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Western Ragweed (*Ambrosia psilostachya*) Control and Bermudagrass Response to Diflufenzopyr Tank-Mix Combinations

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Research was conducted in 2003 and 2004 to evaluate diflufenzopyr tank mixes for western ragweed control and injury to 'Tifton 85′ bermudagrass. In 2003 at 94 DAT, picloram at 0.28 and 0.56 kg ae ha^{-1} with or without diflufenzopyr provided greater than 95% control of western ragweed, whereas triclopyr + dilfufenzopyr, dicamba + diflufenzopyr, triclopyr alone, and diflufenzopyr alone provided < 77% control. In 2004 at 95 DAT, only the highest rate of picloram alone provided 96% control, and the two highest rates of picloram + diflufenzopyr provided at least 95% control. Tifton 85 bermudagrass growth reduction increased with the addition of diflufenzopyr to picloram in 2003, but not in 2004. However, forage dry-matter yield was not reduced by any herbicide treatment compared to the nontreated control. Results of these studies indicate that picloram alone and picloram + diflufenzopyr provide excellent control of western ragweed. The tank mixture of picloram + diflufenzopyr can improve control over picloram alone. However, dicamba + diflufenzopyr, triclopyr + diflufenzopyr, triclopyr alone, and diflufenzopyr alone did not provide adequate control.
Nomenclature: Dicamba; diflufenzopyr; picloram; triclopyr; western ragweed, *Ambrosia psilostachya* DC. AMBPS; bermudagrass, *Cynodon dactylon* (L.) Pers. CYNDA, 'Tifton 85'.
Key words: Bermudagrass, western ragweed, bermudagrass tolerance, weed control.

En 2003 y 2004 se realizó una investigación para evaluar mezclas en tanque con diflufenzopyr para el control de *Ambrosia psilostachya* y el daño en *Cynodon dactylon* 'Tifton 85′. En 2003 a 94 DAT, picloram a 0.28 y 0.56 kg ae ha^{-1} con o sin diflufenzopyr brindó un control superior a 95% de *A. psilostachya*, mientras que triclopyr + diflufenzopyr, dicamba + diflufenzopyr, triclopyr solo, y diflufenzopyr solo, brindaron control <77%. En 2004 a 95 DAT, solamente la dosis más alta de diflufenzopyr solo brindó 96% de control, y las dos dosis más altas de picloram + diflufenzopyr brindaron al menos 95% de control. La reducción en el crecimiento de *C. dactylon* 'Tifton 85′ aumentó con la adición de diflufenzopyr a picloram en 2003, pero no en 2004. Sin embargo, el rendimiento en materia seca del forraje no se redujo con ninguno de los tratamientos de herbicidas al compararse estos con el testigo no-tratado. Los resultados de estos estudios indican que picloram solo y picloram + diflufenzopyr brindan un control excelente de *A. psilostachya*. La mezcla en tanque de picloram + diflufenzopyr puede mejorar el control en comparación con picloram solo. Sin embargo, dicamba + diflufenzopyr, triclopyr + diflufenzopyr, triclopyr solo, y diflufenzopyr solo no brindaron un control adecuado.

Bermudagrass is the most important pasture grass in the southern United States (Burton and Hanna 1995; Mitich 1989). Bermudagrass is used on approximately 12 million ha for livestock grazing and hay production (Taliaferro et al. 2004). Although 'Coastal' bermudagrass has been the predominant hybrid bermudagrass in the southern United States for many years, newer hybrids such as 'Tifton 85' have gained popularity in recent years (Hill et al. 2001). Tifton 85 and 'Jiggs' hybrid bermudagrasses offer high yield and nutritive value (Mislevy and Martin 2006). Tifton 85 is desired by forage producers for its large rhizomes and rapidly spreading stolons capable of growing > 7.5 cm d^{-1} (Burton et al. 1993).

