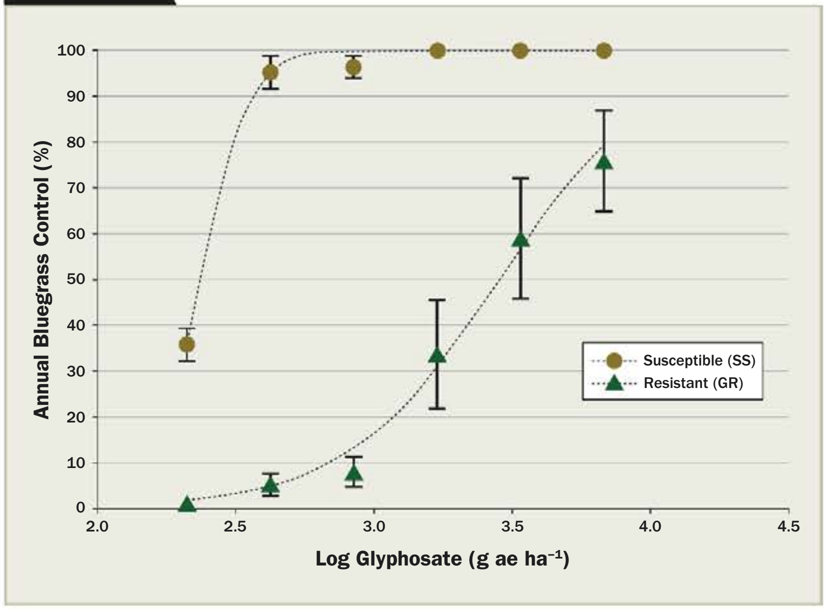
//**HERBICIDE RESISTANCE**

Glyphosate resistance in turf: A problem on the horizon

By James T. Brosnan, Ph.D., and Gregory K. Breeden

The prevalence of herbicide-resistant weed biotypes is an issue challenging all agricultural producers. Currently, there are 396 biotypes across 210 weed species that exhibit some degree of herbicide resistance (Heap 2013) and the rate at which herbicide-resistant biotypes are emerging is increasing. To date, 19 different species with glyphosate resistance have been identified, all resulting from widespread use of glyphosate for broad-spectrum weed control (Heap 2013).

FIGURE 1



Effect of herbicide treatment on control of glyphosate-resistant (GR) and glyphosate-susceptible (SS) annual bluegrass 14 days after treatment. Points represent treatment means, and lines represent the predicted response as determined by log-logistic regression analysis. Log-transformed rates correspond to 8, 16, 32, 64, 128, and 256 fl. oz. /A.

Glyphosate is labeled for broadleaf and grassy weed control in dormant bermudagrass turf at rates of 5 to 44 fl. oz. /A (Anonymous 2010). Glyphosate is commonly used to control annual bluegrass in dormant bermudagrass fairways and roughs, as efficacy with other herbicides, particularly those inhibiting acetolactate synthase (ALS) such as foramsulfuron (Revolver) and bispyribac-sodium (Velocity), can be negatively affected by cold temperature conditions in winter and early spring (Lycan and Hart 2006; Hutto et al. 2008; Willis 2008).

Additionally, glyphosate applications provide turf managers with a more economical option for broad-spectrum winter weed control than the aforementioned ALS inhibitors. Thus, many annual bluegrass populations on golf courses are under yearly glyphosate selection pressure, and superintendents have limited the diversity of herbicides used for control; both of these phenomena have been identified as principal factors in the development of glyphosate-resistant weeds (Duke and Powles 2009). That being said, only a single biotype of annual bluegrass found in golf course turf has shown resistance to glyphosate applications (Binkholder et al. 2011). Glyphosate-resistant annual bluegrass is of concern given this species' prolific seed production and long-term seed viability (Roberts and Feast 1973). Moreover, annual bluegrass biotypes resistant to atrazine, prodiamine, simazine and diuron have also been reported (Heap 2013). A biotype of annual bluegrass at Humboldt Golf and Country Club (Humboldt, Tenn.) was not controlled following treatment with glyphosate at 32 fl. oz. /A during bermudagrass dormancy.

