Imazethapyr for Broadleaf Weed Control in Peanuts (*Arachis hypogaea*)

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ABSTRACT

Field experiments were conducted at the Tidewater Agric. Exp. Station, Suffolk, VA in 1988 and 1989 to evaluate imazethapyr [(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-ethyl-3-pyridine-carboxylic acid]for broadleaf weed control in peanuts (*Arachis hypogaea* L.). Imazethapyr was applied preplant-incorporated (PPI), preemergence (PRE), at ground-cracking (GC), and postemergence (POT) at rates of 0.036, 0.071, or 0.105 kg ai ha^{-1}. Several sequential imazathapyr systems were also included. The standard of pendimethalin (N-ethylpropyl)-3, 4-dimethyl-2,6-dinitrobenzenamine) PPI, metolachlor(2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide) PRE, and acifluorfen (5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid) plus bentazon (3-(1-methyethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one 2, 2-dioxide) POT was included for comparative purposes. Imazethapyr applied either PPI or PRE at 0.071 or 0.105 kg ha^{-1} provided >90% spurred anoda (*Anoda cristata* (L.) Schlecht.), control and >96% prickly sida (*Sida spinosa* L.), control. Eclipta (*Eclipta prostrata* L.) control was 95% when imazathapyr was applied PRE at 0.105 kg ha^{-1}. Greater than 90% annual morningglory (*Ipomoea spp.*) control was only achieved with imazethapyr applied PPI or PRE at 0.105 kg ha^{-1}. The standard provided complete control of eclipta,and 51%, 92%, and 94% control of spurred anoda (*Anoda cristata* (L.) Schlecht.), prickly sida (*Sida spinosa* L.), and annual morningglories, respectively. Several imazethapyr systems yielded equivalent to the standard. Averaged across all rates, imazathapyr applied PPI yielded 4110 kg ha^{-1}, PRE = 3860 kg ha^{-1}, GC = 3680 kg ha^{-1}, and POT = 3370 kg ha^{-1}. Several imazethapyr systems provided net returns equivalent to the standard. Corn grown the following year was not injured by any imazethapyr treatment to peanuts the previous year.

Key Words. Economic analysis, net returns, *Anoda cristata, Eclipta prostrata, Sida spinosa, Ipomoea spp.*

Annual broadleaf weed control in peanuts relies almost exclusively on timely applications of postemergence-active herbicides (4). Most herbicides registered for use in peanuts do not provide residual control of broadleaf weeds, and as a result multiple applications are frequently required for profitable crop production (4, 15, 16, 17, 18, 19, 20). Cultivation can be used to control escape weed problems (15, 16), however, many growers are reluctant to cultivate because of increased disease incidence resulting from soil moved onto the peanut vines (4, 11). Thus, cultivation is not recommended in fields with a history of disease problems (4, 11).

Imazethapyr is a herbicide recently registered for use in soybeans that provides broad spectrum broadleaf weed control (14). Imazethapyr is also being investigated for potential use in peanuts (13). To date, very little published data exists for imazethapyr evaluation in Virginia (13) or elsewhere.

Economic assessment of weed management systems is essential information for producers to maximize profits (3). By using a multidisciplinary approach, weed research encompasing both herbicide efficacy and economic profitability can be examined (3, 15, 16, 17, 18). This approach identifies efficacious as well as cost effective weed management systems that producers are more likely to adopt.

The objectives of this research were: 1) to evaluate the efficacy of imazethapyr rates and methods of application for

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[2]X-77 (a mixture of alkylaryl polyoxyethylene glycols, free fatty acids, and isopropanol). Valent USA Corp., P. O. Box 8025, Walnut Creek, CA 94596-8025.

[3]Storm® (a mixture of 159 g acifluorfen and 320 g bentazon L^{-1}). BASF Corp., 100 Cherry Hill Rd., Parsippany, NJ 07054.

[4]Agridex (a mixture of paraffin base petroleum oil, polyoxyethylate polyol fatty acid ester and polyol fatty ester). Helena Chem. Co., 5100 Poplar St., Memphis, TN 38137.

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annual broadleaf weed control, 2) to determine the resulting peanut yield, and 3) to evaluate economic net returns for weed control with imazethapyr when used in peanut production systems in Virginia.

