

## Research Article

# Management of Palmer Amaranth (*Amaranthus palmeri*) in Glufosinate-Resistant Soybean (*Glycine max*) with Sequential Applications of Herbicides

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Palmer amaranth (*Amaranthus palmeri* S. Wats.) is one of the most difficult weeds to control in soybean (*Glycine max* (L.) Merr.) in North Carolina. Research was conducted during 2010 and 2011 to determine if Palmer amaranth control and soybean yield were affected by soybean plant population and combinations of preemergence (PRE) herbicides followed by a single application of glufosinate postemergence (POST) versus multiple applications of glufosinate POST. Palmer amaranth was controlled more, and soybean yield was greater when soybean was established at 483,000 plants ha<sup>-1</sup> in 3 of 4 experiments compared with soybean at 178,000 plants ha<sup>-1</sup> irrespective of herbicide treatments. In separate experiments, application of PRE herbicides followed by POST application of glufosinate or multiple POST applications of glufosinate provided variable Palmer amaranth control, although combinations of PRE and POST herbicides controlled Palmer amaranth the most and provided the greatest soybean yield. In 1 of 3 experiments, sequential applications of glufosinate were more effective than a single application. Yield was higher in 2 of 3 experiments when glufosinate was applied irrespective of timing of application when compared with the nontreated control. In the experiment where glufosinate was applied at various POST timings, multiple applications of the herbicide provided the best control and the greatest yield compared with single applications.

## 1. Introduction

Resistance of Palmer amaranth to acetolactate synthase (ALS-) inhibiting herbicides and glyphosate is well documented in North Carolina [1–3]. Controlling herbicide-resistant Palmer amaranth can be challenging because alternatives to glyphosate and ALS-inhibiting herbicides require timely application [4, 5]. Row pattern and plant population can influence weed management in soybean [6, 7]. Herbicides that applied PRE or POST other than glyphosate are important in managing glyphosate-resistant Palmer amaranth in soybean [8–10]. Under weed-free conditions, soybean at populations below those established in many fields in North Carolina yield as well as soybean at higher populations considered “standard” (exceeding 300,000 plants ha<sup>-1</sup>) (E. J. Dunphy, personal communication). Establishing soybean

at lower populations can reduce production costs if yields are maintained. Results comparing the economic value of high soybean populations versus increasing the number of POST herbicides are mixed [11–16]. Additional research is needed to determine if Palmer amaranth control is more effective when soybean is established at higher populations in glufosinate-resistant soybean.

Glufosinate-resistant soybean allows producers to apply glufosinate to control problematic weeds like Palmer amaranth [17]. Sequential programs, either as PRE followed by POST applications or multiple POST applications of herbicides, can be effective in controlling weeds, especially glyphosate-resistant Palmer amaranth [18]. Timely applications of glufosinate in glufosinate-resistant soybean can be effective in controlling glyphosate-resistant and glyphosate-susceptible Palmer amaranth [17]. Reed et al. [19] reported

that multiple applications of glufosinate in a total POST herbicide program controlled Palmer amaranth effectively. However, most recommendations by Cooperative Extension Service representatives include sequential applications of PRE herbicides followed by timely POST herbicides, especially in fields where glyphosate-resistant Palmer amaranth is suspected.

Given that Palmer amaranth has become more prevalent in North Carolina, especially herbicide-resistant biotypes, research is needed to better define the role of seeding rate on weed management programs for soybean. Determining if sequential applications of PRE and POST herbicides are as effective as multiple POST applications of glufosinate alone will be important, especially in terms of response to soybean population. Research is also needed to better define the time between multiple applications of glufosinate. Therefore, research was conducted in North Carolina to compare Palmer amaranth control and soybean yield with combinations of PRE and POST herbicides applied to glufosinate-resistant soybean at two soybean populations and to determine the most effective timing of multiple POST applications of glufosinate.

## 2. Materials and Methods

*2.1. Interactions of Plant Population and Herbicide Program.* The experiment was conducted in North Carolina in two separate fields during each year (2010 and 2011) at the Upper Coastal Plain Research Station located near Rocky Mount with natural and relatively high populations of Palmer amaranth. Populations of weed species other than Palmer amaranth were low and inconsistent across fields compared with density and distribution of Palmer amaranth. One field consisted of a Lynchburg fine sandy loam soil (fine-loamy, siliceous, semiactive, thermic, and Aeric Paleaquults) while the second field was a Nahunta loam soil (fine-silty, siliceous, thermic, and Aeric Paleaquults). Corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.) preceded soybean on these respective soil series. Soybean cultivar LL 595 N (Southern States Cooperative, Inc., Farmville, NC 27828, USA) was planted between May 24 and June 7 after disking and field cultivation in rows spaced 20 cm apart in plots 12 rows wide by 9 m.

