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Deertongue (*Dichanthelium clandestinum* L.) control in golf course naturalized areas

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Research Article

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Dicamba; fluazifop; glyphosate; iodosulfuron; imazapic; thiencarbazone; topramezone; deer tongue, *Dichanthelium clandestinum* L. (Gould); fine fescue, *Festuca* spp.

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Abstract

Deertongue is a perennial, warm-season grass, and is problematic in naturalized areas of golf courses due to limited control options. Research was conducted to evaluate several herbicides for deertongue control in naturalized areas consisting primarily of fine fescue. Greenhouse studies assessed 24 herbicide admixtures and indicated that fluazifop, glyphosate, imazapic, and thiencarbazone + iodosulfuron + dicamba (TID) reduced deertongue biomass by >80% at 10 wk after initial treatment (WAIT). Subsequent field trials were conducted on golf course naturalized areas. The first site was on a woodland edge and was partially shaded for 6 h each day, and the second trial site was 50 m away from the woodland edge and not subjected to more than 1 h of daily shade. At 9 WAIT, fluazifop at 420 g ai ha^{-1} applied once or three times at 3-wk intervals and topramezone at 37 g ai ha^{-1} applied thrice at 3-wk intervals injured fine fescue by ≤10% at both sites. Glyphosate applied at 1,120 g ae ha^{-1}, imazapic at 105 g ai ha^{-1}, and imazapic at 53 g ai ha^{-1} tank-mixed with glyphosate at 560 g ae ha^{-1} injured fine fescue by ≥50% under shaded conditions, whereas glyphosate alone did not injure fine fescue under sunny conditions. Fine fescue was completely recovered by 52 WAIT from injury following herbicide treatments, except for glyphosate-containing treatments at the shaded site and glyphosate + imazapic at both sites. At 52 WAIT, glyphosate-containing treatments and sequential applications of fluazifop controlled deertongue by ≥93% and reduced shoot density to ≤5 shoots m^{-2} averaged over both sites. Fluazifop at 420 g ha^{-1} applied thrice at 3-wk intervals selectively controls deertongue with excellent safety to fine fescue. Glyphosate also controls deertongue, but unacceptably injures fine fescue when managed under shaded conditions. Future research will assess how different light intensities influence fine fescue epicuticular wax deposits and associated response to glyphosate.

Introduction

Deertongue is a perennial, warm-season grass native to the eastern United States and southeastern Canada (Gould and Clark 1978; Hitchcock 1951; USDA-NRCS 2015a). Deertongue possesses chasmogamous and cleistogamous flowers on the same plant, where chasmogamous flowers are produced in early summer on expanded panicles and cleistogamous flowers are produced in late summer and fall on reduced panicles enclosed within the leaf sheath (Bell and Quinn 1986). Deertongue is primarily used to revegetate disturbed areas where conditions are not congenial for other species such as sandy infertile soil, soil with a pH of 3.8, or soil with aluminum toxicity (Sharp 1977; USDA-NRCS 2015a, 2015b). Deertongue also provides food and cover for wildlife because it is consumed by deer, gamebirds, and songbirds common to the northeastern United States (USDA-NRCS 2015b). However, the low nutrient content of deertongue limits its ability to serve as a preferred livestock forage (USDA-NRCS 2015b).

On a golf course, deertongue primarily grows in naturalized areas, producing a tall and dense cover that makes it almost impossible for a golfer to find and advance a golf ball from an errant shot (B. Kearns, personal communication). Deertongue produces short, vigorous rhizomes, and under favorable conditions can grow up to 1 m tall (USDA-NRCS 2015a). In the past decade, golf course superintendents have converted heavily maintained rough areas planted with high-input Kentucky bluegrass (*Poa pratensis* L.) to low-input grass species to reduce management costs and enhance the aesthetic appearance of otherwise highly monotonous turf stands (Cavanaugh 2014; Cavanaugh et al. 2011). The low-input types of turfgrass with similar functional and aesthetic qualities for naturalized areas are fine fescue species (*Festuca* spp.), which include Chewings fescue (*F. rubra* L. ssp. *commutata* Gaudin), hard fescue (*F. brevipila* Tracey), sheep fescue (*F. ovina* L.), slender creeping red fescue [*F. rubra* L. ssp. *littoralis* (G. Mey.) Acquier], and strong creeping red fescue (*F. rubra* L. ssp. *rubra* Gaudin) (Cavanaugh 2014). Deertongue and other troublesome weeds disrupt uniformity and playability when they infest naturalized areas on golf courses.

