Florida beggarweed (*Desmodium tortuosum*) management in peanut (*Arachis hypogaea*) with residual herbicides

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ABSTRACT

Field experiments were conducted to evaluate the emergence and control of Florida beggarweed in peanut. Diclosulam preemergence (PRE), flumioxazin PRE, and imazapic postemergence (POST) were evaluated at three rates, along with paraquat plus bentazon plus 2,4-DB POST, and a nontreated control. These treatments were applied alone, or followed by chlorimuron applied late postemergence (LPOST). Variable Florida beggarweed control (16 to 90%) was observed when flumioxazin PRE, diclosulam PRE, paraquat plus bentazon plus 2,4-DB EPOST, or imazapic POST were applied alone. The pre-harvest population of Florida beggarweed was significantly reduced by the application of any residual herbicide (flumioxazin, diclosulam, or imazapic) alone at any rate either PRE or POST as compared to the nontreated control. Use of the contact treatment of paraquat plus bentazon plus 2,4-DB EPOST alone did not reduce Florida beggarweed populations as compared to the nontreated control. Adding chlorimuron LPOST to any treatment did not reduce Florida beggarweed populations, but provided suppression and reduced the biomass of existing plants. Consistent Florida beggarweed control (86 to 95%) was achieved with combinations of flumioxazin PRE at 105 g ha^{-1}, diclosulam PRE at 53 g ha^{-1}, and imazapic POST at 71 g ha^{-1} followed by chlorimuron LPOST at 9 g ha^{-1}. The benefit of chlorimuron LPOST was greatest when early season control was least.

Key Words: *Arachis hypogaea*, *Desmodium tortuosum*, residual herbicide, biomass, weed control.

Residual herbicide options for peanut include imazapic for postemergence (POST) application, diclosulam for preemergence (PRE) or POST, and flumioxazin for PRE application. Each provides broad-spectrum weed control, but has strengths and weaknesses when used in peanut. With respect to mode of action, flumioxazin (Anderson *et al.*, 1994; Yoshida *et al.*, 1991) is a *protoporphyrinogen* oxidase inhibitor (PPO) while diclosulam and imazapic inhibit acetolactate synthase (ALS) (Vencill 2002). ALS herbicide resistance (Wise *et al.*, 2009) in Palmer amaranth (*Amaranthus palmeri* S. Wats.) has increased concerns about proper herbicide stewardship. Concerns about herbicide resistance in other weed species as increased because many herbicides used in the same or in rotational crops, have similar or the same modes of action. Thus, this continuous exposure of the same weeds to the same herbicide modes of action could select for resistance.

Florida beggarweed [(*Desmodium tortuosum* (Sweet) DC)] emergence occurs throughout the growing season and is a vigorous competitor with peanut if emergence occurs within the first 8 wk of planting (Buchanan *et al.*, 1976; Hauser *et al.*, 1982; 1975; Cardina and Brecke, 1991;). Lack of early season Florida beggarweed control can lead to season-long interference that reduces yield (Grey and Bridges, 2005; Hauser *et al.*, 1975; 1982; Cardina and Brecke, 1991; Wehtje *et al.*, 2000a; 2000b) and hinders crop harvest by interfering with digging and threshing (Buchanan *et al.*, 1982; Wehtje *et al.*, 1999). Florida beggarweed consistently ranks as the most troublesome weed of peanut based on surveys for Alabama, Florida, and Georgia (Buchanan *et al.*, 1982; Elmore, 1989; Dowler, 1992, 1998; Prostko, 2001; Webster and MacDonald, 2001; Webster 2005).

