Imidazolinone Herbicide Effects on Rotational Crops Following Peanut (*Arachis hypogaea* L.) in South Texas

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ABSTRACT

The effect of imazapic and imazethapyr on crops that may be rotated with peanut were studied in the field at three south Texas locations. Corn, cotton, grain sorghum, watermelon, potato, and sesame were planted the year following imazapic and imazethapyr POST application to peanut. Plant dry matter weights indicated cotton was most sensitive to a rotational program with imazapic in peanut. Dry matter weights with other crops were variable.

KEYWORDS: groundnut, Cadre, Pursuit

Imazethapyr (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-7l]-5-ethyl-3-pyridinecarboxylic acid) and imazapic (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-methyl-3-pyrindinecarboxylic acid] are two imidazolinone herbicides cleared for use in peanut (*Arachis hypogaea* L.). Imazethapyr may be applied preplant incorporated (PPI), preemergence (PRE), ground cracking (GC), or postemergence (POST) for effective weed control (Wilcut et al., 1995). Imazethapyr applied PPI or PRE controls many troublesome weeds such as coffee senna (*Cassia occidentalis* L.), common lambsquarters (*Chenopodium album* L.), morningglory species (*Ipomoea* spp.), pigweed species (*Amaranthus* spp.) including Palmer amaranth (*Amaranthus palmeri* S. Wats.), prickly sida (*Sida spinosa* L.), purple and yellow nutsedge *Cyperus rotundus* L. and *C. esculentus* L., respectively), spurred anoda (*Anoda cristata* (L.) Schlecht.), and wild poinsettia (*Euphorbia heterophylla* L.) (Cole et al., 1989; Wilcut et al., 1991 a,b; Grichar et al., 1992; York et al., 1995).

Imazethapyr applied POST provides the broadest spectrum and most consistent control when applied within 10 days of weed emergence (Wilcut et al., 1991a, 1994a,b). Imazethapyr and imazapic are the only POST herbicides to control both yellow and purple nutsedge (Grichar et al., 1992; Richburg et al., 1993). Control is most effective when imazethapyr is applied to the soil or yellow nutsedge that is no more than 2 to 4 in tall (Richburg et al., 1993; Wilcut et al., 1994c; Wilcut et al., 1995).

Imazapic was cleared for use in peanut in the spring of 1996. It has shown outstanding activity on a number of weed species (Nester and Grichar, 1993; Grichar et al., 1994; Wilcut et al., 1993b, 1994b, 1995). Imazapic is similar to imazethapyr and controls all the weeds controlled by imazethapyr. In addition, imazapic controls two extremely common and troublesome weeds, Florida beggarweed (*Desmodium tortuosum* (S.W.) D.C.) and sicklepod (*Senna obtusifolia* (L.) Irwin & Barneby), which are not adequately controlled by imazethapyr. Whereas imazethapyr provides consistent control of many broadleaf and sedge species if applied within 10 days after emergence, imazapic has a longer time period for effectiveness of POST applications (Wilcut et al., 1993, 1995; Richburg et al., 1994, 1996). Imazapic also is effective for control of rhizome and seedling johnsongrass (*Sorghum halepense* (L.) Pers.), Texas panicum (*Panicum texanum* Buckl.), large crabgrass (*Digitaria sanguinalis* (L.) Scop.), southern crabgrass (*Digitaria ciliaris* (Retz.)Koel.), and broadleaf signalgrass *(Brachiaria platyphylla* (Griseb.)Nash) (Wilcut et al., 1993).

Both imazethapyr and imazapic persist in soil and can damage rotational crops. Monks and Banks (1991) observed slight corn (*Zea mays* L.) injury and severe cotton (*Gossypium hirsutum* L.) injury from imazaquin (another imidazolinone herbicide) applied to soybean (*Glycine max* (L.) Merr.) the previous year. Renner et al. (1988) observed significant corn injury from imazaquin applied the previous year in one of two years. No imazaquin injury to rice was observed in soybean-rice rotational studies by Helms et al. (1989). Imazethapyr has been observed to injury corn slightly (Mills and Witt, 1989). Johnson et al. (1992) reported slight but significant injury to rice (*Oryza sativa* L.) from imazethapyr applied the previous year to soybean. Rotational crops such as sugarbeet (*Beta vulgaris* L.), canola (*Brassica napus* L.), cauliflower (*Brassica oleracea* L.), broccoli (*Brassica oleracea* L.), and lettuce (*Lactuca sativa* L.) can also be damaged when planted following imazethapyr application (Fellows et al., 1990; Miller and Alley, 1987; Tickes and Umeda, 1991).