Deertongue control has not been reported in scientific literature. Based on growth habit and rhizome production, deertongue appears similar to bermudagrass (*Cynodon dactylon* L.), dallisgrass (*Paspalum dilatatum* Poir.), and orchardgrass (*Dactylis glomerata* L.), all of which are difficult to control (Anonymous 2016). Glyphosate broadcast application is generally recommended during complete renovation when perennial weed infestation is >50%; or a herbicide must be targeted directly to weedy plants if spot-treating, which is labor intensive (Anonymous 2016). Sequential applications of fenoxaprop alone or in combination with triclopyr have been reported to control bermudagrass by >94% in cool-season turfgrass (Cudney et. al. 1997). Triclopyr is generally tank-mixed with several herbicides that inhibit 4-hydroxphenylpyruvate dioxygenase (HPPD) and acetyl-Co-A carboxylase (ACCase) to improve weed control with safety to desirable turf (Brosnan and Breeden 2013; Cox et al. 2017; Cudney et al. 1997). Topramezone and mesotrione both with and without triclopyr selectively control problematic grass weeds without compromising turf safety (Brewer et al. 2017; Brosnan and Breeden 2013; Cox et al. 2017; Yu and McCullough 2016). Graminicides such as fluazifop, clethodim, sethoxydim, and herbicides such as imazapic, imazapyr, metsulfuron, chlorsulfuron that inhibit acetolactate synthase (ALS), constitute a major portion of herbicides used for perennial grass control in golf course naturalized areas (Bussan and Dyer 1999; Tu et al. 2001). ACCase-inhibiting herbicides are generally used for annual and perennial grassy weed control (Shaner 2014), but fluazifop and sethoxydim are safer to use on fine fescue (Braun et al. 2020; Cole et al. 2002). Fluazifop and sethoxydim are also effective at controlling perennial grass weeds such as torpedograss (*Panicum repens* L.) in citrus (Singh and Tucker 1986), but they require further evaluation for deertongue control.

Since deertongue issues appear to have increased with the increasing use of naturalized areas on golf courses due to limited management tools (Kenna 2021). Research experiments were conducted to 1) to identify viable herbicide programs to control deertongue based on weed chlorophyll content and biomass following several herbicide treatments in the greenhouse, and 2) to assess long-term deertongue control following selected herbicide treatments on a golf course naturalized area dominated by fine-leaf fescues.

Materials and Methods

Identifying Candidate Herbicide Mixtures

Two greenhouse trials were initiated in spring 2013 at the Glade Road Research Facility (37.23°N, 80.44°W) in Blacksburg, Virginia, to assess 24 different herbicides or herbicide combinations for deertongue control efficacy. Treatments were selected based on their use and efficacy in controlling perennial grass species among different cropping systems, pastures, turfgrass, landscapes, and ornamentals. The studies were implemented as a single factor, randomized complete block design with 25 treatments, replicated three times with two temporal runs. Deertongue rhizome mats were collected from naturalized areas at the Highland Course at Primland Resort (36.66°N, 80.43°W), in Meadows of Dan, Virginia. Rhizomes of uniform size were visually selected and a 10-cm length of rhizome with a single shoot was transplanted into 10 cm × 12 cm pots filled with a 2:1 ratio of Duffield silt loam (fine-loamy, mixed, active, mesic, Ultic Hapludalf) to Ernest silt loam (fine-loamy, mixed, superactive, mesic Aquic Fragiudult), pH 6.6, and with 4.3% organic matter. Plants were maintained in greenhouse conditions for 5 wk and were all three or four tillers in size with average shoot lengths of 20 to 30 cm at the time of treatment. Plants were sorted into blocks based on the number of tillers (three or four) and height to further ensure uniform plant size before herbicide treatment. The greenhouse was maintained at 27 ± 6 C with 420 µmol m^{-2} s^{-1} photosynthetically active radiation using high-pressure sodium bulbs under a 13-h photoperiod. Herbicide treatments, product names, manufacturers, and rates are listed in Table 1. Crop oil concentrate or nonionic surfactant was used as recommended by herbicide labels (Table 1). All treatments were sprayed in a spray chamber equipped with a single flat-fan nozzle (TeeJet 8001E spray nozzle; Spraying Systems Co., Glendal Heights, IL) calibrated to deliver 281 L ha^{-1} of spray solution at 275 kPa using a CO_2-pressurized tank.