Materials and Methods

Experiments were conducted in 1988 and 1989 at the Tidewater Agricultural Experiment Station, Suffolk, VA, on a Eunola fine loamy sand (Aquic Hapludults). The area was naturally infested with fall panicum (*Panicum dichotomiflorum* Mich.), large crabgrass (*Digitaria sanguinalis* (L.) Scop.), spurred anoda (*Anoda cristata* (L.) Schlecht.), prickly sida (*Sida spinosa* L.), common lambsquarters (*Chenopodium album* L.), eclipta (*Eclipta prostrata* L.), and a morningglory complex consisting of entireleaf (*Ipomoea hederacea* var. *integriuscula* Gray), ivyleaf (*Ipomoea hederaceae* (L.) Jacq.), tall (*Ipomoea purpurea* (L.) Roth), and pitted (*Ipomoea lacunosa* L.) morningglory. These weed species are some of the more common and difficult to control weeds for Virginia and North Carolina peanut producers (8). The experimental area was different each year due to crop rotation requirements. Soil organic matter and pH was 1.7% and 5.9, respectively, in 1988, and 1.0% and 5.5 in 1989.

Florigiant peanuts were planted at a rate of 112 kg ha^{-1}, 5 cm deep in a well-prepared flat seedbed using conventional equipment. Individual plots were four rows, spaced 91 cm apart and 6.1 m long. Planting dates were May 13, 1988 and may 17, 1989.

Preplant-incorporated (PPI) herbicides were applied one day before planting and incorporated 5 to 7 cm deep with two passes of a field cultivator equipped with two rolling baskets. All herbicides were applied as either PPI, preemergence (PRE), ground-cracking (GC), or postemergence (POT) applications. Ground-cracking is defined as the period between hypocotyl emergence and the appearance of the first true leaves (2). Postemergence treatments were applied 3 weeks after GC. Weeds were in the cotyledon to two-leaf stage at the time of GC applications, and in the two- to six-leaf growth stage for POT applications.

Imazethapyr GC and POT applications were applied with a nonionic surfactant[2] at 0.25% (v/v) of the spray volume. Acifluorfen (5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid) plus bentazon (3-(1-methylethyl)-(1H)2, 1, 3-benzothiadizin-4(3H)-one 2, 2-dioxide) was applied as a prepackage commercial mixture[3] and with a crop oil concentrate[4] at 1.25% (v/v) of the spray volume.

Pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) was applied PPI at 1.12 kg ai ha^{-1} to all plots except the weed-free and weedy checks.

Imazethapyr treatments consisted of a factorial arrangement of four methods of application; PPI, PRE, GC, or POT, and three rates; 0.036, 0.071, or 0.105 kg ai ha^{-1}, for a total of twelve treatments. Additional treatments were: imazethapyr applied PPI and again GC, 1) at 0.036 kg ha^{-1} each application; 2) at 0.036 and 0.071 kg ha^{-1} respectively, and 3) at 0.036 and 0.105 kg ha^{-1}, respectively. The next systems consisted of pendimethalin PPI as previously described, or pendimethalin PPI followed by metolachlor (2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide)PRE at 2.24 kg ha^{-1} followed by a POT application of acifluorfen at 0.28 plus bentazon at 0.56 kg ha^{-1}. This system is commonly used by Virginia peanut growers. For comparative purposes, weedy and weed-free checks were included. The latter was maintained with biweekly handweedings.

A randomized complete block design with three replications was used. All herbicides were applied with a tractor-mounted sprayer that used compressed air at 220 kPa as the propellant, and delivered 187 L ha^{-1}. Data collected included visual estimates of weed control by species, peanut yields, and grade. Visual estimates of weed control were taken early-, mid-, and late season using a scale of 0% (no control) to 100% (complete control) based on population density and plant vigor. Peanuts were harvested from the center two rows of each plot using conventional equipment (22).

In 1989, corn was planted in the 1988 experimental site as a field bioassay for imazethapyr residue carryover. Visual evaluations for corn stunting and discoloration were made 30 days after planting and grain yields were harvested.

An enterprise budget was prepared for each plot using budgets prepared by the Virginia Cooperative Extension Service for peanut production. All costs, with the exception of those used for weed control, were based on this budget generator (9). Herbicide prices were based on an average cost quoted by three suppliers from the peanut-producing area in Virginia. The production costs included cultural and pest management procedures, equipment and labor, interest on operating capital, harvest operations including drying and hauling, and general overhead cost. A net return to land, overhead, and management was calculated for each plot as the difference between the gross receipts and the sum of variable and ownership costs. Gross receipts were calculated for the sale of peanuts at $650 for 1000 kg in 1988 and $685 for 1000 kg in 1989.

