Effect of Cover Crop Management and Preemergence Herbicides on the Control of ALS-Resistant Palmer Amaranth (*Amaranthus palmeri*) in Peanut

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ABSTRACT

Palmer amaranth is a troublesome species across the southern US, and has become a serious problem in the SE in recent years. Resistance to acetolactate synthase (ALS) inhibiting herbicides has made control of Palmer amaranth even more difficult for peanut producers. Field studies were conducted in 2008 and 2009 to determine the impact of three rye cover crop management scenarios combined with non–ALS residual herbicides on the duration of control of ALS-resistant Palmer amaranth. Cover crop scenarios included planting into a desiccated rye cover that was left standing, or rolled flat, or no-cover. Within each cover crop scenario five soil residual herbicides were evaluated to determine the duration that each herbicide provided acceptable control of ALS-resistant Palmer amaranth in peanut. Weed counts were conducted weekly to determine the number of Palmer amaranth free days (PFD), which equated to 1 Palmer amaranth per m of row. In 2008, cover crop did not affect the number of PFD and data ranged from 3 to 67 d. In 2009, standing and rolled cover provided greater PFD relative to no-cover. However, herbicide efficacy was reduced in 2009 with PFD ranging between 0.1 and 16 d after treatment. In both years, PFD was ordered as flumioxazin>*S*-metolachlor (at cracking)>*S*-metolachlor (preemergence), norflurazon >pendimethalin.

Key Words: Palmer amaranth, ALS-resistance, peanut, cover crop.

Palmer amaranth is a C4 summer annual (Ehleringer, 1983) that is common in the peanut-producing regions of the southeastern United States (Gleason and Cronquist, 1991; Horak and Loughin, 2000). It is one of three dioecious *Amaranthus* spp. that have become important weed in agronomic cropping systems in North America (Steckel, 2007). Previous research found that Palmer amaranth produced more leaf area, dry weight, and plant volume as compared to common waterhemp (*Amaranthus rudis* S.), another dioecious *Amaranthus* species (Horak and Loughin, 2000). Interference from Palmer amaranth can be attributed to its tremendous seed production, which ranged from 250,700 to 613,074 seed per female plant (Sellers *et al*,. 2003; Keeley *et al.,*1987) and aggressive growth habits, reaching heights of 2 m (Bryson and DeFelice, 2009). Due to these attributes, Palmer amaranth is considered one of the most troublesome weed in Florida, Georgia, and South Carolina (Webster, 2005).

The competitiveness of Palmer amaranth results in significant interference with crop growth and subsequent reduction in yield. In Kansas, Palmer amaranth populations of 0.5 to 8 plants per m of row reduced corn (*Zea mays* L.) yield 11 to 91% (Massinga *et al.,* 2001; Massinga and Currie, 2002). Klingman and Oliver (1994) reported soybean [*Glycine max* (L.) Merr.] yield was reduced 17 to 68% with 0.33 to 10 Palmer amaranth plants per m of row, respectively. In Texas, populations from 1 to 10 Palmer amaranth within 9.1 m of row decreased cotton (*Gossypium hirsutum* L.) yield from 13 to 54% (Morgan, 2001) while Burke *et al.* (2007) in North Carolina reported that one Palmer amaranth plant per m of row will reduce peanut yield by 28%.

Imazapic and diclosulam, both ALS-inhibiting herbicides, were registered for use in peanut in 1996 and 2000, respectively. Other herbicides with this mechanism of action have been widely adopted in many crops because of their low use rates, favorable toxicity profile, wide crop selection, efficacy, and cost effectiveness (Saari *et al.,* 1994). The intensive use of ALS-inhibiting herbicides has contributed to the selection for ALS-resistant biotypes. Over 103 species have been documented with ALS-resistance, including Palmer amaranth (Heap, 2009). Non ALS-resistant Palmer amaranth can be controlled effectively with imazapic (Grichar, 1997; 2007). However, resistance to ALS-inhibiting herbicides has been confirmed in Arkansas, Florida, Georgia, Kansas, Mississippi, North Carolina, South Carolina, and Tennessee (Heap,

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2009). No herbicide other than imazapic is registered for use in peanut that provides equivalent levels of postemergence and residual control of Palmer amaranth. The most common approach for managing ALS-resistant Palmer amaranth is to use a soil residual herbicide at planting followed by a postemergence application of either aciflurofen or lactofen. However, for optimum control, aciflurofen and lactofen must be applied before Palmer amaranth reaches 6 leaf stage or 10 cm tall (Anonymous, 2006; Anonymous, 2007). Due to the rapid growth rate of this weed, growers have a brief window of opportunity to make this application. It is important to know the duration that residual herbicides will provide effective control so that postemergence applications can be properly anticipated and timed.

