Weed Technology. 2003. Volume 17:509–515

Sensitivity of Triploid Hybrid Bermudagrass Cultivars and Common Bermudagrass to Postemergence Herbicides[1]

THEODORE M. WEBSTER, CRAIG W. BEDNARZ, and WAYNE W. HANNA[2]

Abstract: The potential weediness of hybrid bermudagrass cultivars in nontarget areas is an important factor when considering the development of herbicide-resistant cultivars. Field studies evaluated the response of common bermudagrass, hexaploid hybrid '*Tifton-10*', and two triploid hybrid bermudagrass cultivars ('*TifEagle*' and '*TifSport*') to clethodim, fluazifop-p, glufosinate, glyphosate, and quizalofop-p. Glyphosate was more consistent than clethodim and clethodim plus glyphosate in controlling common bermudagrass. The triploid cultivars were equally sensitive to each of these treatments, whereas *Tifton-10* control was highest with treatments that included glyphosate. Variability between years in control of common bermudagrass was attributed to differences in plant size at application, with greater control of smaller plants. All herbicides reduced common bermudagrass plant diameters $\geq$ 93% in 1999 when grown without a crop. However, in 2001, only herbicide treatments that included two applications of 1.1 kg ai/ha glyphosate reduced plant diameters 6 to 59%. None of the other treatments reduced common bermudagrass plant diameters compared with pretreatment values. When grown with cotton, fluazifop-p and 4.5 kg/ha glyphosate were the only treatments consistent across cultivars and years. All herbicide treatments reduced triploid hybrid bermudagrass plant diameters $\geq$ 90%, whereas *Tifton-10* plant diameters were reduced $>$ 86% by all treatments, with the exception of clethodim. As in the non-cropland study, common bermudagrass plant diameters were reduced $\geq$ 97% by herbicides in 1999, whereas in 2001, only fluazifop-p and glyphosate treatments reduced plant diameters compared with the nontreated control. Both the lack of aggressiveness and susceptibility to common herbicides of the triploid hybrid cultivars relative to common bermudagrass indicates that these non–pollen-producing or -receiving cultivars are reasonable candidates for the introduction of herbicide resistance.

Nomenclature: Clethodim; fluazifop-p; glufosinate; glyphosate; quizalofop-p; common bermudagrass, *Cynodon dactylon* (L.) Pers. #[3] CYNDA '*Tifton-10*'; hybrid bermudagrass, *Cynodon dactylon* (L.) Pers. $\times$ *Cynodon transvaalensis* Burtt-Davy '*TifEagle*', '*TifSport*'; cotton, *Gossypium hirsutum* L.

Additional index words: Transgenic turfgrass, turfgrass weed management.

Abbreviations: fb, followed by; triploid hybrid cultivars, grouping of *TifEagle* and *TifSport* bermudagrass cultivars; WAP, weeks after transplanting.

INTRODUCTION

Common bermudagrass reportedly was first brought to the United States, at Savannah, GA, in 1751 and has since become a troublesome weed throughout the southern United States (Mitich 1989). Recent surveys of the Southern Weed Science Society list common bermudagrass among the 10 most troublesome weeds in fruit and nut crops, vegetables, nursery containers and ornamentals, turfgrass, industrial sites, corn (*Zea mays* L.), grain sorghum [*Sorghum bicolor* (L.) Moench], sugar cane (*Saccharum officinarum* L.), cotton, peanut (*Arachis hypogaea* L.), and soybean [*Glycine max* (L.) Merr.] (Dowler 1998, 1999; Webster 2000). A summary of the Southern Weed Science Society Weed Survey indicated that bermudagrass was the sixth most troublesome weed of cotton when averaged across the southern region of the United States (Webster and Coble 1997). In addition, a recent survey by Georgia county agricultural extension agents showed that common bermudagrass was the 18th

[1] Received for publication May 14, 2002, and in revised form March 3, 2003.

[2] Research Agronomist, Crop Protection and Management Research Unit, Agricultural Research Service, U.S. Department of Agriculture, Coastal Plain Experiment Station, Tifton, GA 31794; Assistant Professor, Crop and Soil Sciences Department, University of Georgia, Coastal Plain Experiment Station, Tifton, GA 31794; Research Geneticist, Crop Breeding and Genetics Research Unit, Agricultural Research Service, U.S. Department of Agriculture, Coastal Plain Experiment Station, Tifton, GA 31794. Corresponding author's E-mail: twebster@tifton.usda.gov.

