Influence of Flumioxazin Rate and Herbicide Combinations on Weed Control in Peanut (*Arachis hypogaea* L.)

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ABSTRACT

Field studies were conducted during 1997 and 1998 at three different locations in Georgia to determine peanut and weed response to pendimethalin at 1.1 kg ai/ha applied preplant incorporated (PPI) followed by flumioxazin at 71, 87, and 105 g ai/ha applied preemergence (PRE). Other residual treatments combinations with pendimethalin PPI included flumioxazin mixed with metolachlor or dimethenamid PRE, diclosulam PRE, norflurazon PRE, and imazapic applied postemergence (POST). Herbicide combinations that included flumioxazin controlled Florida beggarweed, tropic croton, and small flower morningglory at least 78% or greater. Late season Florida beggarweed control was 90% or greater with pendimethalin PPI plus flumioxazin at 87 to 105 g/ha applied PRE. Pendimethalin plus flumioxazin did not control sicklepod or yellow nutsedge. Smallflower morningglory control with all herbicide treatments was 90% or greater. Entireleaf morningglory control (when used in combination with pendimethalin PPI) increased from 80% with flumioxazin at 105 g/ha to 90% for flumioxazin in combination with metolachlor. Yields were similar for flumioxazin, norflurazon, imazapic, and diclosulam treated peanut.

Key Words: *Croton glandulosus* L., *Cyperus esculentus* L., *Desmodium tortuosum* (Sweet) DC, *Ipomoea hederacea* (L.) var. *integriuscula* Gray, *Jacquemontia tamnifolia* (L.) Griseb., peanut weed control, *Senna obtusifolia* (L.) Irwin and Barneby.

Florida beggarweed [(*Desmodium tortuosum* (Sweet) DC)] and sicklepod [*Senna obtusifolia* (L.) Irwin and Barneby] are vigorous competitors with peanut if weed emergence occurs within 0 to 8 wk of crop emergence (Hauser *et al.*, 1975; Buchanan *et al.*, 1976; Cardina and Brecke, 1991). Herbicide programs in peanut require contact and residual herbicides applied at various timings throughout the season to control these and other weeds (Wilcut *et al.*, 1995).

Diclosulam {*N*-(2,6-dichlorophenyl)-5-ethoxy-7-fluoro[1,2,4]triazolo-[1,5-c]pyrimidine-2-sulfonamide} is a soil-applied herbicide receiving Federal registration in 2000. In Alabama, Florida, and Georgia, diclosulam applied PPI suppressed Florida beggarweed, sicklepod, and yellow nutsedge (*Cyperus esculentus* L.). However, additional herbicides applied EPOST were needed for acceptable control (Grey *et al.*, 2001b). Imazapic {(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid} applied either EPOST or POST controls sicklepod and yellow nutsedge, but Florida beggarweed control is inconsistent (Webster *et al.*, 1997; Grey *et al.*, 2001b). Tank-mixed treatments of paraquat [1,1'-dimethyl-4,4'-bipyridinium dichloride], bentazon [3-(1-methylethyl)-(1*H*)-2,1,3-benzothia-diazin-4(3*H*)-one 2,2-dioxide], acifluorfen {5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid}, and/or 2,4-DB [4-(2,4-dichlorophenoxy)butanoic acid] are commonly used as EPOST treatments. However, these tank mixtures lack residual activity and have a narrow window of application (Wilcut *et al.*, 1995).

Chlorimuron {ethyl,2-[[[[(4-chloro-6-methoxy-2-pyrimidynly)amino]carbonyl]amino] sulfonly]benzoate} controls Florida beggarweed in peanut and is often used as a midseason salvage treatment (Johnson *et al.*, 1992a). However, the current registration prohibits applications prior to 60 d after peanut emergence (Johnson *et al.*, 1992b) at which time Florida beggarweed can be taller than 25 cm, which is the maximum specified height on the chlorimuron label (Webster *et al.*, 1997). Another potential control method for Florida beggarweed and sicklepod is the use of a wick-bar with paraquat or glyphosate [*N*-(phosphonomethyl)glycine]. This control approach is recommended as a salvage treatment only (Johnson *et al.*, 1999).

Imazapic and diclosulam can be used effectively to control many weed species in peanut, although there are label restrictions of 18 mo for cotton (*Gossypium hirsutum* L.) and corn (*Zea mays* L.), respectively. Additionally, many fall vegetable rotational restrictions limit use (Anon., 2000a,b). Residual herbicides, alone or combinations, that provide season-long, broad-spectrum control of broadleaf weeds and nutsedge with no rotational restrictions would benefit producers.

