Weed Management with Flumioxazin in Strip-Tillage Peanut (*Arachis hypogaea*)[1]

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ABSTRACT

Three experiments were conducted at Lewiston-Woodville, NC in 1999 and 2000 to evaluate weed management systems in strip-tillage peanut. Using a factorial treatment arrangement, flumioxazin was evaluated with standard preemergence (PRE), early postemergence (EPOST), and postemergence (POST) herbicides. Dimethenamid PRE controlled common lambsquarters 77%, eclipta 32 to 100%, prickly sida 14%, and entireleaf, ivyleaf, and pitted morningglory no more than 23%. The addition of flumioxazin PRE to dimethenamid controlled common lambsquarters 97%, eclipta 57 to 100%, prickly sida 79%, and morningglory species 44 to 100%. Common lambsquarters, eclipta, prickly sida, yellow nutsedge, and entireleaf, ivyleaf, and pitted morningglory were controlled at least 96% with dimethenamid plus flumioxazin PRE followed by (fb) paraquat plus bentazon EPOST fb imazapic POST. Peanut injury from dimethenamid PRE alone or in PRE tank mixture with flumioxazin ranged from 0 to 60%, but did not significantly affect yield. Season-long control of goosegrass and large crabgrass required a late POST treatment of clethodim.

Key Words: conservation tillage, peanut yield, weed management.

Peanut growers throughout the Southeastern Coastal Plain have traditionally utilized conventional tillage systems but are increasing conservation tillage production systems. Growers practicing conservation tillage (including minimum, strip, and no-till) plant peanut directly into residue left by winter cover crops or winter native vegetation. The resulting plant residue left on the surface of the soil protects the soil structure, and aids in reducing erosion in the sandy soils of the Southeastern Coastal Plain (Campbell *et al*., 2002; Sholar *et al*., 1995). Additionally, conservation tillage has been credited with better water conservation, increased stand establishment, decreased insect populations, changes in weed densities, and fewer diseases (Campbell *et al*., 2002; Durham, 2003). Furthermore, Johnson *et al*., (2001) documented lower incidences of tomato spotted wilt in reduced and minimum tillage peanut systems, which is significant since there is no other control method for this disease. Reduced tillage systems may increase herbicide inputs into a system due to the need for burndown herbicides, but the overall aim is to reduce the overall inputs (time, fertilizer, etc.) into the system.

Reports differ on overall peanut yields in conventional versus conservation peanut production. Wilcut *et al*., (1987) reported that strip tillage peanut tended to yield more than conventionally grown peanut due to the reduction in weed pressure; however others found that peanut grown in a conventional tillage system yielded better and had a higher gross economic value (Jordan *et al*., 2001, 2002). Other research also found that minimum tillage systems did not negatively affect peanut quality and yield (Clewis *et al*., 2002; Colvin and Brecke, 1988; Johnson *et al*., 2001), which may be due to the fact that peanut planted in raised beds are much easier to dig than peanut planted flat (no raised beds) into stubble (as in conservation tillage). Research in North Carolina on large-seeded Virginia-Carolina (VC) market type peanut indicates that yields are inconsistent under strip tillage conditions because ease of digging depends upon soil type and texture (Jordan *et al*., 2002). Strip tillage systems tend to cause a weed population shift to small-seeded grasses and broadleaf weeds such as green foxtail [*Setaria viridis* (L.) Beauv.], Texas panicum (*Panicum texanum* Buckl.), common lambsquarters, and redroot pigweed (*Amaranthus retroflexus* L.), which increases the need for research into comprehensive, season-long herbicide programs (Johnson *et al*., 2002).

Flumioxazin (formerly S-53482 and V-53482), is a soil-applied herbicide used PRE for broadleaf weed control in peanut and soybean [*Glycine max* (L.) Merr] (Askew *et al*., 1999; Eyherabide, 1996; Price *et al*., 2004; Wilcut *et al*., 2001). The herbicide provides residual control of several problematic broadleaf weeds including Florida beggarweed [*Desmodium tortuosum* (Sw) DC], common ragweed (*Ambrosia artemisiifolia* L.), and eclipta (*Eclipta prostrata* L.) as well as common lambsquarters,

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and prickly sida (*Sida spinosa* L.) (Askew *et al.*, 1999; Burke *et al.*, 2002a; Clewis *et al.*, 2002; Eyherabide, 1996). In North Carolina, Askew *et al.* (1999), found that flumioxazin applied PRE provided better control of common lambsquarters, morningglory and prickly sida than norflurazon and also provided better weed control, and resulted in higher crop yield and net returns than a more traditional system of metolachlor PPI fb EPOST or POST herbicides (Scott *et al.*, 2001). Flumioxazin has also been found to provide ≥ 80% control of common ragweed, and ivyleaf morningglory (*Ipomoea hederacea* L. Jacq.) in soybean (Niekamp and Johnson, 2001). Conversely, flumioxazin alone does not effectively control nutsedges (*Cyperus sp.*) (Clewis *et al.*, 2002), or annual grasses (Grichar and Colburn, 1996).