[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

most troublesome species averaged across nine crops (Webster and MacDonald 2001).

In spite of the weedy nature of common bermudagrass, breeding programs have improved the turf quality of hybrid bermudagrass cultivars to meet the needs of the turfgrass industry. For instance, triploid interspecific hybrid bermudagrass cultivars, such as '*TifEagle*' and '*TifSport*', have been developed for various characteristics, such as high turf quality, tolerance to close mowing, and resistance to pests (e.g., southern mole cricket [*Scapteriscus borellii* Giglio-Tos]) (Hanna and Elsner 1999; Hanna et al. 1997). As a result, common bermudagrass and triploid hybrid bermudagrass cultivars are distinctly different. Common bermudagrass has an aggressive spreading growth habit and is capable of reproducing through seed production or vegetative propagation. In contrast, triploid hybrid bermudagrass cultivars tend to be less aggressive in their growth habit (Rochecouste 1962a), are sterile (i.e., unable to produce pollen or seed), and are propagated vegetatively.

Herbicide-resistant agronomic row crops have been developed, but the adoption of this technology has been slow in the turfgrass industry. This slow adoption is primarily due to concerns that genetic material will be transferred from the transgenic grasses to their weedy relatives. This transfer could result in the creation of a formidable weed that retains its natural weedy characteristics while acquiring pesticide resistance (Kind 2000). An example would be the potential transference of herbicide-resistant genes from bermudagrass turf to weedy common bermudagrasses. Another concern is that the transgenic turfgrasses may become weed problems in agricultural crops and noncrop areas. Both are valid concerns and need to be addressed before the development and release of transgenic turfgrass cultivars.

Transgene cultivars can be contained through insertion of genes into sterile, non–pollen-forming plants (Gressel 1999) such as triploid hybrid bermudagrass cultivars. In theory, genetic material (including herbicide resistance) could not be passed from these cultivars (e.g., *TifSport* and *TifEagle*) to common bermudagrass because neither male nor female flowers are formed (Hanna 1997, 1999). However, the potential weediness of escaped transgenic plants does cause concern. Although differences among common and triploid hybrid bermudagrasses do exist, evidence that hybrid bermudagrass can be controlled with standard herbicides in both fallow and crop production scenarios should be investigated before the creation of herbicide-resistant triploid hybrid bermudagrass cultivars. Therefore, the objective of this study was to evaluate the potential weediness of selected triploid hybrid bermudagrass cultivars compared with common bermudagrass in a cotton production area and under noncropland conditions and to determine whether they can be controlled with commonly used herbicides.

MATERIALS AND METHODS

General. Field studies were conducted at two sites in 1999, at the University of Georgia Ponder Farm near Ty Ty, GA, and at the Coastal Plain Experiment Station in Tifton, GA, and in 2001 at the Jones Farm near Chula, GA. The soil type at these locations was a Tifton loamy sand (fine-loamy, siliceous, thermic plinthic Kandiudults) with a pH of 6.0 to 6.2 and 0.5 to 0.8% organic matter. At each location, soil was treated in March with 90 kg/ha N, 120 kg/ha P, and 450 kg/ha K. Subsequent applications of 70 kg/ha N were in June and July.

Plugs of four cultivars were transplanted on June 3, 1999 and on May 14, 2001. The cultivars included two different triploid interspecific hybrid bermudagrass cultivars (*TifSport* and *TifEagle* [3n = 27]) (Hanna and Elsner 1999; Hanna et al.), the hexaploid '*Tifton-10*' (6n = 54) (Hanna et al. 1990), and tetraploid common bermudagrass (4n = 36) from a naturalized population on the Coastal Plain Experiment Station. Each plot contained six plugs of each cultivar, and each treatment was replicated four times in a randomized complete block design. Plugs consisted of well-rooted plants, grown in 5-cm-diam clay pots that were established from sprigs. Plugs were allowed to establish in the fields for 4 wk before treatments were imposed.

Bermudagrass plant diameters for each plug were measured before treatment at 4, 8, and 23 wk after transplanting (WAP). Visual control of bermudagrass was evaluated in the non-cropland study 8 WAP (just before application of the sequential treatments) and in both studies 23 WAP, using a scale of 0 (no control) to 100 (plant death).

