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Common carpetgrass (*Axonopus fissifolius*) control with POST herbicides

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Abstract

Reductions in MSMA use for weed control in turfgrass systems may have led to increased common carpetgrass infestations. The objective of our research was to identify alternative POST herbicides for control of common carpetgrass using field and controlled-environment experiments. Field applications of MSMA (2.2 kg ai ha^{-1}) and thiencarbazone + iodosulfuron + dicamba (TID) (0.171 kg ai ha^{-1}) resulted in the greatest common carpetgrass control 8 wk after initial treatment (WAIT): 94% and 91%, respectively. Thiencarbazone + foramsulfuron + halosulfuron (TFH) (0.127 kg ai ha^{-1}) applied in the field resulted in 77% control 8 WAIT, whereas all other treatments were ≤19% effective at 8 WAIT. All treatments resulted in greater common carpetgrass control when applied in the greenhouse. Applications of MSMA, TFH, and TID resulted in the highest common carpetgrass control in the greenhouse 8 WAIT: 94%, 94%, and 91%, respectively. Control with nicosulfuron (0.035 kg ai ha^{-1}) and trifloxysulfuron (0.028 kg ai ha^{-1}) (81% and 75%, respectively) was greater in the greenhouse than observed in the field 8 WAIT. Sequential applications of foramsulfuron (0.058 kg ai ha^{-1}) resulted in only ≤11% common carpetgrass control 8 WAIT, regardless of application site. All herbicide treatments in the greenhouse resulted in reduced aboveground common carpetgrass biomass 8 WAIT compared to the nontreated control (12.9 g). Aboveground biomasses of common carpetgrass in response to MSMA, TID, TFH, nicosulfuron, and trifloxysulfuron were 1.6 to 2.1 g, regardless of treatment. Reduced efficacy of foramsulfuron was reflected in greater biomass (4.7 g) in response to treatments. Thiencarbazone + iodosulfuron + dicamba may be an alternative to MSMA for common carpetgrass control; however, long-term assessment may be warranted to evaluate treatment effectiveness. Further investigation into application timing may be necessary to enhance the efficacy of TFH for the control of common carpetgrass.

Introduction

Common carpetgrass is a warm-season perennial grass adapted to grow in tropical and warm subtropical environments (Turgeon 2011). It has spread throughout the coastal plains of the United States from Texas to Virginia following initial introduction into New Orleans, LA, during the early 1800s (Heath et al. 1985; Trenholm et al. 2000; Wang et al. 2010). Common carpetgrass has been utilized on roadsides and as a low-maintenance home lawn throughout the southeastern United States (Christians et al. 2016; Turgeon 2011). Low input requirements and quick establishment from seed make it an ideal candidate for soil stabilization and site reclamation (Turgeon 2011). In fact, Bush et al. (2000) reported that common carpetgrass only required 98 kg N ha^{-1} yr^{-1} to provide acceptable turfgrass quality. Conversely, adaptation to saturated soil, acidic soil pH, and low fertility requirements may encourage the encroachment of common carpetgrass into more desirable turfgrass species (Burton 1992; Heath et al. 1985; Turgeon 2011). Its wide leaf blades, light green color, and abundant seedhead production make common carpetgrass infestations aesthetically unpleasing and may negatively affect turfgrass playability (McCarty and Colvin 1991; McCarty et al. 2008).

Although control of common carpetgrass within other turfgrass species may be desired, few herbicides are labeled for this purpose. Thiencarbazone + iodosulfuron + dicamba (TID) is labeled to control common carpetgrass (Anonymous 2014), but minimal research reporting control efficacy has been published. Hoyle et al. (2013a) observed 100% control of common carpetgrass infesting an ultra-dwarf bermudagrass [*Cynodon dactylon* (L.) Pers. × *C. transvaalensis* Burtt-Davy] putting green with sequential applications of TID.