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The golf course superintendent made

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a single application of glyphosate at 32 fl. oz. /A every year from 1990 to 2009 to control weeds during bermudagrass dormancy (David Green, personal communication). The objective of this research was to determine the sensitivity of a potentially glyphosate-resistant annual bluegrass biotype collected from this location.

MATERIALS AND METHODS

Three standard golf course cup cores were removed from the third fairway at Humboldt Golf and Country Club on February 17, 2010, using a cup cutter. Each core contained mature annual bluegrass plants suspected to be glyphosate resistant.

These glyphosate-resistant plants had not been treated with any herbicide after emerging in the fall of 2009. A biotype known to be susceptible to glyphosate was harvested in the same manner from the East Tennessee Research and Education Center (Knoxville, Tenn.)

Considering that annual bluegrass is a self-pollinated species (Ellis 1973) and seed was limited, individual tillers of the glyphosate-resistant and glyphosate-susceptible biotypes were used in greenhouse experiments. Individual glyphosate-resistant and glyphosate-susceptible tillers were removed from cores harvested in the field and transplanted into containers filled with a peat moss growing medium.

Tillers of the glyphosate-resistant and glyphosate-susceptible biotypes were maintained under controlled greenhouse conditions for five weeks prior to initiating research. During the five-week acclimation period, plants were irrigated to prevent the onset of wilt and clipped daily at a height of ~2 in. Plants were fertilized with a complete fertilizer to promote active growth.

GREENHOUSE EXPERIMENTS

Both glyphosate-resistant and glyphosate-susceptible plants were treated with glyphosate (Roundup ProMax., Monsanto) at 0, 8, 16, 32, 64, 128 and 256 fl. oz. /A using a CO2-powered backpack boom sprayer containing flat-fan nozzles calibrated to deliver 30 gpa of spray volume. Annual bluegrass control was evaluated visually on a 0 (no injury) to 100 percent (complete kill) scale at 7 and 14 days after treatment. Measurements of photochemical efficiency were made on each evaluation date to provide a quantitative assessment of plant response to glyphosate treatment.

Experimental design was a randomized complete block with four replications that was repeated in time. I50 values were calculated for each biotype to determine the rate of glyphosate giving a 50 percent response (i.e., 50 percent annual bluegrass control).

RESULTS AND DISCUSSION

Responses of the glyphosate-resistant and glyphosate-susceptible biotypes to increasing rates of glyphosate varied (Figure 1, pg. 38.) At 14 days after treatment, glyphosate controlled the susceptible biotype >95 percent at rates greater than 16 fl. oz. /A. Comparatively, the resistant biotype was only controlled 76 percent with glyphosate at 256 fl. oz. /A. I50 values for resistant and susceptible biotypes were 107 and 9 g a.e. ha-1, resulting in a resistance factor (RF) of 12.

Moreover, photochemical efficiency values on resistant plants were not significantly different from the untreated control with glyphosate rates ≤ 32 fl. oz.

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TABLE 2

Herbicidal modes of action with activity against annual bluegrass in golf course turf