Norflurazon is registered for PRE use on runner-type peanut and provides control of Florida beggarweed and tropic croton (*Croton glandulosus* L.) and suppression of sicklepod (Wilcut *et al.*, 1994b, 1995) with no cotton rotational restriction (Jordan *et al.*, 1998). However, early season bleaching, injury concerns, and inconsistent efficacy have limited use to only runner market types (Jordan *et al.*, 1998).

Flumioxazin applied PRE controls many broadleaf weed species in soybean [*Glycine max* (L.) Merr.] (Eyherabide, 1993, 1996; Niekamp *et al.*, 1999) and peanut (Grichar and Colburn, 1996; Askew *et al.*, 1999). Flumioxazin has low soil persistence (half-life of 11.9-

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17.5 d) which results in low carryover potential to rotational crops (WSSA, 1998). This could make flumioxazin an excellent herbicide for peanut producers that rotate to fall vegetable production and greater flexibility in corn and cotton rotational schemes. Flumioxazin does not control sicklepod or nutsedge species in peanut (Grey *et al.*, 1993), but certain chloroacetamide herbicides applied PPI suppress these weeds (Cardina and Swann, 1988; Richburg *et al.*, 1995). Thus, metolachlor or dimethenamid in combination with flumioxazin could improve weed control in peanut.

Research is needed to further define appropriate use rates, tolerance, and herbicide combinations for herbicides in peanut. Thus, the objectives of this research were to evaluate weed control and peanut tolerance to flumioxazin, norflurazon, diclosulam, imazapic, and pendimethalin. Flumioxazin in combination with metolachlor and dimethenamid were evaluated also.

Materials and Methods

Experiments were conducted in 1997 and 1998 in Georgia at the Attapulgus Res. Farm in Attapulgus, at the Coastal Plain Exp. Sta. near Tifton, and at the Southwest Georgia Branch Exp. Sta. located near Plains. These studies were conducted twice in 1998 at Tifton and are designated Tifton A 1998 and Tifton B 1998. The soils were a Faceville sandy loam (clayey, kaolinitic, thermic, Typic Kandiudults) with 1.4% organic matter and pH 6.0 at Plains, a Dothan loamy sand (fine-loamy, siliceous, thermic Plinthic Paleudults) with 0.5% organic matter and pH 6.0 at Attapulgus, and a Tifton loamy sand (fine-loamy, siliceous, thermic, Plinthic Paleudults) with 0.5% organic matter and pH 6.0 at Tifton. Across locations, cv. Georgia Green peanut was planted from late April to early May, with emergence occurring 7 to 11 d later. Irrigation was applied when necessary. For all experiments, pendimethalin [*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] at 1.1 kg ai/ha was incorporated to a depth of 5 to 7 cm over the entire test area. Peanut was planted 4 to 5 cm deep and spaced 5 to 6 cm apart. Individual plots consisted of two rows 91 cm apart by 7.6-m long. Irrigation was applied as needed in all studies.

Herbicides evaluated were flumioxazin applied PRE at 71, 87, or 105 g ai/ha alone or mixed with chloroacetamide herbicides. Dimethenamid at 1.3 kg ai/ha was applied at Tifton in 1997. At Tifton A, metolachlor was applied at 2.2 kg ai/ha. Metolachlor at 1.7 kg/ha was applied at Attapulgus, Plains, and Tifton B. Other treatments included norflurazon at 1.3 kg/ha applied PRE, diclosulam at 26 g ai/ha applied PRE, and imazapic at 71 g ai/ha applied EPOST. Pendimethalin PPI alone served as the check. Imazapic POST treatment was applied 5 wk after peanut emergence with nonionic surfactant at 0.25% (v/v). Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 187 L/ha at 210 kPa.

Imazapic POST was applied to broadleaf weeds ranging in size from cotyledon to six leaves. Yellow nutsedge was two to six-leaf and peanut had approximately four to seven true leaves at the POST timing.

Visual estimates of percent weed control were recorded approximately 90 d after the POST applications on a scale of 0 (no control) to 100% (complete control) relative to the pendimethalin alone control. Visual estimates of percent peanut foliar injury (plant stunting, stand reduction, necrosis, and/or chlorosis) were recorded 1 wk after the POST treatment and again prior to harvest using the scale previously described. Peanut was harvested, based on mesocarp pod color determination of maturity, using conventional harvesting equipment.