A sample of peanuts from each replication of a treatment was shelled, combined, and graded to determine percentage (wt/wt) of sound mature kernels and sound split kernels (7). Visual estimtes of weed control, peanut yield, and net returns were subjected to analysis of variance, and means were compared with appropriate Fisher's Protected Least Significant Difference (LSD) Test at the 5% level of probability for all data except eclipta (10% level of probaility). There were no treatment by year interactions; consequently data were combined for presentation.

Results and Discussion

Weed Control

Pendimethalin applied PPI provided at least 96% control of fall panicum and large crabgrass (data not shown) with no differences between weed management systems. Pendimethalin provided only 15% spurred anoda control (Table 1) and illustrated the lack of spurred anoda control with soil-appllied herbicides currently registered in peanuts (4). The standard of pendimethalin PPI, metolachlor PRE, and acifluorfen plus bentazon POT provided 80% early-season control (data not shown). Since spurred anoda seed germinate over an extended portion of the growing season (authors observations), later emerging weeds escape control. As a result, the late season control from the standard decreased to 51%.

Regardless of application rate, spurred anoda control was greater than 90% with all PPI and PRE imazethapyr applications or PPI + GC imazethapyr sequentials. Cracking

Table 1. Influence of herbicide systems on late-season spurred anoda control.[a]

Herbicide system	Rate	Spurred anoda control — Method of imazethapyr application: PPI	PRE	GC	POT
	(kg ha^{-1})	(%)			
Imazethapyr	0.036	94	91	65	49
Imazethapyr	0.071	92	100	88	43
Imazethapyr	0.105	100	100	86	83
Additional treatments					
Imazethapyr (PPI + GC)	0.036 + 0.036	94			
Imazethapyr (PPI + GC)	0.036 + 0.071	100			
Imazethapyr (PPI + GC)	0.036 + 0.105	100			
Metolachlor (PRE), acifluorfen (POT) + bentazon (POT)	2.2, 0.28, 0.56	51			
Pendimethalin (PPI)	1.12	15			
Weed-free		100			
Weedy check		0			
Statistical analyses					
LSD (Application method)		9			
LSD (Rate)		14			
LSD (Any two means)		14			

[a]All treatments except the weedy and weed-free check received an application of pendimethalin PPI at 1.12 kg ha^{-1}.

applications of imazethapyr at the two higher rates provided greater than 85% control. Postemergence applications of 0.036 and 0.071 kg ha^{-1} provided less than 50% control while the 0.105 kg ha^{-1} rate resulted in 83% spurred anoda control.

Prickly sida control (Table 2) equivalent to the weed-free check was obtained with all PPI imazethapyr applications, imazethapyr PRE at the two higher rates, all PPI + GC sequential imazethapyr systems, and with the standard system. Prickly sida control with imazethapyr applied either PRE or PPI at 0.036 kg ha^{-1} was 84 to 89%, respectively, and equal to control from the standard. Postemergence applications were generally less effective than soil applications. Pendimethalin provided only 12% prickly sida control.

Table 2. Influence of herbicide systems on late-season prickly sida control.[a]

Herbicide system	Rate	Prickly sida control — Method of imazethapyr application: PPI	PRE	GC	POT
	(kg ha^{-1})	(%)			
Imazethapyr	0.036	89	84	74	51
Imazethapyr	0.071	99	96	79	69
Imazethapyr	0.105	100	100	81	76
Additional treatments					
Imazethapyr (PPI + GC)	0.036 + 0.036	100			
Imazethapyr (PPI + GC)	0.036 + 0.071	100			
Imazethapyr (PPI + GC)	0.036 + 0.105	99			
Metolachlor (PRE) acifluorfen (POT) + bentazon (POT)	2.2, 0.28 + 0.56	92			
Pendimethalin (PPI)	1.12	12			
Weed-free		100			
Weedy check		0			

Statistical analyses	
LSD (Application method)	13
LSD (Rate)	12
LSD (Any two means)	15

[a]All treatments except the weedy and weed-free check received an application of pendimethalin PPI at 1.12 kg ha^{-1}.