Western ragweed is a competitive perennial weed found in both rangeland and improved pastureland. It reproduces both sexually and asexually and has no forage value (Bovey et al. 1966). Western ragweed is usually considered a detriment to livestock production because of competition with forage grasses (Elder 1951) and the standing grass crop in tallgrass prairies has been reduced due to western ragweed (Dwyer 1958). Vermeire and Gillen (2000) reported standing crops of western ragweed at 600 kg ha^{-1} can be tolerated before control should be considered. However, Reece et al. (2004) reported that seasonal grass production on the sandhills prairie was reduced 21% when western ragweed herbage levels of 189 kg ha^{-1} were present following dry weather in the spring.

Diflufenzopyr acts as an auxin-transport inhibitor in plants and suppresses translocation of indoleacetic acid (IAA) and synthetic auxin-like compounds (Bowe et al. 1999). Evidence of synergism provided by diflufenzopyr and auxin associations was demonstrated in a field experiment conducted by Lym (1998). They evaluated dicamba (140 g ae ha^{-1}), dicamba (196 g ae ha^{-1}) plus the premix (1:2.5 ratio) of diflufenzopyr + dicamba (BAS-662: 107.8 g ae ha^{-1}), picloram (35 g ae ha^{-1}), and picloram + BAS-662 (35 and 39.2 g ae ha^{-1}) for control of Canada thistle (*Cirsium arvense* L.) and leafy spurge (*Euphorbia esula* L.). A dramatic increase in foliar injury (from 17 to 43%) to both species was observed at 1.5 mo after treatment (MAT) when diflufenzopyr was included in a tank mix with either dicamba or picloram. A greenhouse study conducted by Grossman et al. (2002) found that diflufenzopyr increased foliar uptake and translocation of dicamba in redroot pigweed (*Amaranthus retroflexus* L.) 16 h after foliar treatment. Enloe and Kniss (2009) reported that the addition of diflufenzopyr + dicamba to standard rates of several auxinic herbicides did not improve Russian knapweed [*Acroptilon*

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repens (L.) DC.] control at either 12 or 24 MAT. In a turf study, Wehtje (2008) found 20 to 25% less dicamba was required to achieve 90% control of purple cudweed [*Gamochaeata purpurea* (L.) Cabrera] and common lespedeza [*Kummerowia striata* (Thunb.) Schindl.] when tank-mixed with diflufenzopyr than if applied alone.

Bovey et al. (1966) found that annual applications with 2,4-D applied at 0.56, 1.12, and 2.24 kg ae ha^{-1}, provided effective stand reductions of western ragweed 1 yr after treatment (YAT). Plots were then retreated, and similar results were obtained the following year. In contrast, Dahl et al. (1989) observed no significant reduction in western ragweed population over two consecutive years with 2,4-D applied at 0.28 + 0.56 kg ae ha^{-1}. They also observed that triclopyr (0.28 kg ae ha^{-1}) and dicamba + 2,4-D (0.07 and 0.21 kg ae ha^{-1}) did not significantly reduce western ragweed population, but picloram (0.28 kg ae ha^{-1}) did cause a significant reduction. Baumann and Smith (2000) reported > 95% control of western ragweed up to 119 d after treatment (DAT) with early POST (EPOST) applications of picloram + 2,4-D (0.54 + 0.71 kg ae ha^{-1}), picloram alone (0.14 + 0.28 kg ae ha^{-1}), and 2,4-D alone (1.12 kg ae ha^{-1}).

Butler and Muir (2006) reported that total DM yields of 'Coastal' bermudagrass were not reduced by 2,4-D + dicamba (1.2 + 0.42 kg ha^{-1}); however, total DM yield was reduced 25% with picloram (0.56 kg ha^{-1}) and 20% with picloram + fluroxypyr (0.188 +0.188 kg ha^{-1}). Koger et al. (1997) reported that 2,4-D (1.06 kg ha^{-1}) and dicamba (0.56 kg ha^{-1}) did not cause injury to six forage bermudagrass cultivars. In a study evaluating herbicide injury during establishment of Tifton 85 bermudagrass, Butler et al. (2006) reported that picloram + fluroxypyr (0.19 + 0.19 kg ha^{-1}) and picloram + 2,4-D (0.15 + 0.56 kg ha^{-1}) did not injure bermudagrass and aided in its establishment.