Treatments consisted of two levels of soybean population (178,000 plants ha<sup>-1</sup> versus 483,000 plants ha<sup>-1</sup>) and four levels of herbicide program. Herbicide treatments included glufosinate POST applied 2 weeks after planting (WAP), glufosinate applied sequentially 2 and 4 WAP, S-metolachlor plus fomesafen applied PRE, and S-metolachlor plus fomesafen applied PRE followed by glufosinate POST 4 WAP. A nontreated control also was included. S-metolachlor plus fomesafen (Prefix herbicide, Syngenta Crop Protection, Greensboro, NC 27709, USA) was applied at 1200 + 270 g ae ha<sup>-1</sup> while glufosinate-ammonium (Ignite 280 herbicide, Bayer CropScience, Research Triangle Park, NC 27709) was applied at 670 g ae ha<sup>-1</sup>. Herbicides were applied using a CO<sub>2</sub>-pressurized backpack sprayer calibrated to deliver 145 L ha<sup>-1</sup> using 8002 regular flat-fan

nozzles (Teejet Corporation, Wheaton, IL 60187, USA) at 275 kPa.

Palmer amaranth was 2 to 6 cm in height when glufosinate was applied POST. Visible estimates of percent Palmer amaranth control were recorded 6 WAP using a scale of 0 to 100, where 0 is no control and 100 is complete control. Soybean was machine harvested, and final yield was adjusted to 15% moisture.

The experimental design was a randomized complete block with treatments replicated four times. Data for Palmer amaranth control and soybean yield were subjected to ANOVA using the Proc GLM procedure in SAS (SAS Institute, GLM Procedure, Cary, NC 27513, USA) for a four (site/year combinations) by a four (herbicide program) factorial arrangement of treatments. The nontreated control was not included in this analysis because soybean was not harvestable when herbicide was not included. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at  $P \leq 0.05$ .

*2.2. Efficacy of Sequential Herbicide Programs in a Single Plant Population.* Two experiments were conducted with either sequential applications of PRE followed by POST herbicides or multiple applications of glufosinate only. The experiment with sequential applications of PRE and POST herbicides was conducted during 2010 and 2011 at the Upper Coastal Plain Research Station near Rocky Mount in the fields discussed previously (Nahunta soil series during 2010 and Lynchburg soil series during 2011). The experiment with multiple applications of glufosinate was conducted during 2010 on a Norfolk loam sand soil (fine-loamy, kaolinitic, thermic, and Typic Kandiodults) and in two separate fields during 2011 on both the Nahunta and Lynchburg soil series described previously. The glufosinate-resistant soybean cultivar LL 595N (Southern States Cooperative, Inc., Farmville, NC 27828, USA) was planted after disking and field cultivation in rows spaced 20 cm apart with a final plant population of 480,000 plants ha<sup>-1</sup>. Plot size was the same as described previously.

In the experiment with sequential application of PRE and POST herbicides, treatments consisted of seven levels of PRE herbicides, including no PRE, flumioxazin (Valor SX, Valent USA Corporation, Walnut Creek, CA 94596, USA) alone at 70 g ai ha<sup>-1</sup> or with chlorimuron (Valor XLT herbicide, E. I. DuPont de Nemours and Co., Wilmington, DE 19898, USA) at 21 g ai ha<sup>-1</sup>, the sodium salt of fomesafen (Reflex herbicide, Syngenta Crop Protection, Greensboro, NC 27709, USA) at 280 g ae ha<sup>-1</sup>, S-metolachlor (Dual II Magnum, Syngenta Crop Protection, Greensboro, NC 27709, USA) at 1500 g ai ha<sup>-1</sup>, S-metolachlor plus fomesafen (Prefix herbicide, Syngenta Crop Protection, Greensboro, NC 27709, USA) at 1200 + 270 g ha<sup>-1</sup>, and sulfentrazone plus cloransulam-methyl (Authority First herbicide, FMC Corporation, Philadelphia, PA 19103, USA) at 280 + 36 g ai ha<sup>-1</sup>, respectively. Each of these PRE herbicides was followed by no POST herbicide or a single application of glufosinate ammonium (Ignite 280 herbicide, Bayer CropScience, Research Triangle Park, NC 27709, USA) at 670 g ha<sup>-1</sup> 2 WAP or