Non-Cropland Study. Glyphosate was used for early-season weed control over the entire experimental area before the application of herbicide treatments. Desired bermudagrass plants were protected from the glyphosate application with inverted cups. Plots were hand weeded of non-bermudagrass plants, as needed, through the remainder of the season. There were nine herbicide treatments including 0.3 kg ai/ha clethodim 4 WAP, 0.15 kg/ha clethodim 4 WAP followed by (fb) same rate 8 WAP, 0.3 kg/ha clethodim 4 WAP fb same rate 8 WAP, 1.1 kg

ai/ha glyphosate[4] 4 WAP, 0.55 kg/ha glyphosate 4 WAP fb same rate 8 WAP, 1.1 kg/ha glyphosate 4 WAP fb same rate 8 WAP, 0.3 kg/ha clethodim plus 1.1 kg/ha glyphosate 4 WAP, 0.15 kg/ha clethodim plus 0.55 kg/ha glyphosate 4 WAP fb same rates 8 WAP, and 0.3 kg/ha clethodim plus 1.1 kg/ha glyphosate 4 WAP fb same rates 8 WAP. Herbicides were applied with a tractor-mounted sprayer calibrated to deliver 187 L/ha at 221 kPa. Applications of clethodim included a crop oil concentrate at 1% (v/v).[5] A nontreated control and a cultivated treatment (set to a depth of 7.5 cm) consisting of two passes in opposite directions 4 WAP also were included. Average plant diameters before treatment at 4 WAP in 1999 and 2001 measured 32 and 67 cm for common bermudagrass, 9 and 12 cm for *TifEagle*, 23 and 34 cm for *TifSport*, and 36 and 86 cm for *Tifton-10*, respectively.

Cotton Study. Cotton variety 'DPL 5415RR' was planted on June 3, 1999 and May 8, 2001 in 91-cm rows to a final population density of 113,700 plants/ha. Glyphosate and hand weeding were used for weed control as described previously. The following six herbicide treatments were evaluated in cotton: 0.08 kg/ha quizalofop-p, 0.3 kg/ha clethodim, 0.3 kg/ha clethodim plus 1.1 kg/ha glyphosate,[4] 0.4 kg/ha fluazifop-p, 1.1 kg/ha glyphosate, and 4.5 kg/ha glyphosate. Aside from the high rate of glyphosate, which exceeded the labeled rate in cotton, all other herbicide rates were the maximum allowed in cotton. The high rate of glyphosate is registered for bermudagrass control in noncrop situations. All herbicide applications included a crop oil concentrate at 1% (v/v)[5], with the exception of glyphosate treatments. A nontreated control and a cultivated treatment, as described previously, also were included. Average plant diameters before treatment at 4 WAP in 1999 and 2001 measured 16 and 63 cm for common bermudagrass, 5 and 17 cm for *TifEagle*, 16 and 40 cm for *TifSport*, and 12 and 83 cm for *Tifton-10*, respectively. Cotton yield was measured, but data were not presented because of the lack of significant differences among treatments.

Data Analysis. Data were subjected to analysis of variance and means separated using Fisher's Protected $LSD_{0.05}$. Before analysis of variance, it was necessary to arcsine transform bermudagrass control ratings because of the lack of independence between the variance and the mean. Treatment means of bermudagrass control were separated using transformed data, but means are presented in their original form for clarity. There was a significant treatment by year interaction for common bermudagrass in both the non-cropland and cotton studies for changes in plant diameter and weed control. All other species were analyzed over years. The triploid hybrid cultivars (*TifEagle* and *TifSport*) responded similarly to treatments, therefore means were combined and analyzed as a composite group.

RESULTS AND DISCUSSION

Non-Cropland Study. Early-season control (evaluated 8 WAP, before sequential applications) of triploid hybrid cultivars and *Tifton-10* was greatest with glyphosate (94 to 97%) and least with 0.15 kg/ha clethodim (53 to 71%) (Table 1). Application of 0.3 kg/ha clethodim and 0.3 kg/ha clethodim plus 1.1 kg/ha glyphosate controlled *Tifton-10* by 63 and 93%, respectively, and triploid hybrid bermudagrasses 82 and 96%, respectively, 8 WAP. Clethodim applied at 0.15 kg/ha was not as effective as 0.3 kg/ha clethodim in controlling *Tifton-10* and triploid hybrid bermudagrasses. However, 0.15 kg/ha clethodim plus 0.55 kg/ha glyphosate was as effective in controlling triploid hybrid bermudagrasses 8 WAP as was 0.3 kg/ha clethodim plus 1.1 kg/ha glyphosate.