Timing	Mode action	Active ingredient†
PRE	Mitotic inhibition	Benefin (Balan)
		Dithiopyr (Dimension)
		Oryzalin (Surflan)
		Pendimethalin (Pendulum)
		Prodiamine (Barricade)
		Trifluralin (Treflan)
	Lipid biosynthesis inhibition	Bensulide (Bensumec)
	Protoporphyrinogen oxidase (PPO) inhibition	Oxadiazon (Ronstar)
PRE/POST	Mitotic inhibition	Dimethenamid (Tower)
		Pronamide (Kerb)
	Photosystem II inhibition	Amicarbazone (Xonerate)
		Atrazine (Aatrex)
		Metribuzin (Sencor)
		Simazine (Princep)
	Cellulose biosynthesis inhibition	Indaziflam (Specticle)
	Lipid biosynthesis inhibition	Ethofumesate (Prograss)
	Carotenoid biosynthesis inhibition	Mesotrione (Tenacity)
POST	Acetolactate synthase (ALS) inhibition	Bispyrabic-sodium (Velocity)
		Chlorsulfuron (Corsair)
		Flazasulfuron (Katana)
		Foramsulfuron (Revolver)
		Imazaquin (Image)
		Imazapic (Plateau)
		Metsulfuron (Manor)
		Rimsulfuron (TranXit)
		Sulfosulfuron (Certainty)
		Trifloxysulfuron (Monument)
	Enolpyruvyl Shikimate-3 Phosphate (EPSP) synthase inhibition	Glyphosate (Roundup)
	Glutamine synthetase inhibition	Glufosinate (Finale)
	Photosystem I inhibition	Diquat (Reward)
		Paraquat (Gramoxone)

† Active ingredients may be available under multiple trade names. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the University of Tennessee Institute of Agriculture. The omission of a particular trade name is not intended to reflect adversely, or to show bias against, any product or trade name not mentioned. Always refer to the product label for specific information on proper use, tank-mixing compatibility and turfgrass tolerance.

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/A by 14 days after treatment, suggesting that photosynthesis was not affected by glyphosate at these rates. Susceptible plants treated with glyphosate at > 8 fl. oz. /A yielded photochemical efficiency values of 0.000 by 14 days after treatment, indicating that plants had been killed (i.e., no photosynthesis was occurring).

MOVING FORWARD

This research represents the first instance of a weed species having glyphosate resistance in bermudagrass turf. While not compared directly, the level of resistance in the glyphosate-resistant biotype from Tennessee is greater than that reported for a glyphosate-resistant annual bluegrass biotype infesting zoysiagrass turf in Missouri (Binkholder, 2011) and higher than what has been reported for many other grassy weeds in non-turf settings.

Transfer of resistance traits through pollen dispersal or seed movement is not likely in self-pollinated species such as annual bluegrass, where gene flow in managed turfgrass settings is limited (Ellis 1973; Ng et al. 2004; Sweeney and Danneberger 1995).

Rather, glyphosate-resistant biotypes may emerge at specific locations after repeated use of glyphosate for weed control in dormant bermudagrass turf. Such was the case at Humboldt Golf and Country Club, where the golf course superintendent regularly applied glyphosate at 32 fl. oz./A for nearly 20 years. Superintendents should rotate herbicidal modes of action used to control winter annual weed species in dormant bermudagrass turf.

The golf course superintendent at Humboldt Golf and Country Club was able to control this glyphosate-resistant biotype of annual bluegrass with the use of a photosystem II inhibitor (simazine) the following season. It should be noted, though, that continued use of simazine alone would just increase selection pressure for simazine-resistant annual

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bluegrass biotypes.

Alternative modes of action need to be used in regular rotation to guard against resistance development. This will involve using different chemistries at both pre- and postemergent timings. A list of herbicidal modes of action with activity against annual bluegrass is presented in Table 1 (pg. 40). In addition to rotating herbicides annually, tank-mixing active ingredients varying in mode of action can help mitigate the onset of herbicide resistance. However, modes of action included in these tank mixtures should also be rotated regularly.

Weed management programs focused on preventing the onset of herbicide resistance may be more costly than historical maintenance practices of applying the same product year after year. However, the investment in a rotation program will pay off in the long run as weed management costs have been shown to increase dramatically in crop production due to the evolution of herbicide-resistant weeds (Norsworthy et al. 2012).

Future research will evaluate programs for managing herbicide-susceptible annual bluegrass and other weeds in turf with alternative chemistries in rotation to prevent the evolution of new herbicide-resistant biotypes.

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