Hybrid bermudagrass tolerance and western ragweed control with the use of diflufenzopyr tank-mix combinations have not been reported previously. Thus, the objective of this study was to determine western ragweed control and tolerance of hybrid bermudagrass with picloram, triclopyr, or dicamba applied alone or tank-mixed with diflufenzopyr.

Materials and Methods

Western Ragweed Control Study. Field studies were conducted in 2003 in Grimes County near Navasota, TX (30.42°N, 95.99°W) and in Brazos County near Millican, TX (30.42°N, 96.25°W) in 2004. The Grimes County soil was a Latium-Frelsburg soil (Latium: fine, smectitic, thermic Udic Calciusterts; Frelsburg: fine, smectitic, thermic Udic Calciusterts) with 1.9% organic matter and a pH of 8.1. The Brazos County soil was a Gredge soil (fine, smectitic, thermic Udic Paleustalfs) with 3.36% organic matter and a pH of 7.2. Experimental design was a randomized complete block with three replications. Plot size was 3.1 m wide by 6.1 m long.

Herbicide applications were made with a CO_2-pressurized backpack sprayer equipped with 8003 DG flat-fan nozzles (Teejet Spraying Systems Co, P.O. Box 7900, Wheaton, IL 60189) calibrated to deliver 187 L ha^{-1} at 200-kPa pressure. Herbicides used included picloram (Tordon 22K; DowAgroSciences LLC, Indianapolis, IN 46268), diflufenzopyr (Diflufenzopyr; BASF Corporation Agricultural Products, Research Triangle Park, NC 27709), triclopyr (Remedy; DowAgroSciences LLC, Indianapolis, IN 46268), and dicamba + diflufenzopyr (Overdrive; BASF Corporation Agricultural Products, Research Triangle Park, NC 27709). Rainfall in 2004 was much greater compared to 2003 (Table 1); therefore, western ragweed likely grew faster in 2004 with the added moisture. All treatments (Tables 2 and 3) were applied POST when western ragweed plants were 20–30 cm tall. A nontreated check was included for comparison.

Weed control was estimated visually on a scale of 0 to 100 (0 indicated no control and 100 indicated complete control), relative to the untreated check. Data were subjected to ANOVA and means were separated with the use of Duncan's new multiple range test (MRT) test at the $P = 0.05$ level. Arcsine transformation of percentage data did not affect the results; therefore, untransformed data were used in the analysis.

Bermudagrass Tolerance Study. Field experiments were also conducted during the 2003 and 2004 growing seasons, but at different locations than the weed control studies. The Tifton 85 bermudagrass crop tolerance experiment was conducted near Thrall, TX, in eastern Williamson County (30.59°N, 97.29°W), on a Burleson soil (fine, smectitic, thermic Udic Haplusterts) with 1.6% organic matter and a pH of 7.1. The experimental design was a randomized complete block with three replications. Plot size was 3.1 m wide by 6.1 m long. Herbicide applications were made with a backpack sprayer as previously described. Herbicide treatments were the same as those used in the western ragweed control study. Treatments were applied POST to bermudagrass that was 10 to 25 cm in height. All herbicide treatments included a nonionic surfactant at 0.25% (v/v) (SurfKing; Estes, Inc., Wichita Falls, TX 76307).

Tifton 85 bermudagrass injury was evaluated visually prior to each harvest on a scale of 0 to 100 with 0 = no injury and 100 = plant death. The tolerance experiments were harvested twice each season. The first harvest occurred approximately 2 to 6 wk following POST applications. The second harvest was taken approximately 6 to 7 wk following the first harvest. The harvest intervals were targeted to coincide with typical commercial harvest practices, and were subject to climatic conditions during the 2 yr of the studies. At each harvest, a 1 by 6.1–m area from the middle of each plot was harvested with a Carter flail harvester (Carter Mfg. Co., Inc., Brookston, IN 47923). The remaining forage was removed from the test area following harvest, and a broadcast application of 78.4 kg ha^{-1} of nitrogen (ammonium nitrate, 34–0–0) was applied to aid in bermudagrass regrowth for subsequent harvests. Samples from each harvest were oven dried at 65 C for 48 h to a moisture content of less than 8%. After samples were dried, bermudagrass yields on a dry-matter basis were determined. Dry-matter yield data were combined over years; however, year by treatment interactions were observed for growth reduction; therefore, data are presented by year. Data were subjected to ANOVA and treatment means were separated with the use of Duncan's new MRT test at the $P = 0.05$ level. Arcsine transformation of percentage data did