When herbicides are POST applied in peanut, variable Florida beggarweed control can occur. Paraquat provides only early postemergence (EPOST) contact control (Grey *et al.*, 2003), while chlorimuron provides contact and residual activity (Wehtje *et al.*, 2000a). Peanut tolerance to paraquat was first noted in the late 1970s (Wehtje *et al.*, 1986). However, lack of residual activity and the narrow window of application for control of Florida beggarweed reduced the effectiveness of this treatment (Wilcut *et al.*, 1995). Chlorimuron effectively controls Florida beggarweed, but can only be applied 60 d after peanut emergence (Johnson *et al.*, 1992b). This frequently becomes a mid-season salvage treatment (Johnson *et al.*, 1992a). By 60 d after peanut emergence, Florida beggarweed can be taller than the 25 cm in height, which is the maximum specified on the chlor-

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imuron label (Webster *et al.*, 1997; Wehtje *et al.*, 1999). Chlorimuron is still applied to approximately 20% of the Georgia crop (NASS, 2004). Producers have indicated Florida beggarweed control with chlorimuron can be inconsistent. An additional concern is that chlorimuron is an ALS herbicide (Vencil, 2002) with a mode of action similar to other herbicides used in peanut including diclosulam and imazapic.

Studies that have compared the effect of multiple applications of the same mode of action in the same crop for control of Florida beggarweed have not been reported. Thus, research was conducted to evaluate PRE, POST and late POST (LPOST) applications of ALS versus PPO mode of action herbicides for Florida beggarweed establishment, control, population, growth, and competition in peanut.

Materials and Methods

Experiments were conducted in Georgia during 2005 and 2006 at the Ponder Research Farm located near Ty Ty in separate areas of the same field, and in Alabama at the Wiregrass Research and Extension Center near Headland. Soils were Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) at Ty Ty and Dothan fine sandy loam (fine, loamy, siliceous, thermic, Plinthic Paleudult) at Headland. Organic matter ranged from 1.0 to 1.1% with pH from 6.0 to 6.5 at Ty Ty and 1.3% organic matter and pH 6.5 at Headland.

The peanut cultivar Georgia Green (Branch, 1996) was planted in conventionally prepared seedbeds four to five cm deep with seed spaced five to six cm apart at all locations. Planting dates were 10 May 2005 and 2006 at Ty Ty; 17 May 2005 and 15 May 2006 at Headland. Plot size was two rows spaced 91-cm apart by 7.6 m long. Standard cultural practices for peanut production were followed using University of Georgia and Auburn University Extension recommendations. Peanut was irrigated as needed at all locations. Florida beggarweed seed (Adams-Briscoe Seed Co. 325 East 2nd Street, Jackson, GA 30233) were hand sown at approximately 1 kg ha^{-1} to supplement the naturally occurring population.

Herbicide treatments applied alone were diclosulam (27, 40, and 53 g ha^{-1}) PRE, flumioxazin (53, 80, and 105 g ha^{-1}) PRE, imazapic (36, 52, and 71 g ha^{-1}) POST four wk after peanut emergence, or paraquat plus bentazon (280 + 500 g ha^{-1}) EPOST two wk after peanut emergence. These residual and contact herbicide treatments were applied alone or were followed by chlorimuron at 9 g ai/ha late post emergence (LPOST). Nonionic surfactant at 0.25% (v/v) was included with all EPOST, POST, and LPOST treatments. Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L/ha at 210 kPa. Each experiment was arranged as a randomized complete block design with a factorial arrangement of treatments replicated four times.

Paraquat plus bentazon EPOST treatments were applied to Florida beggarweed that ranged in size from cotyledon to three leaves and peanut had approximately one to three true leaves. Imazapic POST was applied when Florida beggarweed ranged in size from cotyledon to six leaves with densities ranging from one to five plants m^{-2} for each location for both years. Peanut had approximately four to seven true leaves when imazapic was POST applied. Chlorimuron LPOST was applied when Florida beggarweed ranged in size from 4 to 10 leaves. Visual estimates of percent Florida beggarweed control were recorded within one wk prior to harvest using a scale of 0 (no control) to 100% (complete control). Pendimethalin (0.9 kg ai ha^{-1}) and *S*-metolachlor (1.4 kg ha^{-1}) were applied PRE to the entire test. Plots were maintained by hand weeding or applications of graminicides for the entire season to remove all weeds except Florida beggarweed.