Cover crop residues provide a number of agronomic benefits such as intercepting light thereby slowing weed seed germination, improving soil moisture, water infiltration, soil tilth, and organic carbon (Liebman and Janke, 1990; Mallory *et al.*, 1998; Sainju and Singh, 1997; Teasdale, 1996; Varco *et al.*, 1999; Yenish *et al.*, 1996). Cover crops have been documented to suppress weed in row crops such as corn (Hoffman *et al.*, 1993; Johnson *et al.*, 1993), soybean (Reddy, 2001; 2003; Liebl *et al.*, 1992) and cotton (Hurst, 1992). Cover crop residues can alter patterns of weed emergence by moderating the microclimate in the weed seed germination zone (Van Wijk *et. al.,* 1959; Willis *et al.*, 1957). Also, residues create a physical barrier that can restrict emergence of certain weed (Facelli and Pickett, 1991). Weed suppression may also occur from allelopathic compound that are released from cover crop residues (Barnes and Putnam, 1986; Barnes *et al.*, 1986; Shilling *et al.*, 1985; 1986). Burgos and Talbert (1996) reported that the cover crops Italian rygrass (*Lolium perenne* L.), oat (*Avena sativa*), and sorghum-sudangrass (*Sorghum bicolor-Sorghum bicolor* var. *Sudanese*) reduced Palmer amaranth populations between 32 and 59% for 9 wk after crop planting, in the absence of herbicides.

Many researchers have documented percent control herbicide efficacy on Palmer amaranth. However, this weed is unique and percent control data can be misleading. For a species such as Palmer amaranth that is capable of producing 100 seedlings per m^2, 90% control would leave 10 plants per m^2. Although the herbicide was highly effective, significant yield and harvest loss would result from the remaining Palmer amaranth plants (Burke *et al.*, 2007). Therefore, the objective of this experiment was to determine the duration of Palmer amaranth control provided by soil residual herbicides applied prior to Palmer amaranth emergence. This number will be expressed as Palmer amaranth free days (PFD) and will provide information when a postemergence application would be necessary to maintain weed populations at an agronomically reasonable level. A second objective was to determine if cover crop residue will influence herbicide activity and affect the duration of preemergence control.

Materials and Method

Field studies were initiated in 2008 and 2009 at Sandlin Farms near Williston, Florida on a Candler fine sand (hyperthermic, uncoated, lamellic quartzipsamments) with less than 1% organic matter. This location had an infestation of ALS-resistant Palmer amaranth ranging between 75 and 100 plants per m^2. Annual rye (*Secale cereale* L.) was planted as a cover crop during mid-December each year over the entire experimental area. Rye was terminated with glyphosate at 1 kg ae/ha five wk prior to planting. Rye was harvested from five 0.25 m^2 areas randomly throughout the experimental area, just prior to planting, both years to determine dry biomass as kg/ha. Peanut cultivar 'SunOleic 97R' (Gorbet and Knauft, 2000) was planted 21 May 2008 and 'Florida-07' (Gorbet and Tillman, 2009) was planted 15 May 2009 in a twin-row configuration. Peanut seed were planted at a depth of 5 cm with a seeding rate of 17 seed per m of row. Each year aldicarb was applied in furrow at 3.2 kg ai/ha for insect and nematode management. Irrigation, fertility, fungicide, and insecticide treatments were applied as need following local production practices.

Treatments were a factorial arrangement of cover crop management (3) and herbicide (5) in a randomized complete block design with a split-plot restriction. The main plots of cover crop treatments were: 1) desiccated with glyphosate and residue left standing followed by planting, 2) desiccated with glyphosate and residue rolled flat with a roller-crimper followed by planting and, 3) residue grazed to 5 cm stubble and roto-tilled to a depth of 10 cm to expose bare soil prior to peanut planting. Cover crop plots were 20 rows by 40 m with 76 cm row spacing. There were no Palmer amaranth seedlings emerged at time of planting.