Monosodium methanearsonate (MSMA) is often applied to control nutsedge (*Cyperus* spp.) (Hamilton 1971; Keeley and Thullen 1971; Lowe et al. 2000; McCarty and Colvin 1991); however, significant common carpetgrass injury was simultaneously observed. McCarty and

Colvin (1991) reported reductions of common carpetgrass turf quality (2.3 to 4.1 and 2.8 to 3.3) in response to MSMA at 1.1 and 2.2 kg ai ha^{-1}, respectively, 3 wk after treatment (WAT) compared to the nontreated check (8.4 to 8.5), whereas Johnson (1975) observed complete common carpetgrass necrosis following sequential applications of MSMA at 2.2 kg ai ha^{-1}. MSMA may be impractical for the control of common carpetgrass because of associated phytotoxicity observed on common turfgrass species like bermudagrass (*Cynodon* spp.) (Johnson 1993; Johnson and Duncan 2001), especially when applications are made during periods of high temperature (≥32 C).

The use of MSMA was eliminated on home lawns and athletic fields, while restricted on sod farms, golf courses, and highway rights-of-way following the 2009 decision by the Environmental Protection Agency (EPA) (US EPA 2009). Commercial availability and continued use of MSMA was prohibited in all turfgrass environments after December 31, 2013 (US EPA 2009). The 2009 EPA decision on MSMA prohibition was subsequently delayed, pending a registration review beginning in 2013 that is scheduled for completion in 2019 (US EPA 2015). A dearth of labeled herbicides and the uncertain future of MSMA warrant the evaluation of alternative chemistries for common carpetgrass control. Therefore, the objective of this research was to identify several POST herbicides for the control of common carpetgrass using field and controlled-environment experiments.

Materials and methods

Field experiments

Trials were initiated during the summer of 2012 at the Pine Hills (PH) Golf Club in Winder, GA (33.97°N, 83.69°W) and at the University of Georgia (UGA) Golf Course in Athens, GA (33.91°N, 83.37°W). The soil at PH was a Madison sandy clay loam (fine, kaolinitic, thermic Typic Kanhapludults) with a pH of 5.1 and organic matter content of 0.7%. The soil at UGA was a Cecil sandy clay loam (fine, kaolinitic, thermic Typic Kanhapludults) with a pH of 5.5 and organic matter content of 1.2%. Research was performed on established common carpetgrass infestations present in a 'Tifway 419' hybrid bermudagrass rough mowed at 2.5 cm at UGA and a common bermudagrass rough mowed at 3.8 cm at PH. Experimental units measured 1.5 m by 1.5 m and were arranged in a randomized complete block design with four replications. All experimental areas were mowed 24 h before herbicide application and once weekly thereafter. Turfgrass clippings were returned to the canopy at both locations. Approximately 2.5 to 4 cm of water wk^{-1} were applied through an overhead irrigation system at UGA, whereas rainfall was the only source of water at PH.

Herbicide treatments included a nontreated check, MSMA (MSMA 6.6 L; Drexel Chemical Co., P.O. Box 13327, Memphis, TN 38113-0327) at 2.2 kg ai ha^{-1}, TID (Celsius; Bayer CropScience, 2 T.W. Alexander Drive, Research Triangle Park, NC 27709) at 0.171 kg ai ha^{-1}, thiencarbazone + foramsulfuron + halosulfuron (TFH) (Tribute Total; Bayer CropScience, 2 T.W. Alexander Dr., Research Triangle Park, NC 27709) at 0.127 kg ai ha^{-1}, nicosulfuron (Accent; DuPont, 1007 Market Street, Wilmington, DE 19898) at 0.035 kg ai ha^{-1}, trifloxysulfuron (Monument; Syngenta Crop Protection, LLC, P.O. Box 18300, Greensboro, NC 27419) at 0.028 kg ai ha^{-1}, and foramsulfuron (Revolver; Bayer CropScience, 2 T.W. Alexander Drive, Research Triangle Park, NC 27709) at 0.058 kg ai ha^{-1} (Table 1). Herbicides were selected based on previously documented activity on perennial grass weeds. Thiencarbazone + iodosulfuron + dicamba and TFH treatments were applied with a methylated seed oil surfactant (Dyne-Amic; Helena Chemical Co., 225 Schilling Boulevard, Suite 300, Collierville, TN 38017) at 0.5% (v/v). Nicosulfuron and trifloxysulfuron treatments were applied with a nonionic surfactant (Induce; Helena Chemical Co., 225 Schilling Boulevard, Suite 300, Collierville, TN 38017) at 0.25% (v/v). Treatments were initiated on July 10, 2012, at both locations with a sequential application made 4 wk later (August 8, 2012) using identical rates. Treatments were applied using a CO_2-pressurized backpack sprayer equipped with two XR8004VS nozzle tips (Teejet; Spraying Systems Co., North Avenue and Schmale Road, Wheaton, IL 60129) calibrated to deliver 375 L ha^{-1} at 221 kPa.