In Georgia, final Florida beggarweed populations (plants m^{-2}) were determined in October of each year by counting all plants in each plot. Prior to peanut harvest, five Florida beggarweed plants were randomly hand harvested from each plot by cutting plants at the soil surface, storing them in paper bags, and then drying for 96 hrs using heated (80 C) forced air. Florida beggarweed dry weight was recorded and dry weights were converted to kg ha^{-1} biomass. In Alabama, only fresh Florida beggarweed weight was determined by hand harvesting the entire plot and converting to kg ha^{-1}. At the Georgia locations, peanut was dug and inverted based on pod mesocarp color (Williams and Drexler, 1981). Pods were combined 10 to 20 d later with conventional harvesting equipment and yield reported on a kg ha^{-1} basis. Peanut yield was not collected for the Alabama studies.

Data were subjected to mixed models analysis of variance for the eleven (PRE, EPOST, and POST herbicide treatments) by two (LPOST treatments) factorial treatment arrangement. As a result, data for locations were combined across years. Locations were then analyzed separately and means for significant main effects and interactions were separated using Fisher's Protected LSD method test at $P \leq 0.05$.

Table 1. Florida beggarweed population, dry weight biomass, and peanut yield as influenced by herbicide for Ty Ty GA[a].

Herbicide	Application timing	Rate	Population[d]	Florida beggarweed biomass[c]	Peanut yield
		g ai ha^{-1}	plants/m^2	kg ha^{-1}	
Flumioxazin	PRE[c]	53	1.3 c[e]	200 c	2520 a
Flumioxazin	PRE	80	1.3 c	310 abc	2370 a
Flumioxazin	PRE	105	0.9 bc	150 c	2590 a
Diclosulam	PRE	27	1.4 c	170 c	2380 a
Diclosulam	PRE	40	1.5 c	200 c	2330 a
Diclosulam	PRE	53	1.4 c	150 c	2200 a
Imazapic	POST	36	1.4 c	350 abc	2310 a
Imazapic	POST	52	1.2 bc	260 bc	2440 a
Imazapic	POST	71	0.5 b	120 c	2380 a
Paraquat + bentazon + 2,4-DB[b]	EPOST	——	2.6 a	490 ab	2360 a
None	——	——	2.9 a	550 a	2270 a

[a]Analysis indicated that timing was not significant for LPOST treatments (none or chlorimuron at 9 g ai ha^{-1}) for any individual treatment, therefore data was combined for the LPOST application timings for presentation.

[b]Rates were EPOST paraquat 140 g ai ha^{-1}, bentazon 280 g ai ha^{-1}, and 2,4-DB 224 g ai ha^{-1}; LPOST - chlorimuron 9 g ai ha^{-1}

[c]Abbreviations: preemergence, PRE; early-postemergence EPOST; postemergence POST; late-postemergence, LPOST.

[d]For analysis year was treated as a random effect.

[e]Means within a column followed by the same letter are not significant according to Fisher's Protected LSD Test at P $\leq$ 0.05.

Results and Discussion

For Georgia, the two-way interactions between the eleven PRE, EPOST, and POST treatments and 2 LPOST treatments were not significant for Florida beggarweed population, dry weight, and peanut yield. Therefore, data for the main effects were combined for presentation. The two-way interaction between the eleven PRE, EPOST, and POST herbicide treatments by the two LPOST treatments was significant for Florida beggarweed control in Georgia and Alabama and fresh weight biomass in Alabama.

Florida beggarweed stand and biomass. In Georgia, the population of Florida beggarweed was significantly reduced by the application of any residual herbicide (flumioxazin, diclosulam, or imazapic) alone at any rate either PRE or POST compared to the nontreated control (Table 1). Flumioxazin at 105, diclosulam at 53, or imazapic at 71 g ha^{-1} reduced Florida beggarweed stand to 0.9, 1.4, and 0.5 plants m^{-2}, respectively, compared to nontreated control with 2.9 plants m^{-2}. Use of the contact treatment of paraquat plus bentazon plus 2,4-DB EPOST alone did not reduce Florida beggarweed populations (2.6 plants m^{-2}) as compared to the nontreated control. The addition of chlorimuron LPOST did not reduce Florida beggarweed population, as noted with no significant interactions (data not shown). These data indicate that the addition of chlorimuron did not reduce Florida beggarweed population but merely provided suppression of existing plants. Grey and Bridges (2005) reported a similar finding in that chlorimuron applied at 49 or 63 days after peanut emergence suppressed Florida beggarweed biomass production but did provide complete control.