Eclipta control was 26% with pendimethalin applied PPI (Table 3). Imazethapyr at 0.036 kg ha^{-1}, regardless of application method, provided little improvement while imazethapyr applied PPI, PRE, or GC at 0.071 kg ha^{-1} provided 67 to 75% control. Control equivalent to the weed-free check was obtained with imazethapyr applied PRE at 0.105 kg ha^{-1} and with sequential systems provided the GC application rate was at least 0.071 kg ha^{-1}. Postemergence applications provided no more than 41% control, and no rate response was evident. The standard controlled eclipta completely.

Pendimethalin provided 17% morningglory control while the standard resulted in 94% control (Table 4). Morningglory control equivalent to the standard was provided with PPI and PRE applications of imazethapyr at the two higher rates and with all sequential systems. Postemergence imazethapyr applications were generally less effective.

Table 3. Influence of herbicide systems on late-season eclipta control.[a]

Herbicide system	Rate	Eclipta control — Method of imazethapyr application: PPI	PRE	GC	POT
	(kg ha^{-1})	(%)			
Imazethapyr	0.036	37	46	28	33
Imazethapyr	0.071	67	75	70	41
Imazethapyr	0.105	83	95	72	35
Additional treatments					
Imazethapyr (PPI + GC)	0.036 + 0.036	65			
Imazethapyr (PPI + GC)	0.036 + 0.071	95			
Imazethapyr (PPI + GC)	0.036 + 0.105	90			
Metolachlor (PRE) acifluorfen (POT) + bentazon (POT)	2.2 0.28 + 0.56	100			
Pendimethalin (PPI)	1.12	26			
Weed-free		100			
Weedy check		0			

Statistical analyses	
LSD (Application method)	13
LSD (Rate)	12
LSD (Any two means)	10

[a]All treatments except the weedy and weed-free check received an application of pendimethalin PPI at 1.12 kg ha^{-1}.

Imazethapyr provided the best weed control with few exceptions when applied either PPI, PRE, or GC or as a sequential of a PPI followed by GC application.

Postemergence applications of imazethapyr generally provided the least control. Cole et. al (5) reported that imazethapyr tolerance was based on differential metablism between tolerant and susceptible species. They further reported that the amount of imazethapyr metabolized varied with site of uptake. Thus, metabolism and tolerance varied with method of application and may explain the observed differences in field efficacy depending on application method in this study. Other field research has reported similar finding[5]. Soil applications of imazethapyr have been shown to provide the best control of prickly sida (19), while postemergence applications provide the best control of common cocklebur[5]. The activity of other translocated herbicides has also been reported to be influenced by the site of application (1, 5, 6, 10).

Peanut yield

Yields equivalent to the weed-free check yield of 4080 kg ha^{-1} were obtained with the standard and with all imazethapyr systems; the exceptions being imazethapyr applied POT at 0.036 kg ha^{-1} (Table 5). However, the highest numerical yield of 4700 kg ha^{-1} was obtained from imazethapyr applied sequentially at 0.036 kg ha^{-1} PPI and 0.071 kg ha^{-1} GC. Yields equivalent to this system were obtained with the standard system, imazethapyr applied at 0.071 kg ha^{-1} PPI, imazethapyr

Table 4. Influence of herbicide systems on late-season morningglory control.[a]

Herbicide system	Rate	Morningglory control: Method of imazethapyr application PPI	PRE	GC	POT
	(kg ha^{-1})	(%)			
Imazethapyr	0.036	82	79	72	49
Imazethapyr	0.071	90	93	83	62
Imazethapyr	0.105	95	95	82	70
Additional treatments					
Imazethapyr	0.036 +	94			
(PPI + GC)	0.036				
Imazethapyr	0.036 +	97			
(PPI + GC)	0.071				
Imazethapyr	0.036 +	96			
(PPI + GC)	0.105				
Metolachlor (PRE)	2.2,	94			
acifluorfen (POT)	0.28 +				
+ bentazon (POT)	0.56				
Pendimethalin (PPI)	1.12	17			
Weed-free		100			
Weedy check		0			
Statistical analyses					
LSD (Application method)			14		
LSD (Rate)			11		
LSD (Any two means)			12		

[a]All treatments except the weedy and weed-free check received an application of pendimethalin PPI at 1.12 kg ha^{-1}.