sequential applications of glufosinate at 400 g ha<sup>-1</sup> at 2 and 4 WAP. In the experiment with only POST applications of glufosinate, treatments consisted of glufosinate applied 2 WAP at 400 and 670 g ha<sup>-1</sup> (referred to as POST 1) followed by no additional applications of glufosinate or followed by a second application of glufosinate at 400 g ha<sup>-1</sup> at 3 WAP (referred to as POST 2) or 4 WAP (referred to as POST 3). Treatments also included three sequential applications of glufosinate at 400 g ha<sup>-1</sup>.

Palmer amaranth size ranged from 5 to 10 cm in height when glufosinate was applied in the experiment with PRE and POST herbicides. In the experiment with multiple applications of glufosinate only, Palmer amaranth height was 5 to 10 cm at POST 1, 5 to 20 cm at POST 2, and 5 to 40 cm at POST 3. The range in size of Palmer amaranth reflected differences in emergence of weeds caused by PRE herbicides prior to the POST application in experiment. In both experiments, glufosinate was applied using the procedures described previously.

Percent Palmer amaranth control was estimated visually and was recorded 10 WAP in both experiments as described previously. Soybean yield was determined in each plot and adjusted to a final moisture of 15%.

The experimental design was a randomized complete block with four replications. Data for Palmer amaranth control and soybean yield were subjected to ANOVA using the Proc GLM procedure in SAS (SAS Institute, Cary, NC 27513, USA) considering the factorial arrangement of treatments. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at  $P \leq 0.05$ .

### 3. Results and Discussion

**3.1. Interactions of Plant Population and Herbicide Program.** Interactions of experiment (site/year combination) by soybean population and experiment by herbicide program were significant for both Palmer amaranth control ( $P = 0.0525$  and  $\leq 0.0001$ , resp.) and soybean yield ( $P \leq 0.0001$  and  $0.0344$ , resp.). The interaction of experiment by soybean population by herbicide program was not significant for Palmer amaranth control ( $P = 0.5630$ ) and soybean yield ( $P = 0.8912$ ). Additionally, the interaction of soybean population by herbicide program was not significant for these parameters ( $P = 0.4373$  and  $0.2719$ , resp.).

Palmer amaranth was controlled more effectively when soybean was established at the higher seeding rate by 11 to 13 percentage points at 3 of 4 locations (Table 1). At a fourth location control was numerically higher by 6 percentage points at the higher plant population. Soybean yield was higher in 3 of 4 experiments when established at the higher population (Table 1). However, there was some discrepancy in Palmer amaranth control and soybean yield among experiments when comparing soybean population. The relatively low soybean yields on the Nahunta soil series during 2010 due to dry weather most likely minimized the possibility of separating yields based on Palmer amaranth control. The higher soybean yield during 2010 on the Lynchburg soil series or during 2011 on the Nahunta soil

series most likely reflected differences in Palmer amaranth control. On the Lynchburg soil series during 2011 there was a slight but nonstatistical difference in Palmer amaranth control but a clear increase in yield at the higher plant population. Other factors could have contributed to higher yields at a higher soybean population that are not related to weed control.

Considerable variation in Palmer amaranth control was noted among herbicide treatments across experiments (Table 2). Control by multiple applications of glufosinate exceeded that of a single application of glufosinate in 3 of 4 experiments. Sequential applications of glufosinate only and S-metolachlor plus fomesafen PRE controlled Palmer amaranth similarly in 3 of 4 experiments. Applying glufosinate following S-metolachlor plus fomesafen was more effective than S-metolachlor plus fomesafen alone, sequential applications of glufosinate, and a single application of glufosinate in 1, 3, and 4 experiments, respectively.

Soybean yield during 2010 on the Nahunta soil series was low and did not differ among herbicide programs, most likely because yield was relatively low compared to the Lynchburg soil series during 2010 and both soil series during 2011 (Table 2). On the Lynchburg series during 2010, soybean yield was higher following sequential applications of glufosinate compared with a single application; yield with S-metolachlor plus fomesafen alone or followed by glufosinate was intermediate. On the Nahunta soil series during 2011, soybean yield with the more intensive program of S-metolachlor plus fomesafen followed by glufosinate yield exceeded yield following the other herbicide programs. On the Lynchburg soil series, yield with this program also was higher than a single application of glufosinate.