Table 1. Herbicide treatments for field and greenhouse experiments evaluating carpetgrass control in Winder and Athens, GA, from 2012 to 2013.

Herbicide treatment[a]		
Common name	Trade name	Rate
		kg ai ha^{-1}
MSMA[b]	MSMA[c]	2.2
TID	Celsius[d]	0.171
TFH	Tribute Total[d]	0.127
Nicosulfuron	Accent[e]	0.035
Trifloxysulfuron	Monument[f]	0.028
Foramsulfuron	Revolver[g]	0.058

[a]Initial field experiment treatments applied July 10, 2012, with sequential applications on August 8, 2012, at both locations. Initial greenhouse experiment treatments applied November 7, 2012, with sequential applications on December 5, 2012.
[b]Abbreviations: MSMA, monosodium methanearsonate; TID, thiencarbazone + iodosulfuron + dicamba; TFH, thiencarbazone + foramsulfuron + halosulfuron.
[c]Drexel Chemical Co., Memphis, TN; www.drexchem.com.
[d]Bayer Environmental Sciences, Research Triangle Park, NC; www.backedbybayer.com. Included a methylated seed oil surfactant at 0.5% (v/v).
[e]DuPont, Wilmington, DE; www.dupont.com. Included a nonionic surfactant at 0.25% (v/v).
[f]Syngenta, Greensboro, NC; www4.syngenta.com. Included a nonionic surfactant at 0.25% (v/v).
[g]Bayer Environmental Sciences, Research Triangle Park, NC; www.backedbybayer.com.

Greenhouse experiments

Greenhouse experiments were conducted at the University of Georgia Plant Science Greenhouse Complex (33.93°N, 83.36°W) in Athens, GA, during the fall and winter of 2012. Common carpetgrass plants were removed from naturally occurring populations present in a common bermudagrass rough (2.5 cm) at UGA in Athens, GA. A golf course cup cutter (10.2 cm wide) centered over each plant was used to remove aboveground and belowground biomass together as a plug (leaves/stolons were trimmed by the perimeter of the cup cutter) to a depth of 12.7 cm. This procedure was conducted similarly to Henry et al. (2007a) and Hephner et al. (2013, 2017). Plants were transplanted into pots (15.2 cm diam) containing a steamed 2:1 mixture of a Cecil sandy clay loam (fine, kaolinitic, thermic Typic Kanhapludults) and Wakulla sand (siliceous, thermic Psammentic Hapludults). Granular fertilizer (Grigg Brothers 7-7-7 Seven Iron, P.O. Box 128, Albion, ID 83311) was applied to each pot at time of transplant at a rate of 37 kg N ha^{-1} and watered in immediately. Pots were watered using an overhead irrigation system calibrated to deliver 3.8 cm water wk^{-1}. Common carpetgrass was allowed to acclimate in the greenhouse for 4 wk. Natural light was supplemented with artificial light (metal halide) at 500 µmol m^{-2} s^{-1} photosynthetic photon flux (measured at the canopy) in a 12-h day to approximate summer light intensity and photoperiod. Conditions in

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the climate-controlled greenhouse were maintained at day/night temperatures of 32 C/24 C. Pots were mowed once a week using sheep shearers (Model 78153-053 ShowMaster; Oster Professional Products, 150 Cadillac Lane, McMinnville, TN 37110-1367) to a height of 3.8 cm. Carpetgrass clippings were not returned to the canopy. Common carpetgrass cover reached 100% for each pot prior to trial initiation, and plants were mowed to a 3.8-cm height just prior to herbicide treatment. No irrigation was applied during the 24-h period after herbicide treatment. Irrigation was applied by hand to deliver 4 cm of water wk^{-1} thereafter. Herbicide treatments and experimental design were identical to field experiments but contained five replications. Experimental blocks were arranged along a gradient created by the greenhouse cooling pads and associated fans. Experimental runs were conducted simultaneously in separate greenhouses. Initial herbicide applications were made on November 7, 2012, with sequential treatments applied 4 wk after initial treatment (WAIT) (December 5, 2012) using identical rates.