Chlorophyll fluorescence ratio (CFR) was assessed from three random leaf samples per experimental unit (pot) using a leaf chlorophyll content meter (CCM-300; Opti-sciences, Inc., Hudson, NH). CFR refers to the fluorescence emission ratio intensity at F_{735}/F_{700} nm, and it provides direct readouts of chlorophyll content in milligrams per square meter (Gitelson et al. 1999). A 3-mm-diam circle on three deertongue leaves selected from the second fully expanded leaf of randomly chosen shoots was assessed using the CCM device to generate chlorophyll content readings. These data were assessed at 1, 2, 4, 6, and 10 wk after initial treatment (WAIT). Aboveground biomass from each experimental unit was harvested at the soil level by hand with scissors at 6 WAIT and again after regrowth at 10 WAIT. Aboveground biomass was oven-dried at 50 C for 72 h and then weighed to evaluate the differences in biomass accumulation among treatments.

Field Evaluation of Herbicide Performance

Best-performing treatments were selected from the greenhouse experiments for further evaluation in subsequent field experiments. Two trials were conducted in summer 2014 on a naturalized area at The Highland Course of Primland Resort in Meadows of Dan, Virginia. The first trial was initiated on May 16, 2014, on a woodland edge partially shaded for 6 h each day. The second trial was initiated on June 27, 2014, adjacent to a golf fairway, approximately 50 m from the tree line and not shaded for more than 1 h each day. Thus, the second site can be characterized as receiving more direct sunlight than the first. Both sites were dominated by a 30% to 60% infestation of deertongue and a mix of sheep, chewing, hard, and creeping red fescues in sandy loam soil (fine-loamy, mixed, active, mesic Ultic Hapludalfs), pH 5.7, and with 3.1% organic matter. Both sites were mowed only once per year in the fall with a 1445 front deck rotary mower (John Deere, Moline, IL). Trials were arranged as a randomized complete block design with eight treatments, replicated three times. Plot size was 1.82 m × 1.82 m for both sites. Herbicide rates, sequences, and mixtures are listed in Table 2. All treatments were sprayed with a CO_2-pressurized backpack sprayer equipped with TeeJet TTI11004 nozzles (Spraying Systems Co.) to deliver 281 L ha^{-1} of spray solution at 275 kPa.

Data were collected for cover and injury or control of fine fescue and deertongue at trial initiation and at 3-wk intervals from then onward until the end of the growing season and again at 52 WAIT. Visual estimations of injury and control were made on a 0% to 100% scale based on a reduction in apparently healthy, green tissue

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Table 1. Herbicides used to assess deertongue control in greenhouse experiments in Blacksburg, VA, in 2013.[e]