The persistence of imidazolinones in soil is influenced by degree of adsorption to soil, soil moisture content, temperature, and amount of exposure to sunlight (Allen and Casely, 1987; Malik et al., 1988; Manges, 1991). The degree of absorption to soil increases as organic matter content increases and pH decreases (Che et al., 1992; Loux et al., 1989). As the primary mode of decomposition is by microbial degradation, dissipation is most rapid in soils with temperatures and moisture contents that favor microbial activity (Goetz et al., 1990; Loux and Reese, 1992). Photodecomposition accounts for a small amount of imidazolinone degradation when the herbicide is on the soil surface but rainfall or incorporation remove the herbicide from exposure to light (Curran et al, 1992; Goetz et al., 1990).

Above pH 4.0 the carboxyl groups on imazethapyr dissociate, and adsorption of the resulting herbicide anion is negligible (Mangels, 1991). However, in the presence of clay at pH 5.0, fluorescence emission spectra indicate imazethapyr is adsorbed in the neutral form (Che et al., 1992). At pH 8.0, only the ionized form was observed even in the presence of clay. Increased adsorption and persistence were observed as soil pH dropped from 6.5 to 4.5 (Loux and Reese, 1992). Injury to crops seeded following imidazolinone herbicide use also increased as soil pH decreased from 7.7 to 6.0 (Fellows et al., 1990), indicating that increased adsorption, at pH 6.0, did not protect crops from imidazolinone herbicide residues.

Most of peanut soils of south Texas have a pH of 6.5 to 7.5 and organic matter contents of $\leq$ 1.5%. Therefore, in south Texas soils, imidazolinone herbicides are readily available for microbial degradation. Since these soils are low in organic matter and pH is near neutral, little of the imidazolinone herbicide should be absorbed on soil particles. Crops with low tolerance to the imidazolinone herbicides such as potatoes (*Solanum tubersum* L.) and cotton are grown in rotation with peanut in many areas where imazethapyr or imazapic are used.

Few studies could be found describing the effects of imazapic soil residues to rotational crops. Wixson and Shaw (1992) planted corn, grain sorghum [*Sorghum bicolor* (L.) Moench], cotton, rice, wheat (*Triticum aestivum* L.), and Italian ryegrass (*Lolium multiflorum* Lam.) directly into treated soil in the field after imazapic was incorporated.

Table 1. Schedule of events for rotational studies at each location.

Event	Location		
	Pearsall	Yoakum	Waller
Pendimethalin applied	April 19, 1995	June 20, 1995	June 15, 1995
Peanut planted	April 19, 1995	June 20, 1995	June 16, 1995
Variety	GK-7	GK-7	Tamspan 90
Imazethapyr/imazapic applied	May 9, 1995	July 10, 1995	July 20, 1995
Peanut dug	Sept 17, 1995	Oct 11, 1995	Oct 18, 1995
Corn planted	Feb 19, 1996	April 2, 1996	April 2, 1996
Melons planted	April 18, 1996	April 22, 1996	April 22, 1996
Cotton planted	April 18, 1996	April 22, 1996	April 22, 1996
Milo planted	March 26, 1996	April 2, 1996	April 2, 1996
Sesame planted	April 18, 1996	April 22, 1996	April 22, 1996
Potatoes planted	Feb 19, 1996	April 2, 1996	April 2, 1996
Corn harvested	April 18, 1996	May 21, 1996	May 24, 1996
Cotton harvested	—	June 14, 1996	—
Melons harvested	—	June 14, 1996	—
Milo harvested	May 23, 1996	May 21, 1996	May 24, 1996
Sesame harvested	—	June 14, 1996	—
Potatoes harvested	May 18, 1996	—	May 24, 1996
Soil type	Duval loamy fine sand	Tremona loamy fine sand	Katy fine sandy loam
% Organic matter	< 1%	< 1%	< 1%
pH	7.1	6.4	7.8

Imazapic rates of 0.055 lb/A did not reduce shoot weight or emergence of any of the species, but 20% or less visual injury was observed for all crops 28 d after planting. Grimes et al. (1995) felt that imazapic injury to rice grown in rotation with soybean may be reduced by implementing a later rice planting date. They felt the later date allowed time for more herbicide degradation in the soil. Herbicide metabolism by the rice plant may also be greater at the later planting date due to warmer temperatures (Grimes et al., 1995).