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Table 1. Monthly rainfall at test sites where selected treatments were evaluated for the control of western ragweed in Tifton 85 bermudagrass in Grimes County, TX in 2003 and in Brazos County, TX in 2004.

Month	2003	2004
	cm	
April	1.4	10.7
May	1.5	19.8
June	9.5	29.8
July	6.9	5.9
August	4.5	6.4
September	16.1	0.7
Totals	39.9	73.3

not affect the results; therefore, untransformed data were used in the analysis.

Results and Discussion

Western Ragweed Control Experiments. At 30 DAT in 2003, treatments containing picloram + diflufenzopyr (0.28 + 0.112 and 0.56 + 0.112 kg ae ha^{-1}) provided 70 and 85% control, respectively (Table 2). This level of control was comparable to picloram applied alone at 0.28 and 0.56 kg ae ha^{-1} (75 and 90%, respectively). Picloram applied alone (0.56 kg ae ha^{-1}) and picloram + diflufenzopyr (0.56 + 0.112 kg ae ha^{-1}) provided greater control (90 and 85%, respectively) than all other treatments 30 DAT. By 60 DAT, control provided by picloram + diflufenzopyr at the two highest rates (0.28 + 0.112 and 0.56 + 0.112 kg ae ha^{-1}), 90 and 95%, respectively, was not different than picloram applied alone at the same rates (87 and 98%), but was better than picloram + diflufenzopyr at the three lowest rates (59 to 73%). By 94 DAT, picloram alone at 0.28 and 0.56 kg ae ha^{-1} provided at least 96% control with or without diflufenzopyr. The combination of triclopyr + diflufenzopyr was no more effective than triclopyr alone, providing < 63% control at all rates and rating dates. Diflufenzopyr alone provided less control (12 to 32%) than picloram + diflufenzopyr at all rates and rating dates. Both rates of diflufenzopyr + dicamba provided < 77% control at all rating intervals in 2003.

In 2004, picloram + diflufenzopyr (0.56 + 0.112 kg ae ha^{-1}) provided greater control (88%) of western ragweed than all rates of picloram alone (43 to 73%), and all but one rate of picloram + diflufenzopyr (0.28 + 0.056 kg ae ha^{-1}) which provided 80% control 32 DAT. Picloram + diflufenzopyr at (0.56 + 0.112 kg ae ha^{-1}) provided greater control (96%) than all other treatments 63 DAT, with the exception of picloram alone at the high rate (87%). By 95 DAT, picloram + diflufenzopyr at the three highest rates and the high rate of picloram alone provided 95 to 100% control. In 2004, no treatment containing of diflufenzopyr + dicamba, triclopyr + diflufenzopyr, or diflufenzopyr alone provided > 70% control. Triclopyr + diflufenzopyr at both rates resulted in greater control (43 to 52%) than triclopyr applied alone (20 to 33%). These results are similar to those of Lym and Deibert (2005), who found that the addition of diflufenzopyr to dicamba, quinclorac, picloram, and picloram plus 2,4-D improved leafy spurge control compared with the herbicides applied alone.

