Cotton Response to Imazapic and Imazethapyr Residues Following Peanut

W. James Grichar
Brent A. Besler
Texas Agricultural Experiment Station, Beeville, TX 78102
Todd A. Baughman
Texas Cooperative Extension, Vernon, TX 76384
Peter A. Dotray
Texas Agricultural Experiment Station, Lubbock, TX 79403
Robert G. Lemon
Scott A. Senseman
Texas Agricultural Experiment Station, College Station, TX 77843

ABSTRACT

Field studies were conducted at Denver City, Munday, and Yoakum (Gaines, Knox, and Lavaca Counties, respectively) to simulate residual concentrations of imazapic and imazethapyr in the soil and subsequent effects on cotton (*Gossypium hirsutum* L.). Simulated imazapic or imazethapyr rates included 1/64X, 1/32X, 1/16X, 1/8X, 1/4X, and 1/2X of the full labeled rate for peanut (*Arachis hypogaea* L.) and incorporated prior to cotton planting. Cotton stunting with imazapic or imazethapyr was more severe at Denver City than other locations. All rates of imazapic and imazethapyr resulted in cotton stunting at Denver City while at Munday and Yoakum the 1/8X, 1/4X, and 1/2X rates of imazapic resulted in reduced cotton growth when compared with the untreated check. At all locations imazapic caused more cotton stunt than imazethapyr. Cotton lint yield was reduced by imazapic or imazethapyr at 1/4 X and 1/2 X rates when compared with the untreated check at all locations.

KEYWORDS: Carryover, cotton height, imidazolinone, lint yield, plant emergence, stunting

Pursuit (imazethapyr) and Cadre (imazapic) are imidazolinone herbicides registered for use in peanut. In most peanut growing regions, imazethapyr may be applied preplant incorporated (PPI), preemergence (PRE), ground cracking (GC), or postemergence (POST) for effective weed control (Wilcut et al. 1995). However, in west Texas, imazethapyr can be applied only after stand establishment. 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. 1991a, b, Grichar et al. 1992, York et al. 1995).

This research was supported by grants from the National Peanut Board administered by The Texas Peanut Producers Board.

Imazapic is applied POST and controls all the weeds controlled by imazethapyr (Nester and Grichar 1993, Grichar et al. 1994, Wilcut et al. 1993, 1994b, 1995). In addition, imazapic provides control and suppression of Florida beggarweed [*Desmodium tortuosum* (S.W.) D.C.] and sicklepod [*Senna* obtusifolia (L.) Irwin & Barneby), which are not adequately controlled by imazethapyr (Grey et al. 2001). Imazethapyr provides consistent control of many broadleaf and sedge species if applied within 10 d after emergence, but imazapic has a longer effectiveness period when applied POST (Wilcut et al. 1993, 1995, Richburg et al. 1993, 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).

In crop rotations, imidazolinone herbicides must be used cautiously. Monks and Banks (1991) observed slight corn (*Zea mays* L.) injury and severe cotton 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. In Arkansas, cotton yield was reduced 7 to 42% as the soil concentration of imazaquin increased from 0.16 to 0.54 oz product/A (Barnes et al. 1989). Imazethapyr has been observed to moderately injure corn (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 (*Lacfuca sativa* L.) can also be damaged when planted following imazethapyr (Fellows et al. 1990, Miller and Alley 1987, Tickes and Umeda 1991).

Previous research on imazapic carryover has shown varying results. In North Carolina, imazapic applied PPI at 0.72 oz product/A reduced cotton yield 43% the following year while imazapic at the same rate applied at GC caused 20% injury but no yield reduction (York and Wilcut 1995). In Georgia, imazapic at 0.72 oz product/A reduced cotton yield an average of 34% the following year regardless of application method (York and Wilcut 1995).

A Mississippi study indicated no reduction in shoot weight when corn, grain sorghum [*Sorghum bicolor* (L.) Moench], cotton, rice, wheat (*Triticum aestivum* L.), soybean, and Italian ryegrass (*Lolium multiflorum* L.) were planted directly into soil treated and incorporated with imazapic at rates up to 0.72 oz productA (Wixson and Shaw 1992). In that study, all crops were more sensitive in the greenhouse with rates of 0.24 oz product/A reducing corn and grain sorghum shoot weights. However, cotton, rice, and wheat tolerated rates of 0.4 to 0.8 oz product/A. Grymes et al. (1995) reported that imazapic at 1.44 oz product/A or imazapic plus imazethapyr each at 0.72 oz product/A reduced rice yield the year following application. Grymes 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 hypothesized that 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 (Grymes et al. 1995).