at 0.105 ka ha^{-1} PPI or PRE, or from a sequential imazethapyr system at 0.036 kg ha^{-1} PPI followed by 0.105 kg ha^{-1} GC. Peanuts treated with only pendimethalin PPI yielded 3260 kg ha^{-1} and reflect yield reduction from broadleaf weed competition and interference with peanuts. Imazethapyr at 0.071 kg ha^{-1} PPI or 0.105 kg ha^{-1} PPI or PRE, imazethapyr PPI + GC at 0.036 and 0.071 or 0.105 kg ha^{-1}, and the standard provided higher yields. Averaged across all rates, yields with imazethapyr applied PPI, PRE, GC, and POT were 4110 kg ha^{-1}, 3860 kg ha^{-1}, 3680 kg ha^{-1}, and 3370 kg ha^{-1}, respectively.

Imazethapyr carryover on corn

There were no visible symptoms of imazethapyr injury to corn grown a year after imazethapyr application (data not shown). Grain yield was also unaffected by imazethapyr treatment. These findings are in agreement with other research in Virginia (21) and Michigan (12).

Net returns

Net return data (Table 6) followed many of the same trends as the yield data. The greatest net returns were from imazethapyr PPI (0.036 kg ha^{-1}) plus GC (0.071 kg ha^{-1}) at \$1425 ha^{-1}, imazethapyr applied at 0.105 kg ha^{-1} PRE (\$1284 ha^{-1}), and from the standard (\$1253 ha^{-1}). Equivalent returns were also obtained from imazethapyr PPI at 0.071 kg ha^{-1} (\$1163 ha^{-1}). The lowest net returns were from POT imazethapyr systems.

Imazethapyr provided the best annual broadleaf control as a soil applied treatment with efficacy depending on application method and species in question. Soil applications of imazethapyr generally provided yields and net returns

Table 5. Influence of herbicide systems on peanut yield.[a]

Herbicide system	Rate	Peanut yield: Method of imazethapyr application PPI	PRE	GC	POT
	(kg ha^{-1})	(kg ha^{-1})			
Imazethapyr	0.036	3950	3610	3650	3210
Imazethapyr	0.071	4240	3510	3600	3390
Imazethapyr	0.105	4150	4460	3790	3520
Additional treatments					
Imazethapyr	0.036 +	3720			
(PPI + GC)	0.036				
Imazethapyr	0.036 +	4700			
(PPI + GC)	0.071				
Imazethapyr	0.036 +	4080			
(PPI + GC)	0.105				
Metolachlor (PRE)	2.2,	4300			
acifluorfen (POT)	0.28 +				
+ bentazon (POT)	0.56				
Pendimethalin (PPI)	1.12	3260			
Weed-free		4080			
Weedy check		1520			
Statistical analyses					
LSD (Application method)			490		
LSD (Rate)			560		
LSD (Any two means)			720		

[a]All treatments except the weedy and weed-free check received an application of pendimethalin PPI at 1.12 kg ha^{-1}.

Table 6. Influence of herbicide systems on net returns.[a]

Herbicide system	Rate	Net returns: Method of imazethapyr application PPI	PRE	GC	POT
	(kg ha^{-1})	(\$ ha^{-1})			
Imazethapyr	0.036	889	701	425	485
Imazethapyr	0.071	1163	718	784	572
Imazethapyr	0.105	1071	1284	832	654
Additional treatments					
Imazethapyr	0.036 +	850			
(PPI + GC)	0.036				
Imazethapyr	0.036 +	1425			
(PPI + GC)	0.071				
Imazethapyr	0.036 +	966			
(PPI + GC)	0.105				
Metolachlor (PRE)	2.2,	1253			
acifluorfen (POT)	0.28 +				
+ bentazon (POT)	0.56				
Pendimethalin (PPI)	1.12	484			
Weed-free		-			
Weedy check		-602			
Statistical analyses					
LSD (Application method)			240		
LSD (Rate)			265		
LSD (Any two means)			270		

[a]All treatments except the weedy and weed-free check received an application of pendimethalin PPI at 1.12 kg ha^{-1}.

equivalent to the current standard. Imazethapyr will provide Virginia peanut producers with a cost-effective soil applied herbicide that may reduce reliance upon postemergence applied herbicides for annual broadleaf weed control.

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