Data collection and analysis

Percent bermudagrass phytotoxicity and percent common carpetgrass cover were evaluated visually 4 and 8 WAIT for field experiments. Visible estimates of injury utilized a 0 (no common carpetgrass cover or no bermudagrass injury) to 100% (complete common carpetgrass cover or complete bermudagrass injury) scale. Common carpetgrass cover was 70% to 95% within each plot at the time of trial initiation. Visible estimates were used, because Hoyle et al. (2013c) reported that visual ratings were closely associated with quantitative assessments in turfgrass weed science trials. Percent common carpetgrass control for each treatment was calculated by cover at each rating time relative to common carpetgrass cover at time of initial herbicide application within each replication and experimental run using Equation 1:

$$\%C = [(I - T)/I] \times 100 \quad [1]$$

where C is control, I is common carpetgrass cover at the time of initial herbicide application, and T is carpetgrass cover at the respective rating date in the treated plot. Percentage of control used a scale of 0 to 100%, where 0 was no common carpetgrass control, and 100% was complete common carpetgrass control.

Percent common carpetgrass control was visually assessed in greenhouse experiments relative to the nontreated check on a percent scale, where 0 represented no common carpetgrass control and 100% represented complete common carpetgrass death 4 and 8 WAIT. Aboveground common carpetgrass biomass (g) was harvested 8 WAIT in greenhouse experiments. All aboveground shoot tissue (living and necrotic tissue) was harvested by hand with scissors, dried for 24 h at 110 C, weighed, and recorded. Aboveground biomass data were collected to supplement visual assessments.

Analysis was conducted separately for 4- and 8-WAIT rating dates for bermudagrass phytotoxicity, common carpetgrass control, and dry aboveground common carpetgrass biomass to make comparisons only within each rating date. ANOVA was performed using PROC GLM with the appropriate expected mean square values described by McIntosh (1983) in SAS (SAS v. 9.2 for Windows; Statistical Analysis Systems Institute, 820 SAS Campus Drive, Cary, NC 27513). Means were separated according to Fisher's protected LSD test with $\alpha = 0.05$. Percent bermudagrass phytotoxicity, common carpetgrass control, and dry aboveground common carpetgrass biomass were arcsine square-root transformed to stabilize variance as described by Bowley (2008). Transformed and nontransformed data were analyzed, and interpretations were not different; therefore, nontransformed means are presented for clarity. The nontreated control was not included in carpetgrass control and aboveground dry-weight analysis for appropriate means separation between herbicide treatments and comparisons.

Table 2. Carpetgrass control 4 and 8 wk after initial treatments (WAIT) in a bermudagrass rough in Winder and Athens, GA in 2012.

		Carpetgrass control	
Treatment[a]	Rate	4 WAIT	8 WAIT
	kg ai ha^{-1}	%	
MSMA[b]	2.2	57 a[c]	94 a
TID	0.171	55 a	91 a
TFH	0.127	44 a	77 b
Nicosulfuron	0.035	19 b	19 c
Trifloxysulfuron	0.028	1 c	19 c
Foramsulfuron	0.058	0 c	11 c
Nontreated[d]	—	0	0
$LSD_{(0.05)}$		14	11

[a]Initial treatments applied July 10, 2012, with sequential applications on August 8, 2012, at both locations. TID and TFH treatments included a methylated seed oil surfactant at 0.5% (v/v). Nicosulfuron and trifloxysulfuron treatments included a nonionic surfactant at 0.25% (v/v).
[b]Abbreviations: MSMA, monosodium methanearsonate; TID, thiencarbazone + iodosulfuron + dicamba; TFH, thiencarbazone + foramsulfuron + halosulfuron; $LSD_{(0.05)}$, least significant difference at $P \leq 0.05$.
[c]Means within a column followed by the same lowercase letter are not statistically different according to Fisher's protected LSD at the $P \leq 0.05$ significance level.
[d]The nontreated control was not included in carpetgrass control analysis for appropriate means separation between herbicide treatments.

Results and Discussion

Field experiments

Experimental run-by-treatment interactions for field trials were not detected in carpetgrass control data ($F = 1.65$, $P = 0.14$). Therefore, data were pooled across experimental runs.