Although some variation in Palmer amaranth control and soybean yield was noted when comparing herbicide programs, lack of a soybean population by herbicide program interaction for these parameters suggests that higher soybean populations will increase Palmer amaranth control and soybean yield irrespective of herbicide program.

**3.2. Efficacy of Sequential Herbicide Programs in a Single Plant Population.** The interaction of year by PRE by POST herbicide was significant for Palmer amaranth control ( $P \leq 0.0001$ ) and for soybean yield ( $P \leq 0.0001$ ). Therefore, data were analyzed by year. The interaction of PRE by POST was not significant for Palmer amaranth control ( $P = 0.1466$ ) but was significant for soybean yield ( $P = 0.0268$ ) during 2010. However, the interaction of PRE by POST herbicides was significant for both Palmer amaranth control ( $P = 0.0011$ ) and soybean yield ( $P = 0.0049$ ).

Palmer amaranth control by flumioxazin alone or with chlorimuron was 93 to 98% while fomesafen alone or with S-metolachlor provided 77 to 80% control (Table 3). Sulfentrazone plus cloransulam methyl controlled Palmer amaranth 66%, while S-metolachlor provided only 56% control. Whitaker et al. [20] found similar results for Palmer amaranth control with flumioxazin and fomesafen PRE.

Palmer amaranth control was similar when glufosinate was applied either once or sequentially (Table 3). Lack of a difference in single and sequential applications most likely

TABLE 1: Interaction of experiment and soybean population for Palmer amaranth control and soybean yield<sup>a</sup>.

Year	Soil series	Palmer amaranth control		Soybean yield	
		Soybean plant population <sup>b</sup>		Soybean plant population <sup>b</sup>	
		Low	High	Low	High
		%		kg ha <sup>-1</sup>	
2010	Nahunta	57	69*	220	430
2010	Lynchburg	80	93*	720	1190*
2011	Nahunta	82	93*	2640	3710*
2011	Lynchburg	83	89	3810	4500*

<sup>a</sup> Indicates a significant difference at  $P \leq 0.05$  within an experiment comparing low and high plant populations for Palmer amaranth control and soybean yield. Data are pooled over herbicide programs.

<sup>b</sup> The low soybean population was approximately 178,000 plants ha<sup>-1</sup>. The high soybean plant population was approximately 483,000 plants ha<sup>-1</sup>.

TABLE 2: Interaction of experiment and herbicide program for Palmer amaranth control and soybean yield<sup>a</sup>.

Herbicide program	Palmer amaranth control				Soybean yield			
	Soil series				Soil series			
	2010		2011		2010		2011	
	Nahunta	Lynchburg	Nahunta	Lynchburg	Nahunta	Lynchburg	Nahunta	Lynchburg
		%				kg ha <sup>-1</sup>		
Glufosinate	46 c	74 c	81 b	71 c	230 a	770 b	2640 c	3840 b
Glufosinate followed by glufosinate	62 b	100 a	74 b	85 b	360 a	1130 a	3170 b	4120 ab
S-metolachlor plus fomesafen	70 b	93 ab	95 a	89 ab	360 a	1110 ab	3020 bc	4220 ab
S-metolachlor plus fomesafen followed by glufosinate	100 a	87 b	100 a	99 a	370 a	950 ab	3870 a	4420 a

<sup>a</sup> Means within a year and field followed by the same letter are not different according to Fisher's Protected LSD test at  $P \leq 0.05$ . Data are pooled over soybean plant population.

reflects limited weed emergence after the first POST application and rapid closure of the soybean canopy.

All PRE herbicides increased soybean yield during 2010 compared with the no-PRE herbicide control (Table 3). Yield of soybean receiving S-metolachlor plus fomesafen exceeded that of soybean treated with flumioxazin alone, sulfentrazone plus cloransulam methyl, or flumioxazin plus chlorimuron. Surprisingly, yield following a single application of glufosinate was lower than soybean yield without a POST application of glufosinate or soybean receiving multiple applications of glufosinate.

Several differences in Palmer amaranth control among PRE herbicides were observed during 2011, especially in absence of glufosinate (Table 4). Flumioxazin, flumioxazin plus chlorimuron, S-metolachlor plus fomesafen, and fomesafen alone provided the best control. Sulfentrazone plus cloransulam-methyl and S-metolachlor alone provided intermediate control between the most effective PRE herbicides and the nontreated control. When glufosinate was applied only once, no difference in control among PRE herbicides was observed.