In general, picloram + diflufenzopyr and picloram applied alone provided the greatest control of western ragweed. Dahl et al. (1989) also reported effective control of western ragweed with applications of picloram alone. An increase in effectiveness of picloram due to the addition of diflufenzopyr was only evident in 2004. A possible explanation for the differences observed in western ragweed control each year between picloram applied with or without diflufenzopyr may

Table 2. Control of western ragweed with selected treatments in Tifton 85 bermudagrass in Grimes and Brazos Counties, TX, 2003 and 2004, respectively.[a]

Treatment	Rate	2003			2004		
		30 DAT[b]	60 DAT	94 DAT	32 DAT	63 DAT	95 DAT
	kg ae ha^{-1}	%					
Picloram + diflufenzopyr	0.07 + 0.028	55 de[a]	59 fg	72 cd	67 cde	63 de	67 ef
Picloram + diflufenzopyr	0.14 + 0.028	65 c	73 de	87 abc	70 cd	74 cd	78 cde
Picloram + diflufenzopyr	0.14 + 0.056	65 c	71 de	84 abc	72 bc	76 bcd	87 bc
Picloram + diflufenzopyr	0.28 + 0.056	65 c	79 cd	98 a	80 ab	81 bc	95 ab
Picloram + diflufenzopyr	0.28 + 0.112	70 bc	90 abc	97 a	72 bc	81 bc	97 ab
Picloram + diflufenzopyr	0.56 + 0.112	85 a	95 ab	98 a	88 a	96 a	100 a
Triclopyr + diflufenzopyr	0.21 + 0.028	47 ef	53 gh	62 de	43 g	50 f	52 h
Triclopyr + diflufenzopyr	0.21 + 0.056	45 f	42 ij	57 e	45 g	50 f	50 h
Dicamba + diflufenzopyr	0.14 + 0.056	55 de	63 efg	72 cde	55 f	57 ef	60 fgh
Dicamba + diflufenzopyr	0.28 + 0.112	65 c	66 ef	76 cd	60 ef	65 de	70 def
Picloram	0.07	62 cd	63 efg	73 cd	43 g	48 f	53 gh
Picloram	0.14	63 cd	65 ef	82 bc	57 f	57 ef	65 fg
Picloram	0.28	75 b	87 bc	96 ab	62 def	67 de	81 cd
Picloram	0.56	90 a	98 a	99 a	73 bc	87 ab	96 ab
Triclopyr	0.21	47 ef	47 hi	62 de	32 h	33 g	20 i
Diflufenzopyr	0.028	20 g	18 k	32 f	20 i	22 gh	17 i
Diflufenzopyr	0.056	13 g	12 k	12 gh	13 i	10 hi	10 ij
Diflufenzopyr	0.112	20 g	33 j	27 fg	15 i	20 h	17 i
Nontreated	–	0 h	0 l	0 h	0 j	0 i	0 j

[a] Treatment means within a column followed by the same letter are not significantly different at the P = 0.05 level.

[b] Abbreviations: DAT, days after treatment.

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Table 3. Response of Tifton 85 bermudagrass to selected treatments applied for western ragweed control in 2003 and DM yield in 2003 and 2004 in Williamson County, TX.[a–c]

Treatment	Rate	Growth reduction 2003 Harv 1	Growth reduction 2003 Harv 2	DM yield Harv 1	DM yield Harv 2
	kg ae ha^{-1}	%		kg ha^{-1}	
Picloram + diflufenzopyr	0.07 + 0.028	30.0 de[a]	2.5 bc	3,865 c–f	2,769 abc
Picloram + diflufenzopyr	0.14 + 0.028	40.0 c	1.3 c	3,887 c–f	2,784 abc
Picloram + diflufenzopyr	0.14 + 0.056	41.3 c	2.5 bc	3,381 ef	2,735 abc
Picloram + diflufenzopyr	0.28 + 0.056	51.3 b	6.3 abc	3,729 def	2,971 ab
Picloram + diflufenzopyr	0.28 + 0.112	57.5 b	2.5 bc	3,712 def	3,120 a
Picloram + diflufenzopyr	0.56 + 0.112	66.3 a	2.5 bc	3,301 f	3,004 ab
Triclopyr + diflufenzopyr	0.21 + 0.028	8.8 k	8.8 ab	4,268 a–d	2,513 bc
Triclopyr + diflufenzopyr	0.21 + 0.056	17.5 ghi	2.5 bc	4,276 a–d	2,598 abc
Dicamba + diflufenzopyr	0.14 + 0.056	10.0 jk	3.8 abc	4,382 a–d	2,512 bc
Dicamba + diflufenzopyr	0.28 + 0.112	13.8 ijk	1.3 c	4,627 ab	2,675 abc
Picloram	0.07	12.5 ijk	5.0 abc	4,055 b–e	2,480 bcd
Picloram	0.14	16.3 hij	6.3 abc	4,179 a–d	2,682 abc
Picloram	0.28	17.5 ghi	2.5 bc	4,869 a	3,084 a
Picloram	0.56	23.8 efg	5.0 abc	4,042 b–e	2,614 abc
Triclopyr	0.21	17.5 ghi	10.0 a	3,867 c–f	1,960 d
Diflufenzopyr	0.028	21.3 fgh	0.0 c	4,203 a–d	2,673 abc
Diflufenzopyr	0.056	27.5 ef	3.8 abc	4,552 abc	2,967 ab
Diflufenzopyr	0.112	35.0 cd	2.5 bc	3,884 c–f	2,516 bc
Nontreated		0.0 l	0.0 c	3,914 b–f	2,416 cd