The experimental design was a randomized complete block with three or four replications. Data were subjected to analysis of variance and tested for year by treatment interactions. Treatments means were separated by Fisher's Protected LSD Test at P = 0.05. Variation in rating date and significant location by treatment interactions were noted for weed control, peanut injury, and pod yield. Therefore, data are presented for individual experiments.

Results and Discussion

Peanut injury recorded 1 wk after the POST treatment was 11% or less and did not differ among treatments at Tifton 1997, Tifton A 1998, Tifton B 1998, Attapulgus, and Plains (data not shown). Peanut injury from all treatments was transient and not observed later in the season. Minor and transient peanut injury with flumioxazin applied alone and in combination with a chloroacetamide herbicide (Grey *et al.*, 1993; Wilcut and Eastin, 1993; Wilcut *et al.*, 1994a; Grichar and Colburn, 1996; Wilcut and Cranmer 1997) and diclosulam (Bailey *et al.*, 1999; Grey *et al.*, 2001a) has been reported previously. Previous research in Texas reported 6 to 24% stunting 2 wk after metolachlor plus flumioxazin was applied PRE, but stunting was not significantly different from nontreated peanut 4 and 6 wk later (Grichar and Colburn, 1996).

Late season Florida beggarweed control was 90% or greater with flumioxazin at 71 to 105 g/ha applied PRE for all locations except at Tifton A 1998 where control was only 78% with flumioxazin at 71 g/ha (Table 1). Flumioxazin in combination with a chloroacetamide herbicide did not improve Florida beggarweed control over flumioxazin alone. Previous research has reported 89% or greater control of Florida beggarweed in peanut with flumioxazin at 71 to 105 g/ha (Grey *et al.*, 1993, 2001b; Wilcut *et al.*, 1994a; Wilcut and Cranmer, 1997). Excellent control of emerged Florida beggarweed can be obtained by paraquat or paraquat plus bentazon applied 2 to 3 wk after peanut emergence (Wilcut *et al.*, 1995). In previous studies, Florida beggarweed that emerged with peanut reduced peanut yield (Buchanan *et al.*, 1976). However, if Florida beggarweed emergence is delayed or proper control measures taken, yield reductions from competition can be minimized or eliminated (Hauser *et al.*, 1975; Grey and Bridges, 2000). Flumioxazin could reduce or eliminate the need for paraquat plus bentazon or chlorimuron to control Florida beggarweed. Flumioxazin Florida beggarweed control was equal too or greater than diclosulam or imazapic when compared across these five trials.

Florida beggarweed control with norflurazon ranged from 58 to 98% (Table 1), which is consistent with previous reports (Wilcut and Eastin, 1993; McLean *et al.*, 1994, 1995). Florida beggarweed control at the end of the season was greater with flumioxazin, norflurazon, and diclosulam compared with imazapic (Table 1).

Flumioxazin controlled sicklepod 68% or less (Table

Table 1. Florida beggarweed control in peanut with herbicide programs containing norflurazon, diclosulam, flumioxazin, imazapic, and flumioxazin with chloroacetamide herbicides.

Herbicide	Herbicide rate	Application timing[a]	Tifton 1997	Tifton A 1998	Tifton B 1998	Attapulgus 1998	Plains 1998
	g/ha		---------------%	---------------		%	%
Norflurazon	1340	PRE	87	58	89	85	98
Diclosulam	26	PRE	87	67	93	90	98
Imazapic	71	POST	83	63	79	70	81
Flumioxazin	71	PRE	90	78	93	94	97
Flumioxazin	87	PRE	90	93	91	97	97
Flumioxazin	105	PRE	90	92	95	95	97
Flumioxazin + chloroacetamide[b]	71	PRE	90	90	94	95	97
Flumioxazin + chloroacetamide	87	PRE	90	93	95	97	97
Flumioxazin + chloroacetamide	105	PRE	90	93	95	98	97
Nontreated control[c]			0	0	0	0	0
LSD (0.05)			6	20	10	10	6

[a]PRE; preemergence; POST, postemergence 5 wk after emergence.

[b]Chloroacetamide herbicides mixed with flumioxazin. Dimethenamid at 1.3 kg/ha at Tifton in 1997. Metolachlor at 2.2 kg/ha at Tifton A. Metolachlor at 1.7 kg/ha at Attapulgus, Plains, and Tifton B.

[c]Pendimethalin at 1.1 kg/ha was applied with all treatments including the nontreated control.