Common name	Product name	Manufacturer[f]	Rate
			g ae or ai ha^{-1}
Amicarbazone[a,c]	Xonerate	FMC	147
Bispyribac-sodium[a,c]	Velocity	Valent	74
Chlorsulfuron[b,c]	Telar	Bayer	26.3
Diclofop[b,d]	Illoxan	Bayer	1,140
Fenoxaprop[b,d]	Acclaim Extra	Bayer	195
Fluazifop[b,d]	Ornamec	PBI-Gordan	95
Fluazifop + fenoxaprop[b,d]	Fusion	Syngenta	140
Glyphosate[b]	Roundup	Monsanto	560
Glyphosate[b]	Roundup	Monsanto	840
Glyphosate[b]	Roundup	Monsanto	1,120
Glyphosate + imazapic[b]	Roundup; Plateau	Monsanto and BASF	840 + 105
Imazapic[b,c]	Plateau	BASF	105
Mesotrione[a,c]	Tenacity	Syngenta	280
Mesotrione + triclopyr[a,c]	Tenacity; Turflon Ester	Syngenta and Dow	280 + 560
Metamifop[b,d]	SAH-001 10% EC	Summit Agro	400
Metsulfuron[b,c]	MSM Turf	Control Solutions	42
Metsulfuron + rimsulfuron[b,c]	Negate	Control Solutions	39
Nicosulfuron + rimsulfuron[b]	Steadfast	E.I. du Pont	39.4
Primisulfuron[b,d]	Beacon	Syngenta	52.5
Quinclorac[a,d]	Drive	BASF	840
Sethoxydim[b,d]	Poast	BASF	210
Thiencarbazone + iodosulfuron + dicamba[b,c]	Celsius	Bayer	234
Topramezone[a,c]	Pylex	BASF	37
Topramezone + triclopyr[a,c]	Pylex; Turflon Ester	BASF and Dow	37 + 560

[a]Herbicide treatments were applied twice at a 3-wk interval.
[b]Herbicide treatments were applied once.
[c]Nonionic surfactant at 2.5 mL L^{-1} was added to the treatment.
[d]Crop oil concentrate at 10 mL L^{-1} was added to the treatment.
[e]A nontreated control was also evaluated.
[f]Manufacturer locations: Bayer Environmental Science, Cary, NC 27513; BASF Corp., Research Triangle Park, NC 27709; Control Solutions, Inc., Pasadena, TX 77507; Dow Agrosciences, Indianapolis IN 46268; E.I. du Pont de Nemours and Company, Wilmington, DE 19898; FMC Corp., Philadelphia, PA 19104; Monsanto Company, St. Louis, MO 63167; PBI-Gordan Corp., Shawnee, KS 66286; Summit Agro International Ltd., Tokyo, Japan; Syngenta Crop Protection, Greensboro, NC 27419; Valent USA LLC, Walnut Creek, CA 94596.

Table 2. Herbicides used to assess the response of fine fescue and deertongue during field experiments at The Highland Course of Primland Resort, VA, in 2014.[e]

Common name	Product name	Manufacturer[f]	Rate
			g ae or ai ha^{-1}
Fluazifop[a,c]	Ornamec	PBI-Gordan	420
Fluazifop[b,c]	Ornamec	PBI-Gordan	420
Glyphosate[a]	Roundup	Monsanto	1120
Glyphosate + imazapic[a]	Roundup; Plateau	Monsanto and BASF	560 + 52.5
Imazapic[a,d]	Plateau	BASF	105
Thiencarbazone + iodosulfuron + dicamba[a,d]	Celsius	Bayer	234
Topramezone[b,d]	Pylex	BASF	37

[a]Herbicide treatments were applied once.
[b]Herbicide treatments were applied three times at a 3-wk interval.
[c]Crop oil concentrate at 10 mL L^{-1} was added to the treatment.
[d]Nonionic surfactant at 2.5 mL L^{-1} was added to the treatment.
[e]A nontreated control was also evaluated.
[f]Manufacturer locations: Bayer Environmental Science, Cary, NC 27513; BASF Corp., Research Triangle Park, NC 27709; Monsanto Company, St. Louis, MO 63167; PBI-Gordan Corp., Shawnee, KS 66286.

compared with the nontreated areas, where 0% represented no injury or no control and 100% represented the complete loss of all green tissue in plots and the apparent death of plants or complete control (Frans et al. 1986). Likewise, visual cover was assessed on a scale of 0% to 100% with 0% being no cover of turf or weed and 100% being complete fine fescue or deertongue cover. Deertongue average height, number of shoots, and number of seedhead-producing shoots per plot were assessed at 52 WAIT. Plant height was measured for five deertongue plants in each plot and averaged before being subjected to data analysis.