Florida beggarweed dry weight biomasses in Georgia were 150, 150, and 120 kg ha^{-1} for flumioxazin at 105 PRE, diclosulam at 53 PRE, and imazapic at 71 g ha^{-1} EPOST, respectively (Table 1). Diclosulam at any rate gave significant reduction in Florida beggarweed dry biomass. In contrast, Florida beggarweed dry biomass for the nontreated control was 550 kg ha^{-1}, which was similar to the paraquat plus bentazon plus 2,4-DB treatment (490 kg ha^{-1}). Flumioxazin at 80 g ha^{-1} resulted in an increase in Florida beggarweed biomass, which could be attributed to partial control which allowed escaped plants to grow with less competition. In Alabama, when chlorimuron was applied to any treatment, data indicated the chlorimuron did not eliminate Florida beggarweed, but provided suppression of existing plants as indicated by reductions in fresh weight biomass (Table 2). This was more noticeable when initial PRE, EPOST, or POST applications did not give good control, as in imazapic at either 36 or 52 g ha^{-1} or paraquat plus bentazon plus 2,4-DB.

Florida beggarweed control. While biomass of Florida beggarweed may have been reduced by the use of PRE and POST residual treatments, this did not translate into consistent visual control. All PRE and POST herbicide treatments provided variable Florida beggarweed control (Table 2).

Flumioxazin PRE Florida beggarweed control was 71% or less for any treatment in Georgia. Control was rate dependent for Georgia in 2005

Table 2. Florida beggarweed control and fresh weight biomass as influenced by herbicide combination for Headland AL and Ty Ty GA.

Herbicide	Application timing	Rate	LPOST	Control		Fresh weight biomass (AL)
				Headland	Ty Ty	
		g ai ha^{-1}		%		kg ha^{-1}
Flumioxazin	PRE[b]	53	none	78 bc[c]	46 fg	1030 e–g
Flumioxazin	PRE	80	none	82 a–c	61 d–f	820 e–h
Flumioxazin	PRE	105	none	92 a–c	71 b–e	420 e–h
Diclosulam	PRE	27	none	90 a–c	50 ef	490 e–h
Diclosulam	PRE	40	none	92 a–c	68 c–e	390 e–h
Diclosulam	PRE	53	none	94 ab	84 a–c	310 e–h
Imazapic	POST	36	none	42 f	43 fg	2540 b
Imazapic	POST	52	none	58 d–f	51 ef	1920 b–d
Imazapic	POST	71	none	74 c–e	50 efg	1220 c–e
Paraquat + bentazon + 2,4-BD[a]	EPOST	——	none	55 ef	29 g	2080 bc
None	——	——	none	0 g	0 h	4500 a
Flumioxazin	PRE	53	chlorimuron[a]	96 ab	94 a	180 f–h
Flumioxazin	PRE	80	chlorimuron	96 a	93 a	210 f–h
Flumioxazin	PRE	105	chlorimuron	98 a	83 a–c	120 gh
Diclosulam	PRE	27	chlorimuron	95 ab	74 a–d	260 f–h
Diclosulam	PRE	40	chlorimuron	98 a	70 b–e	100 gh
Diclosulam	PRE	53	chlorimuron	99 a	79 a–d	30 h
Imazapic	POST	36	chlorimuron	86 a–c	91 ab	630 e–h
Imazapic	POST	52	chlorimuron	92 a–c	92 a	390 e–h
Imazapic	POST	71	chlorimuron	83 a–c	69 c–e	890 e–h
Paraquat + bentazon + 2,4-DB	EPOST	——	chlorimuron	83 a–c	60 d–f	840 e–h
None	——	——	chlorimuron	75 cd	59 d–f	1080 e–f

[a]Rates were paraquat 140 g ai ha^{-1}, bentazon 280 g ai ha^{-1}, and 2,4-DB 224 g ai ha^{-1}; chlorimuron 9 g ai ha^{-1}.
[b]Abbreviations: preemergence, PRE; early-postemergence EPOST; postemergence, POST; late-postemergence, LPOST.
[c]Means within a column followed by the same letter are not significant according to Fisher's Protected LSD Test at $P \leq 0.05$.