Treatments with 1.1 kg/ha glyphosate were most effective for controlling common bermudagrass ($\geq$ 91%), whereas treatments with only clethodim (47 to 60%) were the least effective (Table 1). Application of 0.15 kg/ha clethodim plus 0.55 kg/ha glyphosate (62 to 78%) was not as effective in controlling common bermudagrass as was 0.30 kg/ha clethodim plus 1.1 kg/ha glyphosate ($\geq$ 91%) or either rate of glyphosate alone. There were no differences in control among bermudagrass cultivars 8 WAP when 1.1 kg/ha glyphosate was a component of the treatment.

At 23 WAP, triploid hybrid bermudagrasses were controlled 92 to 100% by treatments that included glyphosate, similar to the level of control observed before sequential treatments at 8 WAP (Table 1). A single application of 0.3 kg/ha clethodim (84%) did not differ in triploid hybrid bermudagrass control from two applications of 0.15 kg/ha clethodim (74%). However, two applications of 0.3 kg/ha clethodim (98%) were better than two applications of 0.15 kg/ha clethodim.

Control of *Tifton-10* at 23 WAP was $\geq$ 97% with 1.1 kg/ha glyphosate and $\geq$ 85% with 0.3 kg/ha clethodim plus 1.1 kg/ha glyphosate (Table 1). There were no differences in *Tifton-10* control with application frequency and rate of glyphosate and clethodim plus glyphosate.

[4] Roundup Ultra herbicide, Monsanto Company, St. Louis, MO 63167.

[5] Crop oil concentrate was Agri-Oil, a mixture of 83% petroleum oil and 17% surfactant blend of polyoil fatty acid esters. Chem Nut Inc., P.O. Box 3706, Albany, GA 31706.

Table 1. The effect of management treatments on early-season and late-season control of bermudagrass cultivars under non-cropland conditions.[a]

Herbicide	Herbicide rate		Control 8 WAP[b]				Control 23 WAP[a]			
					Common bermudagrass				Common bermudagrass	
	4 WAP	8 WAP	Triploid hybrids[c]	*Tifton-10*	1999	2001	Triploid hybrids	*Tifton-10*	1999	2001
	kg/ha		%							
Clethodim	0.30		82 de	63 gh	58 g–i	51 j–l	84 a–c	56 g	83 a–c	0 i
Clethodim	0.15	0.15	71 f	53 i–k	49 kl	47 l	74 c–f	55 g	79 b–d	24 h
Clethodim	0.30	0.30	78 e	64 fg	60 gh	57 h–j	98 a	87 a–c	98 a	59 e–g
Clethodim + glyphosate	0.30 + 1.10		96 ab	93 a–c	91 bc	91 bc	98 a	91 a–c	96 a	44 g
Clethodim + glyphosate	0.15 + 0.55	0.15 + 0.55	92 bc	82 de	78 e	62 gh	92 ab	87 a–c	76 b–e	22 h
Clethodim + glyphosate	0.30 + 1.10	0.30 + 1.10	96 ab	93 ab	94 ab	95 ab	100 a	85 a–c	100 a	62 d–g
Glyphosate	1.10		97 ab	97 ab	95 ab	99 a	99 a	97 a	100 a	87 a–c
Glyphosate	0.55	0.55	96 ab	95 ab	94 ab	87 cd	93 ab	83 a–c	100 a	57 fg
Glyphosate	1.10	1.10	97 ab	94 ab	94 ab	98 a	100 a	100 a	100 a	83 a–c
Cultivation			—	—	—	—	46 g	0 i	0 i	9 hi

[a] Herbicides were applied 4 and 8 wk after transplanting (WAP).

[b] The rating scale used ranged from 0 (no control) to 100 (complete control). Visual control 8 WAP was evaluated just before sequential herbicide applications. Data were arcsine transformed before analysis of variance and Fisher's protected $LSD_{0.05}$ was used to separate transformed means. Treatment means were presented in their original form in the table, and letters were used to indicate the appropriate mean separation within a rating date.

[c] Triploid hybrid cultivars were *TifEagle* and *TifSport*.

Two applications of 0.3 kg/ha clethodim controlled *Tifton-10* similar to glyphosate treatments. However, one application of 0.3 kg/ha clethodim and two applications of 0.15 kg/ha clethodim controlled *Tifton-10* ≤ 56%.