Data Analysis

Since both the greenhouse and field studies had identical experimental designs, the same data analysis strategy was used for both studies. Data for each response variable were tested for normality using the UNIVARIATE procedure and Shapiro-Wilk statistic with SAS software (version 9.3; SAS Institute, Cary, NC) and homogeneity of variance was confirmed by visually inspecting plotted residuals and other metrics using the DIAGNOSTIC option of the PLOT procedure with SAS software. Homogeneity of variance was further assessed using Levene's test where one-way

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Table 3. Effect of herbicide treatments on deertongue chlorophyll content and biomass assessed during greenhouse experiments at Blacksburg, VA.[a]

Treatment	Chlorophyll content 6 WAIT	Biomass reduction 6 WAIT	Biomass reduction 10 WAIT
	mg m^{-2}	%	%
Nontreated	215 bc	–	–
Amicarbazone[b]	253 ab	24 cdefg	32 de
Bispyribac-sodium[b]	211 bc	21 bcdef	−42 a
Chlorsulfuron[c]	268 ab	9 abcd	−19 abc
Diclofop[c]	227 ab	7 ab	−39 a
Fenoxaprop[c]	291 a	44 ghi	−26 abc
Fluazifop[c]	237 ab	46 hi	81 fg
Fluazifop + fenoxaprop[c]	247 ab	36 fghi	32 de
Glyphosate[c]	2 e	76 klm	100 g
Glyphosate[c]	0 e	92 lm	100 g
Glyphosate[c]	0 e	93 lm	100 g
Glyphosate + imazapic[c]	0 e	95 lm	100 g
Imazapic[c]	150 cd	72 jkl	87 g
Mesotrione[b]	234 ab	26 cdefgh	−13 abc
Mesotrione + triclopyr[b]	197 bc	39 FFghi	10 cde
Metamifop[c]	222 abc	32 efgh	−10 abc
Metsulfuron[c]	230 ab	14 abcde	−26 abc
Metsulfuron + rimsulfuron[c]	234 ab	36 ffghi	0 bcd
Nicosulfuron + rimsulfuron[c]	205 bc	29 defgh	−13 abc
Primisulfuron[c]	228 ab	−6 a	−45 a
Quinclorac[b]	208 bc	9 abcd	−32 ab
Sethoxydim[c]	203 bc	45 hi	45 ef
Thiencarbazone + iodosulfuron + dicamba[c]	105 d	70 jk	84 g
Topramezone[b]	222 abc	36 fghi	42 e
Topramezone + triclopyr[b]	208 bc	54 ij	45 ef
P-value	<0.0001	<0.0001	<0.0001

[a]Abbreviation: WAIT, weeks after initial treatment.
[b]Herbicide treatments were applied twice at a 3-wk interval.
[c]Herbicide treatments were applied once.

ANOVAs for main effects or all possible combinations of factorial levels were tested using the HOVTEST WELCH option in the MEANS statement of the GLM procedure with SAS software. When needed, data were transformed to log or arcsin square root to meet assumptions of ANOVA. In such cases where transformation was needed, data were back-transformed for presentation clarity. The experimental run or experimental site was considered as a random effect, while treatment was treated as a fixed effect. Main effects and interactions were tested using mean square error associated with the random variable interaction (McIntosh 1983). Appropriate means were separated using Fisher's protected least significant difference test at a 5% level of significance.