There were no significant differences in soybean yield among PRE herbicide treatments when glufosinate was applied, regardless of the number of glufosinate applications (Table 5). In the absence of glufosinate, soybean yield following fomesafen, S-metolachlor, and sulfentrazone plus

cloransulam methyl was intermediate between the non-treated control and flumioxazin alone or with chlorimuron or S-metolachlor plus fomesafen.

In the second experiment with total POST applications of glufosinate applied sequentially 2, 3, and 4 WAP, the interaction of glufosinate rate with sequence of glufosinate application was not significant for Palmer amaranth control ( $P = 0.1064$ ) or soybean yield ( $P = 0.7318$ ). Although glufosinate rate as a main effect or the interaction with year or sequence of glufosinate application was not significant ( $P \leq 0.05$ ), the interaction of experiment by sequence of glufosinate application was significant for Palmer amaranth control ( $P = 0.0077$ ) and soybean yield ( $P = 0.0100$ ). In 2010, multiple applications of glufosinate controlled Palmer amaranth 97 to 99% than a single application 82% (Table 6). In systems with two applications, timing of the second application had no effect on Palmer amaranth control. Also, Palmer amaranth control was similar with two and three applications. Soybean yield was not affected by the number of glufosinate applications. However, glufosinate POST increased yield over nontreated soybean. During 2011, on the Nahunta soil series, Palmer amaranth control was similar with all glufosinate applications and was at least 97%. In the second field on a Lynchburg soil series, control was greater where glufosinate was applied sequentially compared with a single application.

TABLE 3: Palmer amaranth control and soybean yield as influenced by main effects of PRE and POST herbicide treatments during 2010 on the Nahunta soil series<sup>a</sup>.

Herbicides	Herbicide rate g ha <sup>-1</sup>	Palmer amaranth control %	Soybean yield kg ha <sup>-1</sup>
PRE herbicides			
None		29 e	1150 c
Flumioxazin	700	98 a	1460 b
Sulfentrazone plus cloransulam methyl	28 + 36	66 cd	1450 b
S-metolachlor plus fomesafen	1200 + 270	77 c	1680 a
Flumioxazin plus chlorimuron	70 + 21	93 ab	1420 b
Fomesafen	280	80 bc	1570 ab
S-metolachlor	1500	56 d	1500 ab
POST herbicides			
None		64 b	1500 a
Glufosinate	670	73 a	1340 b
Glufosinate then glufosinate	400 then 400	76 a	1530 a

<sup>a</sup> Means within a treatment factor (PRE or POST herbicides) for each parameter followed by the same letter are not different according to Fisher's Protected LSD test at  $P \leq 0.05$ . Data for PRE herbicides are pooled over levels of POST herbicides. Data for POST herbicides are pooled over levels of PRE herbicides.

TABLE 4: Palmer amaranth control as influenced by the interaction of PRE and POST herbicide treatments during 2011 on the Lynchburg soil series<sup>a</sup>.

PRE herbicides	PRE herbicide rate g ha <sup>-1</sup>	Palmer amaranth control Glufosinate rate (kg ha <sup>-1</sup> )		
		0	0.67 %	0.40 then 0.40
None		0 e	88 a–d	81 bcd
Flumioxazin	700	94 abc	100 a	100 a
Sulfentrazone plus cloransulam methyl	280 + 36	80 cd	100 a	93 a–d
S-metolachlor plus fomesafen	1200 + 270	90 a–d	96 abc	97 abc
Flumioxazin plus chlorimuron	70 + 21	100 a	100 a	96 abc
Fomesafen	280	91 a–d	100 a	98 ab
S-metolachlor	1500	76 d	91 a–d	91 a–d

<sup>a</sup> Means followed by the same letter are not different according to Fisher's Protected LSD test at  $P \leq 0.05$ .

TABLE 5: Soybean yield as influenced by the interaction of PRE and POST herbicide treatments during 2011 on the Lynchburg soil series<sup>a</sup>.

PRE herbicides	PRE herbicide rate g ha <sup>-1</sup>	Soybean yield Glufosinate rate (kg ha <sup>-1</sup> )		
		0	0.67 kg ha <sup>-1</sup>	0.40 then 0.40
None		1340 e	3800 abc	3850 abc
Flumioxazin	700	3940 ab	3500 a–d	3770 a–d
Sulfentrazone plus cloransulam methyl	28 + 36	2880 d	3850 abc	3740 a–d
S-metolachlor plus fomesafen	1200 + 270	3400 a–d	3550 a–d	4090 a
Flumioxazin plus chlorimuron	70 + 21	3720 a–d	4000 ab	3870 abc
Fomesafen	280	3130 bcd	3890 abc	4240 a
S-metolachlor	1500	3020 cd	3350 a–d	3530 a–d

<sup>a</sup> Means followed by the same letter are not different according to Fisher's Protected LSD test at  $P \leq 0.05$ .