Although control of common bermudagrass was similar among years with 1.1 kg/ha glyphosate (≥ 83%), other treatments were not as consistent. Two applications of 0.55 kg/ha glyphosate controlled common bermudagrass 100% 23 WAP in 1999, whereas control was only 57% in 2001 (Table 1). Similarly, control with clethodim was better in 1999 (79 to 98%) than in 2001 (0 to 59%). A single application of 0.3 kg/ha clethodim controlled common bermudagrass as well as the best treatments in 1999, whereas in 2001 this treatment had no effect on common bermudagrass. Common bermudagrass control with 0.28 kg/ha clethodim has been shown to be variable among years (43 to 84%), and control was improved when sequential applications were made (83 to 95% control) (Grichar 1995). In the current study, sequential applications of 0.15 kg/ha clethodim and 0.3 kg/ha clethodim controlled common bermudagrass 79 and 98% in 1999, respectively, and 24 and 59% in 2001, respectively.

There may be some antagonism between clethodim and glyphosate. Compared with two applications of 0.55 kg/ha glyphosate, control of common bermudagrass was 24 to 35% lower with two applications of 0.15 kg/ha clethodim plus 0.55 kg/ha glyphosate (Table 1). This antagonism also occurred in 2001 with 0.3 kg/ha clethodim plus 1.1 kg/ha glyphosate when common bermudagrass control was 21 to 43% lower than control with 1.1 kg/ha glyphosate. This phenomenon was not seen with any of the other bermudagrass cultivars in the study, perhaps because of their high sensitivity to glyphosate in both years.

Previous studies have demonstrated variability among years in common bermudagrass control with glyphosate and other herbicides (Brown et al. 1987; Bryson and Wills 1985). In these studies, common bermudagrass with smaller plant diameters were more sensitive to glyphosate applications than were larger plants (Bedmar 1992, 1997; Brown et al. 1987). Other studies with postemergence graminicides (e.g., clethodim, fluazifop, quizalofop-p, and sethoxydim) indicated greater control of smaller common bermudagrass plants (Bedmar 1997; Grichar and Boswell 1989). Data in the current study support these findings. Common bermudagrass plants were more sensitive to herbicides in 1999 (plant diameters averaged 32 cm) and less sensitive in 2001 (plant diameters averaged 67 cm). Although the other cultivars had differences in pretreatment diameters among years,

Table 2. The effect of management treatments on changes in bermudagrass diameters over the course of the growing season under non-cropland conditions. Treatment means can be separated using Fisher's Protected $LSD_{0.05} = 76$.

Treatment	Herbicide rate applied[a]		Triploid hybrids[b]	*Tifton-10*	Common bermudagrass	
	4 WAP	8 WAP			1999	2001
	kg/ha		% change[c]			
Clethodim	0.30		− 83	− 63	− 94	+ 207
Clethodim	0.15	0.15	− 77	− 91	− 94	+ 56
Clethodim	0.30	0.30	− 98	− 97	− 97	− 9
Clethodim + glyphosate	0.30 + 1.10		− 100	− 94	− 100	+ 4
Clethodim + glyphosate	0.15 + 0.55	0.15 + 0.55	− 94	− 93	− 93	+ 86
Clethodim + glyphosate	0.30 + 1.10	0.30 + 1.10	− 100	− 90	− 100	− 6
Glyphosate	1.10		− 98	− 98	− 100	+ 2
Glyphosate	0.55	0.55	− 97	− 76	− 100	+ 45
Glyphosate	1.10	1.10	− 100	− 100	− 100	− 59
Cultivation			− 18	+ 134	+ 153	+ 159
Nontreated control			+ 199	+ 162	+ 226	+ 150

[a] Herbicides were applied 4 and 8 wk after transplanting (WAP).

[b] Triploid hybrid cultivars were *TifEagle* and *TifSport.*

[c] Change in plug diameter size between 4 and 23 WAP (pretreatment plug diameter subtracted from final plug diameter) expressed as a percentage of the pretreatment diameter size. A negative number indicates a reduction in plug diameter over the course of the season.

there were no detectable differences in herbicide control among years.

Only single and sequential applications of 1.1 kg/ha glyphosate consistently controlled (≥ 83%) all the bermudagrass cultivars across years (Table 1). With the exception of common bermudagrass in 2001, sequential applications of 0.3 kg/ha clethodim and 0.3 kg/ha clethodim plus 1.1 kg/ha glyphosate were among the best treatments in controlling the bermudagrasses. However, these treatments controlled common bermudagrass ≤ 62% in 2001.