Results and Discussion

Identifying Candidate Herbicide Mixtures

The main effect of treatment was significant ($P < 0.0001$) for deertongue chlorophyll content at 6 WAIT and biomass reduction at 6 and 10 WAIT (Table 3). Treatment by experimental run was not significant ($P > 0.05$). Glyphosate-containing treatments reduced the chlorophyll content of deertongue leaves to ≤2 mg m^{-2}, whereas nontreated plants had 215 mg m^{-2} at 6 WAIT (Table 3). Kitchen et al. (1981) also observed a reduction in the chlorophyll content of corn (*Zea mays* L.) leaves after glyphosate treatment. Thiencarbazone + iodosulfuron + dicamba reduced deertongue chlorophyll content to 105 mg m^{-2} at 6 WAIT, but other treatments did not affect the chlorophyll content (Table 3). Although some treatments appeared to stunt deertongue growth or caused discoloration (data not shown), these effects did not always manifest in the newest expanding leaves, and chlorophyll readings were sometimes variable. Glyphosate or iodosulfuron decreased the chlorophyll content and altered the flavonoid concentration in leaves of several Poaceae weed species including *Lolium perenne* L. and *Poa annua* L. (Hjorth et al. 2006).

Glyphosate applied at 840 g ae ha^{-1} or higher reduced deertongue biomass by >90% at 6 WAIT (Table 3). Glyphosate applied at 560 g ae ha^{-1}, imazapic, and thiencarbazone + iodosulfuron + dicamba also caused a ≥70% reduction in deertongue biomass at 6 WAIT (Table 3). After plants were allowed to recover from the initial aboveground biomass assessment, glyphosate-containing treatments, fluazifop, imazapic, thiencarbazone + iodosulfuron + dicamba reduced deertongue aboveground biomass by at least 80% at 10 WAIT (Table 3). Fluazifop + fenoxaprop, sethoxydim, topramezone, and topramezone + triclopyr reduced deertongue aboveground biomass not more than 45% (Table 3). Although mesotrione is better than topramezone at controlling creeping bentgrass (Beam et al. 2006), and research has shown that smooth crabgrass (Post et al. 2013) and bermudagrass (Cox et al. 2017) have similar reactions to topramezone, in our studies the biomass of deertongue was considerably less when topramezone was applied than with mesotrione at 10 WAIT (Table 3). Although previous research has shown that nicosulfuron and primisulfuron were safe to use on tall fescue turf (Beam et al. 2005) and may have utility in naturalized areas, these treatments did not reduce deertongue biomass (Table 3). Overall, of 21 unique herbicide active ingredients evaluated in these greenhouse studies (Table 3), only eight were carried forward to the field studies based on impacts to deertongue biomass.

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Table 4. Response of fine fescue to herbicide treatments at 9 WAIT and 52 WAIT assessed during a field study at The Highland Course of Primland Resort in Meadows of Dan, VA.[a]

Treatment	Injury 9 WAIT		Discoloration 9 WAIT		Injury 52 WAIT	
	Shaded site	Sunny site	Shaded site	Sunny site	Shaded site	Sunny site
	%	%	%	%	%	%
Nontreated	–	–	–	–	–	–
Fluazifop[b]	5 d	0 b	12 d	NS	0 b	0 b
Fluazifop[c]	7 d	10 b	15 d	NS	0 b	0 b
Glyphosate[b]	89 a	0 b	70 a	NS	42 a	0 b
Glyphosate + imazapic[b]	72 b	38 a	49 b	NS	35 a	28 a
Imazapic[b]	50 c	32 a	30 c	NS	0 b	0 b
Thiencarbazone + iodosulfuron + dicamba[b]	47 c	37 a	27 c	NS	0 b	0 b
Topramezone[c]	10 d	0 b	15 d	NS	0 b	0 b
P-value	<0.0001		<0.0001		<0.0001	

[a]Abbreviations: NS, nonsignificant; WAIT, weeks after initial treatment.
[b]Herbicide treatments were applied once.
[c]Herbicide treatments were applied three times at a 3-wk interval.
[d]Means followed by the same letter within a column are not significantly different based on Fisher's protected least significant difference test at $\alpha = 0.05$.