The persistence of the imidazolinones in soil is influenced by the degree of adsorption to soil, soil moisture content, temperature, and amount of exposure to sunlight (Allen and Casely 1987, Malik et al. 1988, Mangels 1991). The degree of soil adsorption increases as organic matter content increases and pH decreases (Che et al. 1992, Loux et al. 1989). The primary mode of decomposition is by microbial degradation. Dissipation is most rapid in soils with

This research was supported by grants from the National Peanut Board administered by The Texas Peanut Producers Board.

temperatures and moisture contents that favor microbial activity (Goetz et al. 1990, Loux and Reese 1993). 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 soil 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 absorbed 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 the 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). This indicated that increased adsorption did not protect crops from imidazolinone herbicide residue at pH 6.0.

Most peanut soils in south and central Texas have a pH of 6.5 to 7.5 and organic matter contents $\leq$ 1%. Therefore, in these soils, imidazolinone herbicides are readily available for microbial degradation. However, in the Texas High Plains, the pH may range from 7.0 to 8.5 resulting in reduced microbial degradation. With soils low in organic matter and near neutral pH, little of the imidazolinone herbicide should be absorbed on soil particles. Crops with low tolerance to the imidazolinone herbicides such as cotton are grown in rotation with peanut in many areas where imazethapyr or imazapic may be used. Evaluating imazethapyr or imazapic at different locations will provide a more relevant understanding of the persistence issue. Therefore, the objective of this research was to evaluate cotton tolerance to imazethapyr and imazapic concentrations when planted at several locations in the peanut growing areas of Texas.

MATERIALS AND METHODS

Field studies were conducted at Knox County (Munday), Lavaca County (Yoakum), and Gaines County (Denver City) in Texas during the 2000 and 2001 growing seasons. In 2000, only imazapic was evaluated while in 2001 imazapic and imazethapyr were evaluated. Where both herbicides were evaluated, the experimental design was a randomized complete block with a factorial arrangement of treatments with four replications. Factors included imazapic and imazethapyr applied at 0, 0.0225 oz product/A (1/64X), 0.045 oz/A (1/32X), 0.09 oz/A (1/16X), 0.18 oz/A (1/8X), 0.36 oz/A (1/4X) and 0.72 oz/A (1/2X). The standard rate in peanut for both herbicides is 1.44 oz product/A (1X). Where only imazapic was evaluated, the experimental design was a randomized complete block with four replications. Cotton stunting was visually recorded 4 to 7 wk after planting (WAP) on a scale of 0 (no stunting or injury) to 100 (complete plant death). Cotton emergence counts were taken 3 to 6 wk after cotton was planted.

At Yoakum each plot contained two rows, 36 inches apart and 25 feet long. Imazapic and imazethapyr were applied within 24 h of cotton planting and incorporated 2 inches deep with a tractor-driven power tiller. Herbicides were applied in water with a compressed air bicycle sprayer, using Teejet 11002 (Spraying Systems Co., North Avenue and Schmale Rd., Wheaton, IL 60188) flat-fan nozzles which delivered a spray volume of 20GPA at 28 PSI.

At Denver City, herbicides were applied to flat ground, incorporated twice 4 inches deep using a tandem disk and bedder. Herbicides were applied 3 wk prior to planting with a tractor-mounted compressed-air spray using Teejet 8002 flat fan nozzles calibrated to deliver 15 GPA at 28 PSI.

At Munday, herbicides were applied immediately prior to cotton planting and

This research was supported by grants from the National Peanut Board administered by The Texas Peanut Producers Board.

incorporated twice, 1 to 2 inches deep using a rolling cultivator. Herbicides were applied in water with a CO_2 backpack sprayer using Teejet 8002 DG or 8004 VS flat fan nozzles calibrated to deliver 20 GPA at 25 PSI. Soil characteristics and other variables are shown in Table 1. All plots were maintained weed-free using standard herbicides recommended by The Texas Cooperative Extension.

Table 1. Cotton varieties, planting dates, and soil characteristics of each site.