2). Chloroacetamide herbicides did not consistently improve sicklepod control. Previous research demonstrated that flumioxazin does not control sicklepod (Grey *et al.*, 1993, 2001b; Wilcut and Eastin, 1993; Wilcut and Cranmer, 1997). Sequential programs of soil-applied and POST herbicides are needed for control of sicklepod in peanut when flumioxazin is applied PRE (Grey *et al.*, 1993, 2001b; Wilcut *et al.*, 1994; Wilcut and Cranmer, 1997). Sicklepod control with imazapic was 75% or greater regardless of year or location (Table 2).

Sicklepod control by norflurazon varied from 50 to 85% (Table 2). Norflurazon suppresses sicklepod (Wilcut *et al.*, 1994b). However, POST treatments containing paraquat are required often for adequate season long control (Wilcut and Eastin, 1993; McLean *et al.*, 1994). Diclosulam did not control sicklepod. Previous research has shown that diclosulam controls dicklepor poorly (Grey *et al.*, 2001a,b).

Yellow nutsedge control by flumioxazin was 68% or less regardless of rate. Control by norflurazon or diclosulam also was poor (Table 3). Yellow nutsedge control by imazapic was at least 75%. Previous research has shown poor yellow nutsedge control by flumioxazin and norflurazon (Grey *et al.*, 1993; Wilcut and Cranmer, 1997; Askew *et al.*, 1999). When flumioxazin was applied with metolachlor PRE, yellow nutsedge control was greater than that by flumioxazin alone at Tifton B but not at Attapulgus. Bailey *et al.* (1999) also determined that flumioxazin in combination with metolachlor improved yellow nutsedge control over flumioxazin alone.

Flumioxazin controlled tropic croton at least 90% regardless of rate, and this level of control was equal to or greater than control by diclosulam, norflurazon, or imazapic (Table 3). Flumioxazin in combination with a chloroacetamide herbicide did not improve control of tropic croton over flumioxazin alone. Tropic croton control by imazapic ranged from 53 to 85% POST. Gooden and Stabler (1996) reported poor tropic croton control with imazapic POST.

Smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb.] control by all herbicide treatments was at least 90% (data not shown). However, for entireleaf morningglory [*Ipomoea hederacea* (L.) var. *integriuscula* Gray], a rate response to flumioxazin was noted when applied alone or with metolachlor (data not presented). Entireleaf morningglory control increased from 80% with flumioxazin at 105 g/ha to 90% for flumioxazin in combination with metolachlor. Previous research has demonstrated that flumioxazin controls smallflower morningglory (Grey *et al.*, 1993; Wilcut and Eastin, 1993; Wilcut and Cranmer, 1997). However, when flumioxazin is used, additional herbicides are required for adequate season long control of other morningglory species in peanut (Grey *et al.*, 1993; Wilcut and Eastin, 1993; Grichar and Colburn, 1996; Wilcut and Cranmer, 1997; Askew *et al.*, 1999) and soybean (Niekamp *et al.*, 1999).

There were no significant yield differences among any treatment at Tifton in 1997 and Tifton A 1998 (Table 4). For Tifton B 1998, Attapulgus, and Plains, yield for all treatments was similar to or greater than the pendimethalin-treated control. Peanut yields with norflurazon were comparable to or greater than any other treatment. No trends for yield were evident across

Table 2. Sicklepod control in peanut with herbicide programs containing norflurazon, diclosulam, flumioxazin, imazapic, and flumioxazin with chloroacetamide herbicides.

Herbicide	Herbicide rate	Application timing[a]	Tifton 1997	Tifton A 1998	Tifton B 1998	Attapulgus 1998	Plains 1998
	g/ha		----%	----	----	%	%
Norflurazon	1340	PRE	50	85	79	81	60
Diclosulam	26	PRE	37	67	63	49	51
Imazapic	71	POST	90	95	88	91	75
Flumioxazin	71	PRE	27	67	56	58	29
Flumioxazin	87	PRE	43	63	51	59	31
Flumioxazin	105	PRE	47	63	55	68	24
Flumioxazin + chloroacetamide[b]	71	PRE	33	65	50	63	38
Flumioxazin + chloroacetamide	87	PRE	50	73	68	61	15
Flumioxazin + chloroacetamide	105	PRE	37	62	71	79	40
Nontreated control[c]			0	0	0	0	0
LSD (0.05)			13	14	19	17	18

[a]PRE; preemergence; POST, postemergence 5 wk after emergence.

[b]Chloroacetamide herbicides mixed with flumioxazin. Dimethenamid at 1.3 kg/ha at Tifton in 1997. Metolachlor at 2.2 kg/ha at Tifton A. Metolachlor at 1.7 kg/ha at Attapulgus, Plains, and Tifton B.