Over the course of the growing season, plant diameters of *Tifton-10* and triploid hybrid bermudagrasses were reduced 76 to 100% and 94 to 100%, respectively, by glyphosate and clethodim plus glyphosate (Table 2). Only two applications of 1.1 kg/ha glyphosate eliminated growth of *Tifton-10,* whereas this treatment in addition to single and double applications of 0.3 kg/ha clethodim plus 1.1 kg/ha glyphosate eliminated the triploid hybrid cultivars. Triploid hybrid and *Tifton-10* bermudagrass plant diameters in the nontreated control increased by ≥ 162% of pretreatment size.

Common bermudagrass plant diameters were reduced ≥ 93% by all herbicide treatments in 1999, whereas the cultivated and nontreated control increased to 153 and 226%, respectively, of the pretreatment diameter (Table 2). All glyphosate treatments and the two applications of 0.3 kg/ha clethodim plus 1.1 kg/ha glyphosate killed common bermudagrass plants by the end of the 1999 season (Table 1). In contrast to 1999, there were differences in common bermudagrass growth among treatments in 2001. Two applications of 0.3 kg/ha clethodim reduced plant diameter compared with the nontreated control and one application of 0.3 kg/ha clethodim (Table 2). Common bermudagrass plant diameters increased after two applications of 0.55 kg/ha glyphosate (+ 45%), whereas two applications of 1.1 kg/ha glyphosate reduced the diameters by 59% (Table 2). However, the antagonism observed in visual control ratings with clethodim plus glyphosate compared with glyphosate was not present in plant diameter measurements. Cultivation did not reduce common bermudagrass plant diameter in either year. In fact, spreading fragments of common bermudagrass, similar to common bermudagrass created through cultivation, has been an effective means of establishing common bermudagrass plots for research purposes (W. W. Hanna, personal communication).

Cotton Study. When growing in the shade of the cotton canopy, triploid hybrid bermudagrasses and *Tifton-10* were controlled ≥ 88% by 1.1 kg/ha glyphosate, whereas 4.5 kg/ha glyphosate eliminated plant growth (Table 3). Only fluazifop-p was as effective as 1.1 kg/ha glyphosate in controlling *Tifton-10,* whereas clethodim plus glyphosate, fluazifop-p, and quizalofop-p were equally effective as 1.1 kg/ha glyphosate in controlling triploid hybrid cultivars. The addition of 0.3 kg/ha clethodim to glyphosate appeared to antagonize control of *Tifton-10* considering that control was 43% lower with the mixture. However, there was no significant antagonism with triploid hybrid cultivars. Cultivation was as effective as clethodim and quizalofop-p in controlling triploid hybrid and as effective as clethodim, clethodim plus glyphosate, and quizalofop-p in controlling *Tifton-10.*

Response of common bermudagrass to management treatments was different among years. All herbicide

Table 3. The effect of management treatments on bermudagrass cultivar control at the conclusion of the season when grown in competition with cotton.[a]

Treatment	Rate	Triploid hybrid cultivars[b]	*Tifton-10*	Common bermudagrass 1999	Common bermudagrass 2001
	kg/ha	%[c]			
Clethodim	0.30	61 d–h	55 f–i	86 a–d	30 i
Clethodim + glyphosate	0.30 + 1.10	74 b–f	57 e–h	81 a–e	30 i
Fluazifop-p	0.40	80 a–f	88 a–c	100 a	89 a–c
Glyphosate	1.10	88 a–c	100 a	100 a	59 e–h
Glyphosate	4.50	100 a	100 a	100 a	97 ab
Quizalofop-p	0.08	72 b–g	68 c–g	91 a–c	36 hi
Cultivation		47 g–i	60 e–h	0 j	0 j

[a] Data were transformed before to analysis of variance and Fisher's Protected $LSD_{0.05}$ was used to separate transformed means. Treatment means were presented in their original form in the table, and letters were used to indicate the appropriate mean separation.

[b] Triploid hybrid cultivars were *TifEagle* and *TifSport*.

[c] Visual bermudagrass control was evaluated using a scale with a range of 0 (plant death) to 100 (vigorous plant) at 23 WAP.

treatments controlled common bermudagrass ≥ 81% in 1999 (Table 3). Fluazifop-p and both rates of glyphosate eliminated common bermudagrass growth in 1999. Only fluazifop-p (89 to 100%) and 4.5 kg/ha glyphosate (97 to 100%) were consistent among years in controlling common bermudagrass. Previous studies have found common bermudagrass control with 0.28 kg/ha fluazifop-p to be variable across years, ranging from 18 to 80% (Brown et al. 1987) and from 68 to 98% (Bryson and Wills 1985). In 2001, common bermudagrass control with clethodim, clethodim plus glyphosate, 1.1 kg/ha glyphosate, and quizalofop-p ranged from 30 to 59% compared with 81 to 100% control in 1999. As was seen in the previous study, common bermudagrass plant diameter at the time of application may have affected herbicide efficacy. Plant diameters were almost four times larger in 2001 (63 cm) than in 1999 (16 cm).