The objective of this research was to evaluate weed control, crop injury, and peanut yield when flumioxazin was applied in combination with PRE and POST herbicides commonly used in strip tillage peanut production.

Materials and Methods

Field experiments were conducted in three locations at the Peanut Belt Research Station located near Lewiston-Woodville, NC in 1999 and 2000 to evaluate weed management systems in strip-tillage peanut. Peanut cultivars 'NC 10 C' in 1999 and 'NC 12 C' in 2000 were planted 8 cm deep in rows spaced 91 cm wide. Peanuts were planted at 120 to130 kg/ha in early May of both years. Plots measured 6.1 m long and 3.6 m wide, and were arranged in a randomized complete block design with three replications of treatments. Lewiston-Woodville soils are classified as Norfolk sandy loams (fine-loamy, siliceous, thermic Typic Kandiudults) with 1.0% organic matter and pH 5.9 to 6.1.

Paraquat at 0.7 kg ai/ha was applied to all plots 3 wk before planting to control existing vegetation. The PRE herbicide options included: (1) paraquat at 0.7 kg/ha plus dimethenamid at 1.4 kg ai/ha, (2) paraquat at 0.7 kg/ha plus dimethenamid at 1.4 kg/ha plus flumioxazin at 71 g ai/ha or (3) paraquat at 0.7 kg/ha plus flumioxazin at 71 g/ha. At the time of PRE treatment, broadleaf weeds were in the cotyledon to three-leaf stage, and weed densities ranged from 2 to 50 per m^2 depending on species (data not shown). For those plots that received an EPOST herbicide treatment, paraquat at 145 g/ha plus bentazon at 0.28 kg ai/ha was applied approximately 15 days after planting. Weed stage and density at time of EPOST was cotyledon to 5-leaf growth stage at densities from 10 to 20 plants per species (data not shown). POST treatments were applied two weeks after the EPOST treatments. At the time of POST treatments, broadleaf weeds were in the cotyledon to seven-leaf stage, and weed densities ranged from 2 to 30 per m^2 depending on species (data not shown). POST herbicide options included: (1) a prepackaged mixture[3] of bentazon at 0.56 kg/ha and acifluorfen at 0.28 kg ai/ha or (2) imazapic at 71 g ai/ha. A nontreated check was included for comparative purposes.

A nonionic surfactant[4] at 0.25% (v/v) was included in all PRE, EPOST, and POST herbicide treatments. Herbicides were applied with a CO_2 powered backpack sprayer calibrated to deliver 140 L/ha at 146 kPa. Weeds evaluated at either two or three sites included common lambsquarters (*Chenopodium album* L.), eclipta, goosegrass [*Eleusine indica* (L.) Gaertn], ivyleaf morningglory, large crabgrass [*Digitaria sanguinalis* (L.) Scop.], prickly sida, pitted morningglory (*Ipomoea lacunosa* L.) and yellow nutsedge (*Cyperus escultenus* L.). A late POST treatment of clethodim at 0.28 kg ai/ha plus 1.0% COC (crop oil concentrate) was applied in late July to all tests to control escaped goosegrass and large crabgrass.

Peanut injury ratings, based on visual estimations of discoloration, stunting and stand reduction, were made 4 and 12 weeks after planting (WAP). Visual estimates of weed control were recorded early (mid-June) and late season (late August) approximately one month prior to harvest. Weed control and peanut injury ratings were based upon visual estimations of leaf discoloration and biomass reduction when compared to the nontreated control. Ratings are based on a scale of 0 (no injury symptoms) to 100 (complete death of all plants or no plants present) (Frans *et al.*, 1986). The crop was dug and inverted and left to air dry in the field for approximately 2 weeks before being combined. Peanuts were harvested from the center two rows of each plot using a combine modified for small plot research in early November of each year. Data were subjected to ANOVA using the general linear models procedure in SAS (SAS, 2001). PRE and POST herbicide treatment options were analyzed in terms of crop injury, weed control, and crop yield. Data were tested for homogeneity of variance by plotting residuals. The nontreated

[3]Storm®, 29% bentazon, and 13.4% Acifluorfen. BASF Corporation. Agricultural Products Group, PO Box 13528, Research Triangle Park, NC 27709.

