications were made at 2 to 3 weeks before breaking dormancy, both glufosinate and glyphosate had minimal impact on zoysiagrass turf quality during green-up. Delaying herbicide applications until 2 to 3 d before zoysiagrass breaking

dormancy resulted in significant delays in zoysiagrass development regardless of using glufosinate or glyphosate. Our study suggests that glufosinate appears similar to glyphosate for reducing weed incidence and impacting zoysiagrass turf quality during spring green-up. Adoption of glufosinate as a later winter application should be considered further and can be an effective tool to minimize selection of additional weed species resistant to glyphosate.

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