All herbicide treatments reduced plant diameters of triploid hybrid bermudagrass cultivars ≥ 90% (Table 4). Glyphosate applied at 4.5 kg/ha killed both triploid cultivars and *Tifton-10* by the conclusion of the season. All other herbicide treatments reduced plant diameters of *Tifton-10* by 84 to 100%, with the exception of clethodim (62% reduction). Cultivation was not effective in suppressing triploid hybrid and *Tifton-10* because changes in plant diameter were similar to the nontreated control. The shade of the cotton canopy hindered the growth of triploid hybrid cultivars. Plant diameters in the nontreated control were reduced 23% from the initial plant diameter. The diameter of *Tifton-10* plants in the nontreated control increased only 16%.

Herbicide treatments in 1999 reduced plant diameters of common bermudagrass ≥ 97% from the pretreatment diameters (Table 4). However, only fluazifop-p and 4.5 kg/ha glyphosate were consistent between the years in reducing common bermudagrass plant diameters. Common bermudagrass plant diameters of clethodim- and quizalofop-treated plants in 2001 were not different from the nontreated control.

Of the four bermudagrass cultivars tested, common

Table 4. The effect of management treatments on change in the pretreatment plant diameter at the conclusion of the season for four cultivars of bermudagrass grown in cotton. Treatment means are separated using Fisher's Protected $LSD_{0.05} = 42$.

Treatment	Rate	Triploid hybrid cultivars[a]	*Tifton-10*	Common bermudagrass 1999	Common bermudagrass 2001
	kg/ha	%[b]			
Clethodim	0.30	− 93	− 62	− 98	− 18
Clethodim + glyphosate	0.30 + 1.10	− 92	− 84	− 97	− 23
Fluazifop-p	0.40	− 97	− 96	− 100	− 89
Glyphosate	1.10	− 98	− 100	− 100	− 52
Glyphosate	4.50	− 100	− 100	− 100	− 99
Quizalofop-p	0.08	− 90	− 86	− 97	+ 19
Cultivation		− 26	+ 66	+ 53	+ 25
Nontreated control		− 23	+ 16	+ 67	+ 20

[a] Triploid hybrid cultivars were *TifEagle* and *TifSport*.

[b] Change in plug diameter size over the course of the growing season (pretreatment plug diameter subtracted from final plug diameter) expressed as a percentage of the pretreatment diameter size. A negative number indicates a reduction in plug diameter over the course of the season.

bermudagrass and *Tifton-10* appeared to be the most aggressive in their growth habit. Although each cultivar was established using a 5-cm-diam plug, plant diameters in the non-cropland study in 2001 at 23 WAP were ≥ 158 cm for common bermudagrass and *Tifton-10,* whereas diameters for *TifEagle* and *TifSport* plants were 28 and 50 cm, respectively. Plant growth was not as vigorous in the cotton study as plant diameters in 2001 in the nontreated control were ≥ 56 cm for common bermudagrass and *Tifton-10,* whereas those for *TifEagle* and *TifSport* were 5 and 21 cm, respectively. These results confirm those of a previous study that found that tetraploid bermudagrasses (e.g., common bermudagrass) were more aggressive than triploid bermudagrasses (Rochecouste 1962a).

In addition, the two tested triploid hybrid bermudagrass cultivars were more sensitive to the applied treatments than was common bermudagrass (Tables 1–4). A similar study found tetraploid bermudagrasses were more tolerant than triploid bermudagrasses to the two herbicides dalapon and trichloroacetic acid (Rochecouste 1962b). Therefore, in the event that a yet-to-be-developed transgenic *TifEagle* or *TifSport* plant does escape to a nontarget area, recently established triploid bermudagrass cultivars could be controlled with commonly used herbicides.

In terms of weed control, first year plants of bermudagrass may not respond as established perennial stands of these cultivars. Established stands of common bermudagrass were more competitive with cotton than with first-year sprigged plugs (Brown et al. 1985). The increased competitiveness observed in perennial bermudagrass stands also may translate into increased difficulty in control. Future studies will need to address the herbicide rate response issue in established perennial stands of these triploid hybrid cultivars in greater detail. However, this study has demonstrated that compared with *Tifton-10* and common bermudagrass, the triploid hybrid bermudagrass cultivars tested were not as aggressive or as difficult to control as common bermudagrass with recommended herbicide use rates in both cotton and noncropland situations.