[4]Induce nonionic low foam wetter-spreader adjuvant containing 90% non-ionic surfactant (alkylarylopolyoxyalkane ether and isopropanol), free fatty acids, and 10% water. Helena Chemical Company, Suite 500, 6075 Poplar Avenue, Memphis, TN 38137.

Table 1. Interaction of PRE, EPOST, and POST herbicide systems on yellow nutsedge and broadleaf weed control at three North Carolina locations in 1999 and 2000.[d]

Herbicides			Yellow nutsedge[d] Lewiston-Woodville			Common lambs-quarters[d]	Eclipta[d] Lewiston-Woodville			Prickly sida
PRE[a]	EPOST[b]	POST[c]	1999	2000A	2000B		1999	2000A	2000B	
			%							
Dimethenamid	None	None	57 d	65 bc	100 a	77 b	45 d	32 c	100 a	14 c
Dimethenamid + flumioxazin	None	None	70 bc	43 d	97 a	97 a	76 c	57 b	100 a	79 b
Flumioxazin	None	None	20 e	40 d	72 b	99 a	42 d	45 b	56 b	79 b
Dimethenamid	Paraquat + bentazon	Acifluorfen + bentazon	82 b	70 bc	100 a	100 a	80 c	97 a	100 a	87 b
Dimethenamid + flumioxazin	Paraquat + bentazon	Acifluorfen + bentazon	77 bc	53 cd	100 a	100 a	83 bc	100 a	100 a	100 a
Flumioxazin	Paraquat + bentazon	Acifluorfen + bentazon	68 c	81 b	85 ab	100 a	68 c	100 a	97 a	84 b
Dimethenamid	Paraquat + bentazon	Imazapic	97 a	99 a	100 a	100 a	96 ab	100 a	100 a	100 a
Dimethenamid + flumioxazin	Paraquat + bentazon	Imazapic	97 a	99 a	100 a	100 a	98 ab	99 a	100 a	100 a
Flumioxazin	Paraquat + bentazon	Imazapic	97 a	100 a	98 a	100 a	100 a	97 a	100 a	100 a

[a]Paraquat was applied PRE to all plots at 0.70 kg ai/ha. Rates of PRE herbicides were: dimethenamid at 1.4 kg/ha, and flumioxazin at 71 g/ha.

[b]Rates of EPOST herbicides were: bentazon at 0.28 kg/ha and paraquat at 0.14 kg/ha.

[c]Rates of POST herbicides were: bentazon at 0.56 kg/ha, acifluorfen at 0.28 kg/ha, and imazapic at 71 g/ha.

[d]Mean separations followed by the same letter are not significantly different at 5% level of probability.

control was not included in the analyses of visually estimated data. Error was partitioned to evaluate location and associated error terms. Arcsine transformations did not improve variance homogeneity, so nontransformed data were used in analyses and presentation. Mean separations were performed using Fisher's protected LSD test at $p \leq 0.05$.

Results and Discussion

Because there were only minor differences in weed control between the two ratings, and weed pressure late in the season is more influential on peanut yield and harvesting efficiency, only the late season ratings are presented

Weed Control. Data were pooled over location and years for those species for which no treatment by location interaction was found, but weed responses to herbicides are discussed separately by location/year in cases where a treatment by location interaction occurred.

Common lambsquarters. There was no location by treatment interaction for this weed species; therefore the data were combined over locations and years (Table 1). Dimethenamid PRE controlled common lambsquarters 77%, whereas all other PRE, EPOST, and POST treatment combinations controlled common lambsquarters ≥ 97%. Similar results have been seen with these herbicides in conventional tillage peanuts in previous research (Burke *et al.*, 2002a; Clewis *et al.*, 2002; Scott *et al.*, 2001; Wilcut, 1991a, 1991b;Wilcut *et al.*, 1994, 1995).