[a] Treatment means within a column followed by the same letter are not significantly different at the P = 0.05 level.

[b] DM yield data combined over 2003 and 2004.

[c] Abbreviations: DM, dry matter; Harv 1, first harvest; Harv 2, second harvest.

be the differences in rainfall during the evaluation period (Table 1).

Tolerance Experiments. In 2003, visual injury ratings for Tifton 85 bermudagrass at harvest one revealed that treatments caused a reduction in growth ranging from 10 to 66% (Table 3). All treatments of picloram + diflufenzopyr resulted in more growth reduction than the corresponding picloram rates applied alone. By the second harvest in 2003, growth reduction was substantially less evident across all treatments and rates and ranged from 0 to 10%. In 2004, growth reduction was not observed in any of the treatments evaluated prior to harvest one or two (data not shown). Wehtje (2008) reported that dicamba + diflufenzopyr did not cause injury to hybrid bermudagrass turf.

At the first harvest, dry-matter forage yields of Tifton 85 bermudagrass were not different than the untreated across all but one treatment (Table 3). Picloram alone (0.28 kg ae ha^{-1}) yielded more dry matter forage than the untreated. All combinations of picloram + diflufenzopyr produced less forage yield than picloram applied alone at 0.28 kg ae ha^{-1}. In addition, the highest rate of picloram + diflufenzopyr (0.56 + 0.112 kg ae ha^{-1}) yielded less than picloram applied alone at the equivalent rate.

The second harvest of Tifton 85 bermudagrass yielded less forage across all treatments and no treatment reduced dry matter yield compared to the untreated. Similar to the first harvest, yields between treatments containing picloram + diflufenzopyr were not significantly different. Unlike the first harvest, differences between all treatments consisting of either picloram + diflufenzopyr or picloram alone at equivalent rates were not significant. The three highest rates of picloram + diflufenzopyr, picloram alone (0.28 kg ae ha^{-1}), and diflufenzopyr alone (0.56 kg ae ha^{-1}), resulted in greater yields than the untreated. These results are in contrast to those of Butler and Muir (2006) who reported that total DM yields of Coastal bermudagrass was reduced 25% by 0.19 kg ae ha^{-1} picloram. These results are similar to what was reported by Koger et al. (1997) who reported picloram + 2,4-D did not reduce either stem height or forage yield of six forage bermudagrass varieties. Furthermore, Matocha et al. (2010) reported no yield reduction of Tifton 85 bermudagrass from tank mix combinations of nicosulfuron + metsulfuron.

Results of these studies indicate that both picloram alone and picloram + diflufenzopyr provide excellent control of western ragweed. The tank mixture of picloram + diflufenzopyr can improve control of western ragweed under certain conditions. However, neither dicamba + diflufenzopyr, triclopyr + diflufenzopyr, triclopyr alone, nor diflufenzopyr alone provided adequate control.

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