Field Evaluation of Herbicide Performance

The treatment by experimental site interaction was significant ($P < 0.0001$) for fine fescue injury and discoloration at 9 WAIT and fine fescue injury at 52 WAIT (Table 4). At 9 WAIT, fine fescue was injured by not more than 10% at both experimental sites when treated with fluazifop and topramezone (Table 4). Previous research has also suggested that fluazifop applied at 560 g ha^{-1} did not injure creeping red fescue (Warren et al. 1989), and turfgrass was also tolerant to topramezone applied at 37 g ai ha^{-1} (Patton et al. 2021). Under shady conditions at the woodland edge site fine fescue injury was 89% when glyphosate was applied, but no injury was observed on the site that was 50 m away from the tree line, which received more sunlight throughout the season (Table 4). Askew et al. (2019) also documented that several fine fescue varieties are inherently tolerant to glyphosate applications of up to 1,000 g ae ha^{-1} but they also suggested that future research is required to assess fine fescue response to glyphosate under different environmental conditions. Differences in tolerance of fine fescue to glyphosate under prolonged shade versus light could be attributed to higher herbicide absorption under shade conditions. Mota et al. (2020) also showed that palisade grass (*Urochloa brizantha* cv. Marandu) plants had 27% higher absorption of ^{14}C-glyphosate when maintained under dark conditions for 72 h compared to light conditions. The leaf thickness of *Festuca* species was decreased under shade stress due to morphological and physiological changes (Boardman 1977; Fan et al. 2020). Previous research has documented that glyphosate is absorbed more rapidly into plants that exhibit less epicuticular waxes and cuticle barriers (Norsworthy et al. 2001; Wyrill and Burnside 1976). Tate et al. (2019) also proposed that the low absorption of foliar-applied mesotrione by fine fescue could be associated with fine fescue leaf morphology, which limits herbicide entry.

Imazapic and glyphosate + imazapic treatments injured fine fescue above the commercially acceptable threshold of 30% at both sites 9 WAIT, but fine fescue injury was more severe at the shaded site near the woodland edge (Table 4). Shinn and Thill (2004) also suggested that tolerance of perennial grasses to imazapic is dependent on environmental conditions and could explain the variability in fine fescue response to imazapic at the two experimental sites. Glyphosate or imazapic treatments caused discoloration of fine fescue by ≥49% at the shaded site, but no differences were observed in fine fescue discoloration from herbicides at the sunny site (Table 4). Thiencarbazone + iodosulfuron + dicamba injured fine fescue by 47% and 37% at the shaded and sunny sites, respectively (Table 4). Fine fescue had completely recovered from herbicide injury by 52 WAIT except turf that had been treated with glyphosate at the shaded site and turf that had been treated with glyphosate + imazapic at both sites (Table 4). Glyphosate caused 42% injury to fine fescue at 52 WAIT under shade conditions, but fine fescue injury was not observed in the sun-exposed site (Table 4).

The interaction of treatment by experimental site was significant for deertongue control and cover at 9 WAIT, so data are presented by experimental site (Table 5). The interaction was likely caused by an apparent increase in short-term weed control at the shaded site. At 9 WAIT, fluazifop regardless of application frequency controlled deertongue by >85% at the shaded site, but a single application was not effective in controlling deertongue at the sun-exposed site (Table 5). Previous research (Coupland 1986) also showed that higher light intensity maintained for 4 wk after fluazifop treatment resulted in reduced herbicide efficacy on quackgrass (*Elymus repens* L.) compared with weed control under lower light intensity due to higher translocation. Glyphosate-containing treatments controlled deertongue by >98% at both experimental sites and weed cover was almost completely eliminated at 9 WAIT (Table 5). Imazapic alone, thiencarbazone + iodosulfuron + dicamba, and topramezone treatments did not effectively control deertongue at 9 WAIT regardless of experimental site (Table 5).