Ivyleaf, entireleaf, and pitted morningglories. There were treatment by location interactions for control of ivyleaf and pitted morningglories; therefore the data are discussed separately. Entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray) was only found in one location, however control responses were similar to that of pitted morningglory in Lewiston-Woodville 2000B (Table 2). Dimethenamid PRE provided little (< 23%) control of ivyleaf, entireleaf, and pitted morningglory. Flumioxazin PRE and dimethenamid fb flumioxazin PRE provided between 44 and 100% control of all three species. The additional inputs of the EPOST treatments and acifluorfen plus bentazon POST to dimethenamid plus flumioxazin programs controlled greater than 73% of the morningglories, whereas the imazapic POST system controlled greater than 97% of the morningglories at all locations. The residual control properties of imazapic may have contributed to

Table 2. Interaction of PRE, EPOST, and POST herbicide systems on ivyleaf morningglory, and pitted morningglory control at three North Carolina locations in 1999 and 2000.[d]

Herbicides			Ivyleaf morningglory[d]		Entireleaf morningglory[d]	Pitted morningglory[d]	
			Lewiston-Woodville			Lewiston-Woodville	
PRE[a]	EPOST[b]	POST[c]	1999	2000A		2000A	2000B
			%				
Dimethenamid	None	None	0 d	0 e	17 c	0 e	23 c
Dimethenamid + flumioxazin	None	None	92 ab	44 d	100 a	72 d	100 a
Flumioxazin	None	None	78 c	61 c	59 b	60 c	42 b
Dimethenamid	Paraquat + bentazon	Acifluorfen + bentazon	86 b	73 b	100 a	70 b	100 a
Dimethenamid + flumioxazin	Paraquat + bentazon	Acifluorfen + bentazon	95 a	75 b	100 a	73 b	100 a
Flumioxazin	Paraquat + bentazon	Acifluorfen + bentazon	85 b	83 b	97 a	99 a	97 a
Dimethenamid	Paraquat + bentazon	Imazapic	100 a	100 a	100 a	97 a	100 a
Dimethenamid + flumioxazin	Paraquat + bentazon	Imazapic	98 a	100 a	100 a	98 a	99 a
Flumioxazin	Paraquat + bentazon	Imazapic	100 a	100 a	100 a	99 a	100 a

[a]Paraquat was applied PRE to all plots at 0.70 kg ai/ha. Rates of PRE herbicides were: dimethenamid at 1.4 kg/ha, and flumioxazin at 71 g/ha.
[b]Rates of EPOST herbicides were: bentazon at 0.28 kg/ha and paraquat at 0.14 kg/ha.
[c]Rates of POST herbicides were: bentazon at 0.56 kg/ha, acifluorfen at 0.28 kg/ha, and imazapic at 71 g/ha
[d]Mean separations followed by the same letter are not significantly different at 5% level of probability.

these higher levels of control (Richburg *et al*., 1995, 1996). Similar results with imazapic (AC 263,222) control of *Ipomoea* morningglories have been previously reported (Richburg *et al*., 1995, 1996; Wilcut *et al*., 1996).

Eclipta. There was a location by herbicide interaction; therefore each location is discussed separately. Dimethenamid or flumioxazin PRE or in PRE tank mixture controlled eclipta variably (Table 1). The addition of EPOST herbicides fb acifluorfen plus bentazon POST controlled eclipta 68 to 100%. Imazapic POST systems, regardless of PRE treatments, controlled eclipta 96 to 100%.

Goosegrass and large crabgrass. No treatment by location interactions were present for goosegrass or large crabgrass; therefore the data were combined over locations (data not shown). Dimethenamid PRE controlled goosegrass 95% and large crabgrass 97% initially. However a late application of clethodim was needed for season-long control and to facilitate harvest (≥99% control for both weed species at all locations). Clethodim controls goosegrass and large crabgrass (Burke *et al*., 2002b, 2004).

Prickly sida. No treatment by location interactions were seen for prickly sida control; therefore the data were combined over locations (Table 1). Dimethenamid PRE controlled prickly sida 14%. The addition of flumioxazin PRE improved control to 79%. Regardless of PRE herbicide inputs, acifluorfen plus bentazon POST systems controlled prickly sida 84 to 100%. Both imazapic systems controlled prickly sida 100%, regardless of PRE herbicide treatment. Other researchers have also reported excellent control of prickly sida with imazapic (Richburg *et al*., 1995, 1996; Wilcut *et al*., 1996).