TABLE 6: Palmer amaranth control and soybean yield as influenced by the glufosinate rate and number of applications<sup>a</sup>.

Glufosinate application timing (WAP)			Palmer amaranth control or soybean yield		
			2011		
2	3	4	2010 <sup>b</sup>	Nahunta soil series	Lynchburg soil series
Palmer amaranth control					
Yes	No	No	82 b	98 a	89 b
Yes	No	Yes	97 a	100 a	100 a
Yes	Yes	No	99 a	98 a	100 a
Yes	Yes	Yes	98 a	100 a	100 a
Soybean yield (kg ha <sup>-1</sup> )					
Yes	No	No	1040 a	2950 b	3030 a
Yes	No	Yes	1020 a	3350 ab	2990 a
Yes	Yes	No	970 a	3360 a	2940 a
Yes	Yes	Yes	1240 a	3030 ab	2530 b
No	No	No	600 b	2780 b	870 c

<sup>a</sup> Means within a year or year and soil series combination for each parameter followed by the same letter are not significantly different according to Fisher's Protected LSD test at  $P \leq 0.05$ . Data are pooled over glufosinate rates. Data for the nontreated control were not included in the statistical analyses to allow consideration of factorial treatment structure.

<sup>b</sup> Norfolk soil series.

During 2011, on the Nahunta soil series, soybean receiving a single application of glufosinate and nontreated soybean yielded similarly. Yield was increased when a second application of glufosinate was made 3 WAP (Table 6). On the Lynchburg series during 2011, soybean yield exceeded that of the nontreated control when glufosinate was applied irrespective of sequence of application. However, soybean yield was lower with three applications of glufosinate compared with two applications only. Given Palmer amaranth control was high with the program containing three applications, lower yield most likely reflected soybean injury. The total amount of glufosinate applied in this treatment exceeds the manufacturer's recommendations [21].

#### 4. Conclusions

The most consistent Palmer amaranth control was obtained with multiple applications of herbicides either as PRE followed by POST or POST applications of glufosinate. Additionally, timing of glufosinate was not critical when two applications were made within the first 4 weeks after planting. Concern for overreliance on protoporphyrinogen oxidase (PPO-) inhibiting herbicides and subsequent development of PPO-resistant biotypes in fields with glyphosate-resistant Palmer amaranth has been expressed [9]. Results from this research indicate that while treatments including PPO herbicides controlled Palmer amaranth more effectively when applied alone for the entire season, the PRE herbicide treatment with a non-PPO mode of action, in this case S-metolachlor alone, performed as well in a comprehensive program including one or two applications of glufosinate. While multiple applications of glufosinate are currently effective in controlling Palmer amaranth as described here and from other research [17–19], the long-term sequential

application of PRE and POST herbicides with a greater diversity of modes of action is the best approach when considering herbicide resistance management.

#### Conflict of Interests

None of the authors have any conflict of interests in terms of the products mentioned in the paper.

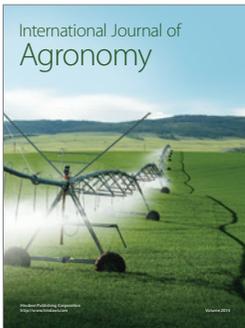
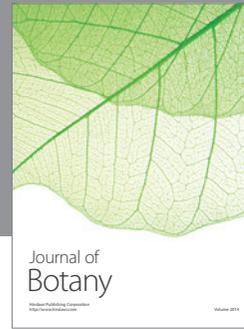
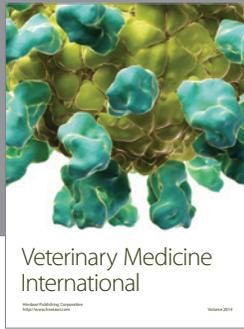
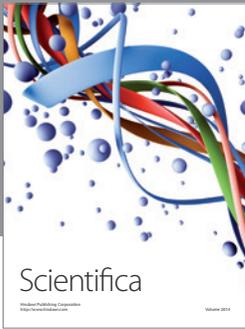
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