MATERIALS AND METHODS

In 1995 and 1996, studies were conducted at three locations in South Texas to determine the effect of imazethapyr or imazapic applied POST on peanut (*Arachis hypogaea* L.) to crops planted the following year. These studies were conducted near Pearsall in Frio County, near Yoakum in Lavaca County, and near Waller in Waller County. These locations represent three different average rainfall amounts. The average annual rainfall for Waller County is approximately 45 in while the Frio County average is approximately 28 in. The average for Lavaca County is intermediate at 38 in.

A schedule of operations and specifics about the test area are included in Table 1. Land preparation procedures followed those commonly practiced by south Texas peanut producers. This includes discing the area, flatbreaking, and then bedding the soil, prior to application of a herbicide. Prior to planting of peanuts, pendimethalin [*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] at 1.0 lb/A was applied and incorporated 2 in deep with tractor-driven power tiller to control Texas panicum (*Panicum texanum* L.), Palmer amaranth (*Amaranthus palmari* S. Wats.), and southern crabgrass [*Digitaria ciliaris* (Retz.) Koel].

The soil type at Pearsall was a Duval loamy fine sand (fine-loamy, mixed, hyperthermic Aridic Haplustalfs), at Yoakum the soil was a Tremona loamy fine sand (thermic Aquic Arenic Palenstalfs), and at Waller the soil was a Katy fine sandy loam (Udalf Paleudalf).

Peanuts were planted immediately after the incorporation of pendimethalin. 'GK-7' variety was planted at Pearsall and Yoakum while 'Tamspan 90' was planted at Waller. Seeding rate for 'GK-7' was 90 lb/A while for 'Tamspan 90' the seeding rates was 70 lb/A.

Plot size at each location was 8 rows spaced 36 in apart and 100 ft long. The larger plot size was to prevent herbicide contamination in adjacent plots by any soil movement with various farm implements. The follow crops were planted parallel in these plots in the middle 4 rows in a 33 ft length. All harvest data were taken from these 4 rows. The experimental design for all studies was a randomized complete block with four replications. Supplemental irrigation was applied as needed to peanut and any follow crop.

POST treatments were applied 20 days after planting (DAP)[1] at Pearsall and Yoakum and 35 DAP at Waller. Treatments included an untreated check, imazethapyr applied at 0.063 lb/A, and imazapic applied at 0.035, 0.063, and 0.13 lb/A. A nonionic surfactant[2], at a rate of 0.25% v/v, was added to each treatment. Treatments were applied in water at 20 gal/A at 26 psi with a compressed-air bicycle sprayer.

Peanuts were harvested in the fall and the test area was allowed to lay fallow until the following spring when follow crops were planted. However, at the Pearsall location, the producer disked the test area twice in December prior to leaving fallow until the spring. Prior to planting of follow crops the land was prepared with a disk and field cultivator operated at a 2.5 in depth.

Corn 'Yellow Dent', cotton 'DP-50', melons 'Black Diamond', milo 'DK-54', sesame 'S-17', and potatoes 'Red La Soya' were planted parallel to the previous year's treatment. Corn, cotton, milo, and sesame were planted with the appropriate seed drill while melons and potatoes were seeded by hand. Melons were planted 36 in apart while potatoes were planted 12 in apart.

Each crop was harvested by cutting the stem at the ground line and green matter was forced air dried at 160°F for 96 h. The follow crops were not carried to yield because of problems with water management on a small scale throughout the growing season and also the authors felt that the initial growth would show any carryover effects with the imidazolinone herbicides. Also only limited space was available at each location to observe the numerous follow crops effects and weeds would become a problem in follow crops if the different crops were allowed to grow to maturity.

Corn was harvested 58 DAP at Pearsall, 49 DAP at Yoakum, and 52 DAP at Waller. Cotton was harvested 53 DAP at Yoakum, but was not harvested at Pearsall because of high number of Palmer amaranth which emerged about the same time as cotton and prevented any cotton growth or at Waller because of poor soil moisture after planting

[1]Abbreviations: DAP, days after planting.

[2]X-77 Valent USA Corp., 1333 N. California Blvd., Walnut Creek, CA 94596-8025. Nonionic surfactant with 80% principal functioning agents as: alklarylpolyoxy ethylene glycols, free fatty acids, and isopropanol.