and Alabama. For both locations, 105 g ha^{-1} was required to obtain maximum levels of control. Previous research has indicated that Florida beggarweed was controlled at least 89% when flumioxazin was PRE applied at 71 to 105 g ha^{-1} (Grey *et al.*, 2002; 2003). Thus, for maximum Florida beggarweed control, the 105 g ha^{-1} rate was required. Diclosulam PRE Florida beggarweed control was similar for Georgia in 2005 and 2006 to flumioxazin PRE. However, in Alabama control was 90% or greater for any diclosulam treatment. Across all rates, imazapic POST Florida beggarweed control was 51% or less for Georgia. Florida beggarweed control exhibited a rate response for imazapic POST ranging from 42 to 74% in Alabama. The developing crop canopy can cover Florida beggarweed seedlings and inhibit herbicide spray contact (Cardina and Brecke, 1991). This can limit imazapic POST weed activity resulting in variable Florida beggarweed control which was observed in these and other trials (Grey and Wehtje, 2005). Paraquat plus bentazon plus 2,4-DB Florida beggarweed control was 55% or less across all experiments and has been previously noted (Wehtje *et al.*, 2000a; 2000b).

The addition of chlorimuron LPOST improved Florida beggarweed control for all PRE, EPOST, and POST treatments (Table 2). Generally, the less Florida beggarweed control observed by an early season treatment, the greater the benefit obtained from chlorimuron LPOST. In Alabama, Florida beggarweed control was 95% and greater for PRE treatments of flumioxazin and diclosulam followed by chlorimuron LPOST. Similarly, imazapic followed by chlorimuron Florida beggarweed control was improved to 83% or greater. These Florida beggarweed responses indicate that using either a PPO or ALS herbicide PRE or POST followed by a LPOST ALS application did not reduce Florida beggarweed control.

Florida beggarweed morphology can vary with location and this contributes to its adaptability to changing environments, cultural practices, and control measures (Cardina and Brecke, 1989). Thus, biotype differences between the Alabama and Georgia populations could have resulted in different responses to herbicide treatment. By using multiple applications of the same mode of action, there is an increased potential for selection of ALS herbicide resistant weeds (Retzinger and Mallory-

Smith, 1997; Niekamp *et al.*, 1999). Given the adaptability of Florida beggarweed to different environments, there is always potential for development of ALS resistance, especially with the over use of herbicides with that same mode of action. In Georgia the use of ALS herbicides has continued to increase since their introduction. The use of ALS herbicides has increased in peanut from 63% of the hectares treated in 1999 to 93% treated by 2003 (UGA extension survey, 1997–2003).

Peanut yield. Peanut yield in Georgia ranged from 2270 to 2590 kg ha^{-1} (Table 1). Peanut yield was variable and there was no significant difference between PRE, EPOST, or POST treatments. Overall peanut yield was poor and not indicative of weed control. Buchanan *et al.* (1976) reported peanut biomass correlated more closely with the weights of the Florida beggarweed rather than with their populations.

Conclusions

Variable Florida beggarweed control (29 to 94%) was noted when flumioxazin PRE, diclosulam PRE, paraquat plus bentazon plus 2,4-DB EPOST, or imazapic POST were applied alone. Florida beggarweed control was 68 to 98% with combinations of flumioxazin PRE at 105 g ha^{-1}, diclosulam PRE at 53 g ha^{-1}, and imazapic POST at 71 g ha^{-1} followed by chlorimuron LPOST at 9 g ha^{-1}. Florida beggarweed population was not reduced when chlorimuron was LPOST applied following any residual herbicide PRE or POST application. This is of concern since seed would still be produced by these plants. If ALS resistance does develop in Florida beggarweed, it will likely occur as a result of these types of control methods. Weed resistance to ALS herbicides occurs because of the repetitive use of this mode of action in multiple crops, and the ability of different mutations to hinder herbicide binding (McNaughton et al. 2005; Tranel and Wright 2002). For this study, chlorimuron did reduce Florida beggarweed biomass but it did not reduce the populations. Therefore, growers should utilize PRE herbicides that will effectively control Florida beggarweed early in the season and not be reliant on POST applications.

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