ACKNOWLEDGMENTS

We acknowledge the coordination of this study by James E. Davis and the technical support provided by Larry Baldree, Freddie Cheek, Earl Cook, T. Dudley Cook, Walter C. Harvey, Tony Howell, Lola C. Sexton, and T. Eddie Sklany. We also acknowledge the efforts of Duncan McClusky and Emily Cheek of the Coastal Plain Experiment Station Library, Tifton, GA. Cooperative investigation of the USDA-ARS and the University of Georgia, College of Agriculture and Environmental Sciences, and Agricultural Experiment Stations is also acknowledged.

LITERATURE CITED

Bedmar, F. 1992. Evaluation on postemergence grass herbicides against *Cynodon dactylon* in sunflower. Ann. Appl. Biol. 120:58–59.

Bedmar, F. 1997. Bermudagrass (*Cynodon dactylon*) control in sunflower (*Helianthus annuus*), soybean (*Glycine max*), and potato (*Solanum tuberosum*) with postemergence graminicides. Weed Technol. 11:683–688.

Brown, S. M., J. M. Chandler, and D. C. Bridges. 1987. Bermudagrass (*Cynodon dactylon*) and johnsongrass (*Sorghum halepense*) ecotype response to herbicides. Weed Technol. 1:221–225.

Brown, S. M., T. Whitwell, and J. E. Street. 1985. Common bermudagrass (*Cynodon dactylon*) competition in cotton (*Gossypium hirsutum*). Weed Sci. 33:503–506.

Bryson, C. T. and G. D. Wills. 1985. Susceptibility of bermudagrass (*Cynodon dactylon*) biotypes to several herbicides. Weed Sci. 33:848–852.

Dowler, C. C. 1998. Weed survey—southern states—broadleaf crops subsection. Proc. South. Weed Sci. Soc. 51:299–313.

Dowler, C. C. 1999. Weed survey—southern states: horticultural, pasture, recreational, and industrial subsection. Proc. South. Weed Sci. Soc. 52:280–318.

Gressel, J. 1999. Tandem constructs: preventing the rise of superweeds. Trends Biotechnol. 17:361–366.

Grichar, W. J. 1995. Comparison of postemergence herbicides for common bermudagrass (*Cynodon dactylon*) control in peanut (*Arachis hypogaea*). Weed Technol. 9:825–828.

Grichar, W. J. and T. E. Boswell. 1989. Bermudagrass (*Cynodon dactylon*) control with postemergence herbicides in peanut (*Arachis hypogaea*). Weed Technol. 3:267–271.

Hanna, W. W. 1997. '*Tift 94*' bermudagrass. U.S. plant patent 10,079. October 21, 1997.

Hanna, W. W. 1999. Bermudagrass named '*TifEagle*'. U.S. plant patent 11,163. December 21, 1999.

Hanna, W. W., G. W. Burton, and A. W. Johnson. 1990. Registration of '*Tifton 10*' turf bermudagrass. Crop Sci. 30:1355–1356.

Hanna, W. W., R. N. Carrow, and A. J. Powell. 1997. Registration of '*Tift 94*' bermudagrass. Crop Sci. 37:1012.

Hanna, W. W. and J. E. Elsner. 1999. Registration of '*TifEagle*' bermudagrass. Crop Sci. 39:1258.

Kind, M. 2000. Turf talk: transgenic turf? Not yet. Golf Course Manage. February: 48.

Mitich, L. W. 1989. Intriguing world of weeds: bermudagrass. Weed Technol. 3:433–435.

Rochecouste, E . 1962a. Studies on the biotypes of *Cynodon dactylon* (L.) Pers. I. Botanical investigations. Weed Res. 2:1–23.

Rochecouste, E. 1962b. Studies on the biotypes of *Cynodon dactyon* (L.) Pers. II. Growth response to trichloroacetic and 2,2-dichloropropionic acids. Weed Res. 2:136–145.

Webster, T. M. 2000. Weed survey—southern states: grass crops subsection. Proc. South. Weed Sci. Soc. 53:247–274.

Webster, T. M. and H. D. Coble. 1997. Changes in the weed species composition of the southern United States: 1974 to 1995. Weed Technol. 11: 308–317.

Webster, T. M. and G. E. MacDonald. 2001. A survey of weeds in various crops in Georgia. Weed Technol. 15:771–790.