Bermudagrass phytotoxicity was similar to the nontreated control (0%) throughout the length of the trial for all treatments (≤2%), and no differences between treatments were observed, excluding MSMA (data not shown). Bermudagrass phytotoxicity (15%) was observed at 1 and 5 WAIT in response to MSMA applications; however, bermudagrass recovered to ≤5% phytotoxicity 2 and 6 WAIT (data not shown). Henry et al. (2013) and Johnston and Henry (2016) observed ≤3% bermudagrass phytotoxicity 1 WAIT with comparable rates of TID and TFH. Similarly, only 3% to 7% bermudagrass injury was reported by Busey (2004) 5 WAIT in response to foramsulfuron applications at rates up to 0.044 kg ha^{-1}. Stephenson et al. (2006) and Hephner et al. (2012) noted no bermudagrass injury in response to applications of trifloxysulfuron (0.018 to 0.075 kg ai ha^{-1}).

The greatest amount of common carpetgrass control 4 WAIT was observed in response to MSMA (57%), TID (55%), and TFH (44%) (Table 2). All other treatments resulted in ≤19% control 4 WAIT. Common carpetgrass control increased following sequential herbicide treatments. Applications of MSMA and TID resulted in the greatest common carpetgrass control 8 WAIT, 94% and 91%, respectively (Table 2). Sequential herbicide applications often enhance weed control, but this effect may be species-specific. For example, Johnson (1975) reported complete control of common carpetgrass in response to sequential applications of MSMA at 2.2 kg ai ha^{-1}, whereas Hoyle et al. (2013b) observed ≥92% of Virginia buttonweed (*Diodia virginiana* L.) 10 WAIT in response

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Table 3. Carpetgrass control 4 and 8 wk after initial treatment (WAIT) and aboveground dry weight 8 WAIT in response to herbicides applied in the greenhouse in Athens, GA, in 2012 and 2013.

		Carpetgrass control		Aboveground dry weight
Treatment[a]	Rate	4 WAIT	8 WAIT	8 WAIT
	kg ai ha^{-1}	———%———		g
MSMA[b]	2.2	87 a[c]	94 a	2.1 b
TID	0.171	63 b	91 a	1.9 b
TFH	0.127	59 b	94 a	1.6 b
Nicosulfuron	0.035	26 c	81 b	1.8 b
Trifloxysulfuron	0.028	29 c	75 b	1.7 b
Foramsulfuron	0.058	4 d	7 c	4.7 a
Nontreated[d]	—	0	0	12.9
$LSD_{(0.05)}$		11	6	1

[a]Initial treatments applied November 7, 2012, with sequential applications on December 5, 2012. TID and TFH treatments included a methylated seed oil surfactant at 0.5% (v/v). Nicosulfuron and trifloxysulfuron treatments included a nonionic surfactant at 0.25% (v/v).
[b]Abbreviations: MSMA, monosodium methanearsonate; TID, thiencarbazone + iodosulfuron + dicamba; TFH, thiencarbazone + foramsulfuron + halosulfuron; $LSD_{(0.05)}$, least significant difference at $P \leq 0.05$.
[c]Means within a column followed by the same lowercase letter are not statistically different according to Fisher's protected LSD at the $P \leq 0.05$ significance level.
[d]The nontreated control was not included in carpetgrass control and aboveground dry-weight analysis for appropriate means separation between herbicide treatments.

to sequential applications of TID at 0.17 kg ai ha^{-1}. Contrarily, sequential applications of MSMA at 2.5 kg ai ha^{-1} only resulted in 52% control of dallisgrass (*Paspalum dilatatum* Poir.) 3 mo after initial treatment (Henry et al. 2007b). Although not statistically similar to MSMA and TID, TFH provided 77% common carpetgrass control 8 WAIT in our research (Table 2). Sequential applications of similar rates of TFH (~0.136 kg ai ha^{-1}) in other studies resulted in 65% dallisgrass control 10 WAIT, 82% purple nutsedge (*Cyperus rotundus* L.) control 8 WAIT, and 95% tropical signalgrass [*Urochloa distachya* (L.) T.Q. Nguyen] control 57 d after initial treatment (Henry et al. 2013; Johnston and Henry 2016; Wells et al. 2014). Sequential treatments of all other herbicides in our research still resulted in ≤19% control 8 WAIT (Table 2). Henry et al. (2007b) reported similar control of dallisgrass 3 mo after initial treatment with sequential foramsulfuron applications at 0.05 kg ai ha^{-1}, whereas Johnston and Henry (2016) observed 35% dallisgrass control 10 WAIT following sequential applications of a higher rate of foramsulfuron (0.106 kg ai ha^{-1}). Although trifloxysulfuron treatments resulted in minimal common carpetgrass control (19%) in our research (Table 2), Henry et al. (2012) reported 96% purple nutsedge control 4 WAIT, and Stephenson et al. (2006) noted 48% to 64% torpedo grass (*Panicum repens* L.) control 7 WAIT in response to single applications of trifloxysulfuron.