Table 2. Biomass yields of crops seeded one year after imazapic and imazethapyr at Pearsall.

Herbicide	Rate	Follow crop		
		Corn	Potatoes	Grain sorghum
	lb ai/A	g/ft^2		
Check	—	63	76	242
Imazapic	0.063	65	64	227
Imazapic	0.032	55	68	255
Imazapic	0.063	64	86	206
Imazapic	0.124	55	60	248
LSD (0.05)		NS	NS	NS

which resulted in sporadic plant stands. Melons were harvested 53 DAP at Yoakum and 33 DAP at Waller. Melons were not harvested at Pearsall because of difficulty in obtaining plant stands due to Palmer amaranth (*Amaranthus palmeri*) competition. Grain sorghum was harvested 58 DAP at Pearsall, 49 DAP at Yoakum, and 52 DAP at Waller. Sesame was not harvested at Pearsall or Waller because of difficulty in obtaining plant stands. Potatoes were harvested 88 DAP at Pearsall and 52 DAP at Waller. Potatoes were not harvested at Yoakum because of blowing sands which resulted in poor potato growth. The spring of 1996 was not only dry but will be remembered as having above normal winds which moved soil in some areas.

Dry weight yield data from each crop were analyzed separately for each site. Variation due to differences of environmental conditions at each site prevented the combining of data. Differences between herbicide treatments and the untreated check were separated using Fisher's Protected LSD Test at the 0.05 level of significance.

RESULTS AND DISCUSSION

Pearsall Location

Corn, potatoes, and grain sorghum vegetative growth yields were not reduced with either imazapic or imazethapyr, although there were trends toward reduced potato growth with the 0.13 lb/A (2X) rate of imazapic (Table 2). Mayer and Esau (1996) reported, in southern Alberta, potato yields from imazethapyr treated plots were significantly reduced by imazethapyr. They also noted that potato tubers in imazethapyr treated plots had many growth cracks that reduced marketable yields. Two years after application, imazethapyr did not reduce potato yields (Mayer and Esau, 1996). Southern Alberta, in contrast to south Texas, have short summers, mean temperatures above 50°F for only May to September and a mean annual rainfall of 10.7 in (Grace and Hobbs 1986) which limit microbial decomposition.

Imazapic also did not affect dry weight of corn or grain sorghum. In contrast other research has found imazaquin {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-71]-3-guinolinecarboxylic acid} and imazethapyr residues injured corn (Renner et al 1988a, 1988b). However, Wixson and Shaw (1992) reported in studies in Mississippi that visual injury (striped leaves, shortening of internodia, and reduction in plant height)

Table 3. Biomass yields of crops seeded one year after imazapic and imazethapyr at Waller.

Herbicide	Rate	Follow crop			
		Corn	Grain sorghum	Potato	Melons
	lb ai/A	g/ft^2			
Check	—	405	332	104	46
Imazethapyr	0.063	486	432	157	67
Imazapic	0.032	352	462	141	34
Imazapic	0.063	415	408	172	24
Imazapic	0.124	328	328	108	28
LSD (0.05)		NS	NS	NS	NS

symptoms were observed on corn and grain sorghum with imazapic but was not reflected in a reduction of biomass.

Waller Location

Although not significant, corn and melons exhibited trends toward reduced growth following imazapic (Table 3). Imazapic at 0.063 lb/A treated plots produced corn dry weight yields comparable with the untreated check while increasing the rate of imazapic reduced melon growth. Renner et al. (1988a, 1988b) found that corn was injured by both imazaquin and imazethapyr at 10.5g ai/A. Imazapic controls burgherkin (*Cucumis anguria* L.) and citronmellon [*Citrullus lanatus* var. *citroides* (Bailey) Mansf.] (authors personal observation). Since melon is a close relative of these two weed species it is not surprising that some reduced growth was noted following imazapic application.

Grain sorghum and potato dry weights were not affected by imazapic (Table 3). This grain sorghum data agrees with results from Mississippi (Wixson and Shaw 1992). Similarly, imazaquin at rates of up to 227g/A did not reduce emergence of grain sorghum (Basham et al. 1987). However, as the rate of imazapic increased grain sorghum injury increased (Wixson and Shaw 1992).