Yellow nutsedge. There were treatment by location interactions for yellow nutsedge control, thus each location will be discussed separately. Control by most herbicides was greater in Lewiston-Woodville 2000B than in the other locations. Yellow nutsedge populations at Lewiston 2000B were approximately 10 to 15 plant/m^2 while at other locations they ranged from 30 to 50 plants/m^2 (data not shown). Dimethenamid PRE alone controlled yellow nutsedge by 57 to 100% depending on location (Table 1). Flumioxazin PRE alone control of yellow nutsedge varied from 20 to 72% depending on location. Flumioxazin plus dimethenamid PRE controlled yellow nutsedge by 43 to 97%, and was not different than the control of dimethenamid PRE. The addition of paraquat plus bentazon EPOST fb aciflourfen plus bentazon

Table 3. Interaction of PRE, EPOST, and POST herbicide systems on peanut yield and crop injury at three North Carolina locations in 1999 and 2000.[d]

Herbicides			Peanut yield[d]			Peanut injury[d]		
			Lewiston - Woodville			Lewiston - Woodville		
PRE[a]	EPOST[b]	POST[c]	1999	2000A	2000B	1999	2000A	2000B
			kg/ha			%		
Dimethenamid	None	None	1520 e	2880 c	3320 b	0 a	3 ab	32 b
Dimethenamid + flumioxazin	None	None	3830 cd	4810 b	4640 a	0 a	1 b	60 a
Flumioxazin	None	None	3290 d	4650 b	3760 b	0 a	1 b	0 c
Dimethenamid	Paraquat + bentazon	Acifluorfen + bentazon	3800 cd	6230 a	4950 a	0 a	6 ab	40 ab
Dimethenamid + flumioxazin	Paraquat + bentazon	Acifluorfen + bentazon	3800 cd	6320 a	5080 a	0 a	5 ab	43 ab
Flumioxazin	Paraquat + bentazon	Acifluorfen + bentazon	3900 bcd	6340 a	4980 a	0 a	6 ab	0 c
Dimethenamid	Paraquat + bentazon	Imazapic	4580 ab	6370 a	5130 a	0 a	5 ab	40 ab
Dimethenamid + flumioxazin	Paraquat + bentazon	Imazapic	4880 a	6200 a	5190 a	0 a	2 b	52 ab
Flumioxazin	Paraquat + bentazon	Imazapic	4300 abc	6580 a	5120 a	0 a	5 ab	3 c

[a]Paraquat was applied PRE to all plots at 0.70 kg ai/ha. Rates of PRE herbicides were: dimethenamid at 1.4 kg/ha, and flumioxazin at 71 g/ha.
[b]Rates of EPOST herbicides were: bentazon at 0.25 kg/ha and paraquat at 0.14 kg/ha.
[c]Rates of POST herbicides were: bentazon at 0.56 kg/ha, acifluorfen at 0.28 kg/ha, and imazapic at 71 g/ha.
[d]Mean separations followed by the same letter are not significantly different at 5% level of probability.

POST provided 70 to 100% control depending on location. Paraquat and bentazon EPOST fb imazapic POST controlled yellow nutsedge ≥97% in all locations, regardless of PRE herbicide treatment. These data also show that imazapic POST is an excellent treatment for control of yellow nutsedge in peanut, which agrees with previous research findings (Richburg *et al*., 1994, 1995, 1996; Wilcut *et al*., 1994, 1995, 1996).

Peanut Injury. There was a treatment by location interaction for peanut injury ($P < 0.05$), therefore data are discussed by location. Overall peanut injury was based upon stand reduction due to stunting, leaf discoloration, and spots of necrosis (data not shown). Injury was very erratic, and in 1999 there was no visible injury (Table 3). However, there was significant injury (between 32 and 60% at Lewiston 2000B with treatments that included dimethenamid PRE and in tank mixtures with flumioxazin PRE, regardless of EPOST and POST herbicide treatments. These levels of injury are not typical of dimethenamid PRE and we have no explanation. Other than these exceptions with dimethenamid PRE alone or in tank mixture with flumioxazin, injury levels are consistent with previous research (Wilcut *et al*., 1994, 1995; Richburg *et al*., 195, 1996).

Peanut Yield. Location interactions were significant: therefore, each location is discussed separately. Peanut treated with dimethenamid PRE yielded 1,520 to 3,320 kg/ha, depending on location (Table 3). The addition of flumioxazin PRE, or EPOST and POST herbicides always increased yields. The increased yields reflect the increased levels of weed control provided by the additional herbicide inputs (Tables 1 and 2). Dimethenamid or flumioxazin PRE or in PRE tank mixture plus EPOST and POST herbicide treatments yielded between 4,980 and 6,580 kg/ha at both Lewiston locations in 2000. There was no significant correlation between peanut injury and peanut yield. Other research (Main *et al*., 2003) showed that flumioxazin did not directly result in yield differences between three runner-type cultivars. These data show that weeds in strip-tillage peanut can be controlled with appropriate selection and timely application of PRE, EPOST, and POST herbicide treatments.

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