Greenhouse experiments

Experimental run-by-treatment interaction for dry aboveground carpetgrass biomass and carpetgrass control data ($F = 0.06$, $P = 0.99$; $F = 0.40$, $P = 0.87$; respectively) were also not detected, and data were pooled over experimental runs. The greatest amount of common carpetgrass control 4 WAIT was observed in response to MSMA (87%) (Table 3). Applications of TID and TFH resulted in 63% and 59% common carpetgrass control 4 WAIT, respectively, whereas all other treatments provided ≤29% control. Applications of MSMA, TFH, and TID resulted in the greatest common carpetgrass control 8 WAIT: 94%, 94%, and 91%, respectively (Table 3). Common carpetgrass control with nicosulfuron and trifloxysulfuron (81% and 75%, respectively) was greater in the greenhouse than observed in the field 8 WAIT. Sequential applications of foramsulfuron only resulted in 7% control 8 WAIT.

All herbicide treatments resulted in ≤4.7 g aboveground biomass 8 WAIT. The nontreated check resulted in 12.9 g aboveground biomass 8 WAIT (Table 3). Aboveground biomasses of common carpetgrass in response to MSMA, TID, TFH, nicosulfuron, and trifloxysulfuron were statistically similar and resulted in 1.6 to 2.1 g, regardless of treatment. However, reductions in biomass did not correspond to visual control data. Although nicosulfuron and trifloxysulfuron treatments resulted in less common carpetgrass control (75% to 81%) than MSMA, TID, and TFH, they provided similar reductions in aboveground biomass. Nicosulfuron and trifloxysulfuron treatments resulted in growth regulation of common carpetgrass rather than necrosis; therefore, reductions in biomass were similar to more efficacious treatments. Foramsulfuron resulted in the worst common carpetgrass visual control and the greatest amount of aboveground biomass (4.7 g) 8 WAIT.

Observed differences between common carpetgrass control in the field and in the greenhouse may be attributed to the research methods employed in this study. Plants grown in the greenhouse are not exposed to the same environmental stresses (temperature, light intensity, etc.) as those grown in the field. This often makes greenhouse plants more susceptible to herbicides; therefore, they may exhibit higher levels of control. Lingenfelter and Curran (2007) reported 98% control of wirestem muhly [*Muhlenbergia frondosa* (Poir.) Fernald] 4 WAT in response to glyphosate (0.42 and 0.84 kg ai ha^{-1}) applied in the greenhouse. Less control (60% to 87%) was observed in the field 4 WAT in response to those same applications. Sequential applications of metamifop (0.3 to 0.5 kg ai ha^{-1}) applied in the greenhouse completely controlled bermudagrass (100%) 6 WAIT (Cooper et al. 2016), whereas sequential applications of metamifop (0.4 kg ai ha^{-1}) in the field only controlled bermudagrass 36% 9 WAIT (Doroh et al. 2011).

Both field and greenhouse experiments indicated that single applications of the herbicides evaluated do not provide effective common carpetgrass control. However, sequential applications of MSMA and TID resulted in excellent control (≥91%) of common carpetgrass in the field, whereas TFH treatments provided moderate control (77%) 8 WAIT. Thiencarbazone + iodosulfuron + dicamba may be a possible alternative to MSMA for the control of common carpetgrass; however, additional assessment (1 yr after treatment) may be warranted to evaluate long-term effectiveness of this treatment. Further research may be necessary to enhance the efficacy of TFH for control of common carpetgrass. Johnston and Henry (2016) observed ≥92% dallisgrass control 37 WAIT in response to applications of TFH (0.093 and 0.137 kg ai ha^{-1}) when applied in the fall. The authors hypothesized that increased control in the fall may be attributed to an increase in herbicide translocation that follows the sink/source relationship of perennial turfgrass organs.

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