	Yoakum		Denver City	Munday
Variables	2000	2001	2001	
Planting date	Apr 18	Apr 27	May 18	May 11
Soil texture	Sand	Sandy loam	Sandy loam	Sandy loam
Soil Name	Hallettsville	Hallettsville	Brownfield	Miles
pH	6.7	6.8	7.6	8.1
OM (%)	1.3	1.2	<1.0	0.1
Sand (%)	64	65	80	75
Silt (%)	18	18	2.5	16
Clay (%)	18	17	17.5	8
Cotton varieties	DP436RR	ST4793RR	PM1218BG/RR	PM1218BG/RR

Cotton was mechanically harvested at all locations except Yoakum where cotton was hand-picked. Harvest dates varied by location due to cotton maturity and weather conditions.

RESULTS AND DISCUSSION

Cotton emergence. At Yoakum none of the herbicides reduced plant numbers when compared with the untreated check (data not shown). Wixson and Shaw (1992) reported that imazapic did not reduce the emergence of cotton with rates up to 0.72 oz product/A on a silty clay soil with pH of 7.2 and 3.2% organic matter. Walsh et al. (1993) reported that imazethapyr at 1 to 2 oz product/A did not cause a loss of cotton stand.

Cotton stunting. There was a herbicide by rate interaction; therefore, data are presented individually by herbicide. Stunting with imazapic and/or imazethapyr was more severe at Denver City than the other locations (Table 2). All rates of imazapic and imazethapyr resulted in cotton stunting when compared with the untreated check. At Monday and Yoakum, the 1/8, 1/4, and 1/2X rates of imazapic resulted in reduced cotton growth when compared with the untreated check.

With imazethapyr, the 1/4 and 1/2 X rates reduced cotton growth at Yoakum while at Monday only the 1/2 X rate reduced cotton growth when compared with the untreated check (Table 2). Wixson and Shaw (1992) reported that in soils with a pH 7.2 and 3.2% organic matter, corn and cotton tolerated imazapic up to 0.72 oz product/A. Crop injury was observed with imazethapyr in both crops at rates from 0.12 to 0.36 oz product/A. The authors indicated that the injury noted with low rates of imazethapyr could be related to the increase of absorption of the imidazoline herbicides with increasing organic matter content.

Table 2. Cotton stunting as influenced by imazapic or imazethapyr.

This research was supported by grants from the National Peanut Board administered by The Texas Peanut Producers Board.

	Denver City[a]		Munday[b]		Yoakum[c]	
Herbicide rate[d]	Imazapic	Imazethapyr	Imazapic	Imazethapyr	Imazapic	Imazethapyr
	----------%----------					
0	0	0	0	0	0	0
1/64 X	14	8	0	0	8	0
1/32 X	48	17	3	3	0	0
1/16 X	81	60	4	1	10	0
1/8 X	84	70	8	1	20	9
1/4 X	98	89	23	6	50	32
1/2 X	100	100	48	16	70	33
LSD(0.05)	9		7		11	

[a] Injury ratings taken 5 weeks after planting (WAP).
[b] Injury ratings taken 7 WAP.
[c] Injury ratings taken 4 WAP.
[d] Labeled 1X rate of imazapic or imazethapyr on peanut is 1.44 oz product/A.

Cotton yield. There was no herbicide (imazapic and imazethapyr) by rate interaction; therefore, herbicides were combined over rates. At Yoakum in 2000, the 1/4 and 1/2X rate of imazapic reduced cotton yield when compared with the untreated check (Table 3). None of the other imazapic rates resulted in any cotton yield reduction.

In 2001, lint yields at Denver City were reduced by 1/8X, 1/4X, and 1/2X rates of imazethapyr or imazapic while at Munday and Yoakum cotton lint yields were reduced by the 1/4X and 1/2X rates when compared with the untreated check (Table 3). Previous research on imazapic carryover has shown varying results. In North Carolina, imazapic applied PPI to peanut at 0.72 oz product/A reduced cotton yield 43% the following year while the same rate applied at GC to peanut resulted in 20% injury but no yield reduction (York and Wilcut 1995). In Georgia, imazapic at 0.72 oz product/A reduced cotton yield an average of 34% the following year regardless of application timing (York and Wilcut 1995).

Table 3. Cotton lint yield as influenced by imazapic and imazethapyr rate.