Despite trial dependency on fine fescue turf and short-term weed response to herbicide treatments, long-term weed control at 52 WAIT was consistent between trials and only the main effect of treatment was significant for deertongue control, cover, shoot density, and plant height (Table 5). Fluazifop applied sequentially, glyphosate, and glyphosate + imazapic controlled deertongue by ≥93% and nearly eliminated weed cover at 52 WAIT (Table 5). At 52 WAIT, a single application of fluazifop, imazapic, thiencarbazone + iodosulfuron + dicamba, and sequential topramezone applications did not control deertongue by >70% and did not reduce weed cover below 16%, which was approximately half that of the nontreated check (Table 5). Sequential applications of fluazifop and a single application of glyphosate or glyphosate + imazapic reduced deertongue shoot density and plant height to ≤5 shoots m^{-2} and ≤8 cm, respectively (Table 5).

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Table 5. Effect of herbicide treatments on deertongue at 9 WAIT and 1 yr after initial treatment evaluated in two field experiments at The Highland Course of Primland Resort in Meadows of Dan, VA.[a]

	Control 9 WAIT		Cover 9 WAIT		Control 52 WAIT	Cover 52 WAIT	Shoot density 52 WAIT	Plant height 52 WAIT
Treatment	Shaded site	Sunny site	Shaded site	Sunny site	–	–	–	–
	%	%	%	%	%	%	number m^{-2} cm	
Nontreated	–	–	50 a	12 a	–	33 a	47 a	23 a
Fluazifop[b]	86 b	55 e	6 bcd	10 a	64 b	16 bcd	25 abc	14 b
Fluazifop[c]	95 a	83 b	3 cd	5 ab	93 a	3 cde	5 bc	8 cd
Glyphosate[b]	100 a	100 a	0 d	0 b	99 a	1 e	0 c	2 e
Glyphosate + imazapic[b]	100 a	98 a	0 d	1 b	96 a	2 de	2 c	6 de
Imazapic[b]	55 c	60 de	21 bc	12 a	58 b	18 bc	28 abc	12 bc
Thiencarbazone + iodosulfuron + dicamba[b]	55 c	70 cd	19 bcd	11 a	56 b	20 ab	33 a	14 b
Topramezone[c]	45 d	73 bc	25 b	9 ab	68 b	18 bc	23 abc	12 bc
P-value	<0.0001		0.0042		0.0007	0.0476	0.0057	0.0126

[a]Abbreviation: WAIT, weeks after initial treatment.
[b]Herbicide treatments were applied once.
[c]Herbicide treatments were applied three times at a 3-wk interval.
[d]Means followed by the same letter within a column are not significantly different based on Fisher's protected least significant difference test at $\alpha = 0.05$.

Our research findings suggest that fluazifop at 420 g ha^{-1} applied thrice at 3-wk intervals effectively controlled deertongue without compromising fine fescue safety. Glyphosate-containing treatments completely controlled deertongue and almost eliminated weed cover at 52 WAIT. Fine fescue completely recovered from injury following herbicide applications, except glyphosate-containing treatments at the shaded site where it caused commercially unacceptable levels of injury 1 yr later. We can conclude from our experimental design that one site differed in initial deertongue control compared with another site, but we are unable to statistically relate that difference to shade. Future research will assess the response of fine fescue to glyphosate under different light intensities and associated herbicide absorption, translocation, and metabolism under varied light conditions.

Practical Implications

A literature search did not yield any peer-reviewed publication on deertongue grass control but golf superintendents in the northeastern United States continue to struggle with this weed due to limited control options. Existing extension literature suggests hand-pulling or using glyphosate to control deertongue, but both options have their limitations. Our research suggests using a selective herbicide, particularly fluazifop, to effectively manage deertongue on naturalized areas of golf courses. The fluazifop rate used in these studies is labeled for "perennial grass control" in "noncrop" areas, spot treatment scenarios, or sites with approved ornamental plantings. In highly managed or ornamental turfgrass, approved rates vary between product labels, but some products allow fine fescue turf to be treated at rates that are 25% lower than the rates used in this study. Still, fluazifop demonstrated the highest margin of safety to fine fescue among treatments that strongly suppressed deertongue. Glyphosate or glyphosate with imazapic should be limited to spot treatment of deertongue to minimize potential injury of grasses growing in naturalized areas.

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