Herbicide treatments consisted of (a) pendimethalin (1.07 kg ai/ha) preemergence (PRE), (b) *S*-metolacholor (1.35 kg ai/ha) PRE, (c) flumioxazin (0.10 kg ai/ha) PRE, (d) norflurazon (1.34 kg ai/ha) PRE, and (e) *S*-metolachlor (1.35 kg ai/ha) plus paraquat (0.21 kg ai/ha) plus 2, 4-DB (0.25 kg ai/ha) at cracking (AC). Herbicides were applied to sub-plots which measured 4 rows by 7.6 m. Preemergence herbicides were applied one d after planting and the AC application was made 14 d later. All experimental treatments were applied with a CO_2-pressurized plot sprayer calibrated to deliver 187 L/ha. In both years, the entire plot area received approximately 2 cm of rainfall or irrigation within 5 d of herbicide application.

Weed density was recorded one wk after herbicide application and subsequent counts were recorded weekly. Counts were repeatedly recorded from the same location within each sub-plot in an area measuring 3.0 m by 0.76 m until 1 Palmer amaranth per m was recorded. The number of days from planting to a population of 1 Palmer amaranth per m will be referred to as Palmer amaranth free days (PFD). Though counts were recorded weekly, linear interpolation was used to back-calculate the day that 1 plant per m was reached. Palmer amaranth free days was used as an indicator of when the preemergence herbicide was no longer effective and a subsequent postemergence application would be warranted. If the threshold was not reached prior to crop canopy closure, the day of the last evaluation was used as the PFD datum.

Data were subjected to analysis of variance using the PROC MIXED procedure of SAS (2008) to test for treatment effects and interactions. LSMEANS was used to develop confidence intervals for mean separation at $P \leq 0.05$.

Results and Discussion

Statistical analysis detected a significant treatment by year interaction, so data are presented by year. In 2008, the main effect of cover crop treatment was not significant and data were pooled across cover crop. In 2009, both cover crop and herbicides were significant and data are presented accordingly.

In 2008, dry weight of annual rye cover crop was 2,067 kg/ha at the time of planting (data not shown). For pendimethalin and norflurazon, the 1 plant per m threshold (PFD) was reached within 3 to 8 d after application, respectively, which was similar to the non-treated control (Table 1). This lack of control was expected with norflurazon as the label indicates *Amaranthus* spp. will only be "suppressed" (Anonymous, 2009). The label for pendimethalin, indicates that Palmer amaranth will be controlled (Anonymous, 2008), but Grichar (2008) also reported that pendimethalin applied PRE in peanut provided less than 42% control approximately 10 wk after planting. *S*-metolachlor applied PRE suppressed Palmer amaranth for 22 d after application; however, delaying the application by 7 d significantly increased duration of control and PFD was not reached until 54 d after application. Flumioxazin PRE provided the longest duration of control in 2008. This application greatly suppressed Palmer amaranth and PFD was found to be 67 d after application.

Table 1. Influence of herbicides on Palmer amaranth days to threshold in 2008.[a]

Herbicide	Rate	Timing	Palmer amaranth free d (PFD)[b]
	kg ai/ha		
Flumioxazin	0.10	PRE	67a[c]
Pendimethalin	1.07	PRE	3d
Norflurazon	1.34	PRE	8d
S-metolachlor	1.35	PRE	22c
S-metolachlor +	1.35	AC	54b
Paraquat +	0.21	AC	
2, 4-DB	0.25	AC	
Untreated	-	-	2d

[a]Timing of herbicide application: PRE=preemergence, AC=At-crack.

[b]Number of days after planting before Palmer amaranth density reached 1 plant per m of crop row.

[c]Values are the mean of 4 replications. Means within a column followed by different letters are significantly different from each other at the 0.05 level.