Yoakum Location

Corn, grain sorghum, melon, and sesame plant dry weights were not affected by imazapic. However, there were trends to reduced plant growth when corn or grain sorghum following imazapic applications to peanut (Table 4.) Sesame emergence and growth have been affected by imazapic and imazethapyr application on a heavier soil type with higher organic matter (authors personal observation). Loux et al (1989) observed low herbicide dissipation rates of imazaquin, imazethapyr, and clomazone {2-[(2-chlorophenl)-methyl]-4,4-dimethyl-3-isoxazolidinone} in a soil with high organic matter. Miller and Allen (1987) noted that alfalfa (*Medicago sativa* L.), pinto bean (*Phaseolus vulgaris* L.), corn, and sunflower (*Helianthus annus* L.) were not injured and stands were not reduced when these crops were planted into areas which had been treated the previous fall with imazapic.

Cotton dry matter yields were significantly reduced with imazethapyr and imazapic. York and Wilcut (1995) expressed a concern about imazethapyr and imazapic carryover

Table 4. Biomass yields of crops seeded one year after imazameth and imazethapyr at Yoakum.

		Follow crop				
Herbicide	Rate	Cotton	Sesame	Corn	Melons	Grain sorghum
	lb ai/A	g/ft²				
Check	—	61	22	330	60	197
Imazethapyr	0.063	29	32	229	56	147
Imazapic	0.032	42	19	316	118	156
Imazapic	0.063	22	23	186	80	118
Imazapic	0.124	—	29	200	105	164
LSD (0.05)		29	NS	NS	37	NS

Table 5. Rainfall received from POST imidazolinone application until follow crop harvest.

	Location		
Time[a]	Pearsall	Yoakum	Waller
30 D	3.0	3.4	3.5
60 D	2.2	5.1	5.4
90 D	1.1	4.3	4.2
120 D	1.5	0.3	1.2
150 D	3.1	1.1	3.6
180 D	1.8	2.1	3.6
210 D	2.8	0.2	0.2
240 D	0.8	2.1	1.8
270 D	0	0.7	0.4
300 D	0	2.7	2.2
330 D	0.6	4.0	3.9
TOTAL	16.9	26.0	30.0

[a]Days after POST application of imazethapyr or imazapic.

to cotton following a peanut rotation. Wixson and Shaw (1992) noted that imazapic did not reduce the emergence of cotton but did cause visual injury symptoms. They concluded that cotton tolerated imazapic at up to 0.055 lb/A in the field.

Since imazapic is used only as a POST herbicide it may be less phytotoxic to rotational crops. Imazaquin applied POST is much less phytotoxic to rotational crops than when incorporated into the soil due to increased dissipation (Renner et al. 1988a).

The amount of rainfall and/or irrigation may have influenced persistence of imazapic in the soil. Microbial degradation of these herbicides tends to increase as soil moisture increases (Goetz et al. 1990). However, at each of the three locations, rainfall following imidazolinone application was approximately 40% below the yearly average (Table 5).

Warm temperatures (Table 6) in the south Texas area may have played a role in lack of rotational crop injury. Cooler temperatures have been shown to decrease the metabolism rate (two-fold decrease per 41°F temperature decrease) of imazethapyr applied POST to soybean (Malefyte and Quakenbush 1991). Grimes et al (1995) noted in a study with rice (*Oryza sativa* L.) following imazapic in soybeans that earlier planted rice showed more injury from imazapic than the later planting. They concluded that rice emergence

Table 6. Average monthly air temperatures at Waller, Yoakum, Pearsall following imidazolinone POST applications.

	Location		
Time	Yoakum	Waller	Pearsall °F
30 D	79	81	82
60 D	84	85	86
90 D	83	85	86
120 D	80	82	81
150 D	71	70	73
180 D	62	61	61
210 D	56	57	54
240 D	52	52	53
270 D	57	59	58
300 D	56	58	58
330 D	69	69	70

was slower under cooler temperatures which resulted in more emerging plant exposure to the herbicide in the soil.

These studies indicate that cotton was the most sensitive crop to the use of imazapic in a peanut rotation program. This agrees with work in Virginia-Carolina are (York and Wilcut, 1995). However, Wixson and Shaw (1992) in Mississippi reported cotton tolerated imazapic up to 0.055 lb/A. Corn, melon, and potato sensitivity to imazapic varied from location to location. In central and west Texas when temperatures are cooler, the use of imazapic in peanuts may create more of a problem with rotation due to reduced microbial breakdown of the herbicide.

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