[c]Pendimethalin at 1.1 kg/ha was applied with all treatments including the nontreated control.

Table 3. Yellow nutsedge and tropic croton control in peanut with herbicide programs containing norflurazon, diclosulam, flumioxazin, imazapic, and flumioxazin with chloroacetamides.

Herbicide	Herbicide rate	Application timing[a]	Yellow nutsedge Tifton B 1998	Yellow nutsedge Attapulgus 1998	Tropic croton Tifton B 1998	Tropic croton Attapulgus 1998
	g/ha		----%	----	----%	----
Norflurazon	1340	PRE	44	17	88	73
Diclosulam	26	PRE	68	25	95	83
Imazapic	71	POST	89	75	85	53
Flumioxazin	71	PRE	55	50	90	95
Flumioxazin	87	PRE	50	43	96	95
Flumioxazin	105	PRE	48	34	97	95
Flumioxazin + chloroacetamide[b]	71	PRE	75	27	98	95
Flumioxazin + chloroacetamide	87	PRE	77	41	96	93
Flumioxazin + chloroacetamide	105	PRE	79	56	98	95
Nontreated control[c]			0	0	0	0
LSD (0.05)			18	18	8	10

[a]PRE; preemergence; POST, postemergence 5 wk after emergence.

[b]Chloroacetamide herbicides mixed with flumioxazin. Dimethenamid at 1.3 kg/ha at Tifton in 1997. Metolachlor at 2.2 kg/ha at Tifton A. Metolachlor at 1.7 kg/ha at Attapulgus, Plains, and Tifton B.

[c]Pendimethalin at 1.1 kg/ha was applied with all treatments including the nontreated control.

locations or years for any herbicide treatment. However, yield was affected by late season competition from a nonuniform sicklepod infestation at Plains.

Across rates, flumioxazin controlled Florida beggarweed and tropic croton greater than norflurazon, diclosulam, or imazapic. Florida beggarweed and smallflower morningglory control by flumioxazin has been reported previously in peanut (Grey *et al.*, 1993; Wilcut *et al.*, 1994; Wilcut and Cranmer, 1997). Flumioxazin did not adequately control sicklepod or

Table 4. Peanut yield as influenced by herbicide programs containing norflurazon, diclosulam, flumioxazin, imazapic, and flumioxazin with chloroacetamide herbicides.

Herbicide	Herbicide rate	Application timing[a]	Tifton 1997	Tifton A 1998	Tifton B 1998	Attapulgus 1998	Plains 1998
	g/ha		kg/ha			kg/ha	kg/ha
Norflurazon	1340	PRE	2060	2640	5600	1640	990
Diclosulam	26	PRE	2740	3655	3890	2470	2210
Imazapic	71	POST	2410	3200	4710	2320	2150
Flumioxazin	71	PRE	2550	2850	3480	1350	1910
Flumioxazin	87	PRE	2910	3780	4330	1610	750
Flumioxazin	105	PRE	2900	3580	5400	1330	1280
Flumioxazin + chloroacetamide[b]	71	PRE	2900	3290	4130	1870	1740
Flumioxazin + chloroacetamide	87	PRE	2710	3300	4840	1760	840
Flumioxazin + chloroacetamide	105	PRE	3330	3400	4520	2080	1280
Nontreated control[c]			2630	2410	3330	1500	830
LSD (0.05)			NS	NS	900	430	330

[a]PRE; preemergence; POST, postemergence 5 wk after emergence.

[b]Chloroacetamide herbicides mixed with flumioxazin. Dimethenamid at 1.3 kg/ha at Tifton in 1997. Metolachlor at 2.2 kg/ha at Tifton A. Metolachlor at 1.7 kg/ha at Attapulgus, Plains, and Tifton B.

[c]Pendimethalin at 1.1 kg/ha was applied with all treatments including the nontreated control.

yellow nutsedge. Flumioxazin in combination with a chloroacetamide herbicide improved yellow nutsedge and entireleaf morningglory control over flumioxazin alone. However this combination did not increase Florida beggarweed, tropic croton, or sicklepod control.

Flumioxazin controlled Florida beggarweed and tropic croton season long. In contrast, Florida beggarweed control by imazapic and diclosulam was erratic (Webster *et al.*, 1997; Grey *et al.*, 2001a). These data show the utility of incorporating flumioxazin into peanut for season-long weed control. Future research should emphasize the use of POST herbicides—such as imazapic, paraquat, or bentazon—in sequence with flumioxazin for specific weed control (i.e., sicklepod and *Ipomoea* spp. morningglories).

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