In 2009, there was a significant cover crop by herbicide interaction (Table 2). Annual rye dry biomass, at the time of planting was 2,436 kg/ha. Palmer amaranth free days for pendimethalin and norflurazon was < 4 d after application, neither of which were different from the non-treated control (Table 2). *S*-metolachlor applied PRE was ineffective in 2009 with a PFD of ≤ 1 d after application. This was unexpected considering that previous research has shown metolachlor applied PRE in peanut controlled Palmer amaranth at least 90% (Grichar, 1994; 2008). Differences were found between standing, rolled, and no-cover for flumioxazin PRE and *S*-metolachlor plus paraquat plus 2,4-DB applied AC. Again, flumioxazin provided the greatest PFD of 16 d without cover crop and 35 d when in conjunction with a standing rye cover crop. In both years, flumioxazin was the most effective herbicide. This was expected considering the excellent control of Palmer amaranth with flumioxazin as described by Grichar (2008). The AC application of *S*-metolachlor suppressed Palmer amaranth for 6 to 21 d, relative to the no-cover verses standing rye, respectively. Differences were detected between the standing cover and no-cover regimes, however, no differences were detected between standing and rolled cover.

Table 2. Influence of cover crop and herbicides on Palmer amaranth d to threshold in 2009.[a]

Herbicide	Rate	Timing[a]	Cover crop management		
			No-cover	Rolled	Standing
	kg ai/ha		Palmer amaranth free d (PFD)[b]		
Flumioxazin	0.10	PRE	16a[c]A[d]	27abA	35bA
Pendimethalin	1.07	PRE	0.3aC	0.2aC	0.2aC
Norflurazon	1.34	PRE	2aC	4aBC	2aC
S-metolachlor	1.35	PRE	0.1aC	0.5aC	1aC
S-metolachlor +	1.35	AC	6aB	9abB	21bB
Paraquat +	0.21	AC			
2, 4-DB	0.25	AC			
Untreated	-	-	0.1aC	0.1aC	0.3aC

[a]Abbreviations: PRE, preemergence, AC, at-crack.

[b]Number of days after planting before Palmer amaranth density reached 1 plant per m of crop row. Values are the mean of 4 replications.

[c]Means within a row followed by lower case letters are significantly different from each other at the 0.05 level.

[d]Means within a column followed by upper case letters are significantly different from each other at the 0.05 level.

Palmer amaranth free days decreased for all herbicides in 2009 compared to 2008. This could have been due to rainfall patterns in 2009. In May, the month of herbicide application, rainfall was nearly 120 mm above normal. Conversely, June received 100 mm less precipitation than normal. May of 2008 had less than normal rainfall as well, but the rainfall that was received occurred within 1 d of PRE herbicide application and was likely sufficient to activate the soil residual herbicides. It is possible that the overabundance of rain followed by the lack of rainfall in the months following herbicide application adversely impacted the duration of Palmer amaranth control in 2009.

The influence of cover crop on weed control was less than expected. The annual rye cover crop of <2,500 kg/ha dry biomass did not significantly increase PFD for most treatments. Other studies that produced cover crop biomass > 7,500 kg/ha reported reduced numbers of weed compared to no-cover treatments (Reddy, 2001; 2003). The authors acknowledge that rye density in these experiments was lower than other researchers have utilized. However, this level of rye cover crop is customary for soil stabilization prior to peanut planting in central Florida and it was desirable to understand if this density was sufficient to suppress Palmer amaranth emergence. Therefore, increasing cover crop density may have a greater impact on weed control than was observed here.

Summary

The purpose of this experiment was to determine the duration of control, not simply percent control, provided by various herbicides and whether cover crops significantly influenced this value. These data indicate that flumioxazin applied PRE would require a postemergence herbicide at an average of 16 to 67 d after the PRE application. *S*-metolachlor plus paraquat plus 2,4-DB applied AC provided an average of 23 d until threshold was achieved. It is unknown why delaying *S*-metolachlor application by 7 d (PRE vs AC) so greatly influences Palmer amaranth control. However, similar results have been observed for the control of benghal dayflower (*Commelina benghalensis* L.) in peanut (Flanders and Prostko, 2003). Additionally, pendimethalin and norflurazon are not reliable control options for the high populations encountered in this trial. These herbicides would likely have performed better if Palmer amaranth populations were lower. Regardless of whether *S*-metolachlor or flumioxazin is applied, it would be necessary to start a weekly scouting regime approximately 3 wk after application in order to ensure that timely POST applications can be made to control ALS-resistant Palmer amaranth in peanut.

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