	2000[a]	2001[b]		
Herbicide rate	Yoakum	DenverCity	Munday	Yoakum
	----------Lb/A----------			
0	460	980	1620	830
1/64 X	460	1050	1590	840
1/32 X	420	1000	1610	1050
1/16 X	440	810	1610	830
1/8 X	390	720	1590	800
1/4 X	260	300	1520	380
1/2 X	180	50	1400	210
LSD (0.05)	90	180	100	240

[a]Imazapic only.
[b]No herbicide (imazapic and imazethapyr) by rate interaction, therefore herbicides were combined over rate.

This research was supported by grants from the National Peanut Board administered by The Texas Peanut Producers Board.

CONCLUSION

Cotton stunting did not always result in reduced yield. However, when stunting was greater than 50% there was almost always a decrease in cotton yield when compared with the untreated check. This study reveals that by possibly knowing the level of imazapic or imazethapyr residual in the soil, producers could have some flexibility in crop rotations if sensitive crops such as cotton are to be planted following imidazolinone use on peanut.

REFERENCES

Allen, R. and J. C. Casely. 1987. The persistence and mobility of AC 222,293 in cropped and fallow land. Proc. Br. Crop Prot. Conf. pp. 569-576.

Barnes, C. J., A. J. Goetz, and T. L. Lavy. 1989. Effects of imazaquin residues on cotton (*Gossypium hirsutum*). Weed Sci. 37:820-824.

Che, M., M. M. Loux, S. J. Traina, and T. J. Logan. 1992. Effect of pH on sorption and desorption of imazaquin and imazethapyr on clays and humic acid. J. Environ. Qual. 21:698-703.

Cole, T. A., G. R. Wehtje, J. W. Wilcut, and T. V. Hicks. 1989. Behavior of imazethapyr in soybeans (*Glycine max*), peanuts (*Arachis hypogaea*), and selected weeds. Weed Sci. 37:639-644.

Curran, W. S., M. M. Loux, R. A. Liebl, and F. W. Simmons. 1992. Photolysis of imidazolinone herbicides in aqueous solutions and on soil. Weed Sci. 40:143-148.

Fellows, G. M., P. K. Kay, G. R. Carlson, and V. R. Stewart. 1990. Effect of AC 222,293 soil residues on rotational crops. Weed Technol. 4:48-51.

Goetz, A. J., T. L. Lavy, and E. E. Gbur. 1990. Degradation and field persistence of imazethapyr. Weed Sci. 38:421-428.

Grey, T. L., G. R. Wehtje, R. H. Walker, and K. P. Paudel. 1995. Comparison of imazethapyr and paraquat-based weed control systems in peanut. Weed Technol. 9:813-818.

Grey, T. L., D. C. Bridges, E. F. Eastin, E. P. Prostko, W. K. Vencil, W. C. Johnson, III, B. J. Brecke, G. E. MacDonald, J. A. Tredaway, J. W. Everest, G. R. Wehtje, and J. W. Wilcut. 2001. Residual weed control for peanut (*Arachis hypogaea*) with imazapic, diclosulam, flumioxazin, and sulfentrazone in Alabama, Georgia, and Florida: A multi-state and year summary. Proc. Amer. Peanut Res. And Educ. Soc. 33:19.

Grichar, W. J., P. R. Nester, and A. E. Colburn. 1992. Nutsedge (*Cyperus* spp.) control in peanuts (*Arachis hypogaea*) with imazethapyr. Weed Technol. 6:396-400.

Grichar, W. J., A. E. Colburn, and P. R. Nester. 1994. Weed control in Texas peanut with Cadre. Proc. Amer. Peanut Res. and Educ. Soc. 26:70.

Grymes, C. F., J. M. Chandler, and P. R. Nester. 1995. Response of soybean (*Glycine max*) and rice (*Oryza sativa*) in rotation to AC 263,222. Weed Technol. 9:504-511.

Johnson, D. H., R. E. Talbert, J. D. Beaty, C. B. Guy, and R. J. Smith. 1992. Rice response following imazaquin, imazethapyr, chlorimurion, and clomazone use. Proc. South. Weed Sci. Soc. 45:371.

Loux, M. M., R. A. Liebl, and F. W. Slife. 1989. Adsorption of imazaquin and imazethapyr on soils, sediments, and selected adsorbents. Weed Sci. 37:712-718.

Loux, M. M. and K. D. Reese. 1992. Effect of soil pH on absorption and persistence of imazaquin. Weed Sci. 40:490-496.

This research was supported by grants from the National Peanut Board administered by The Texas Peanut Producers Board.

Loux, M. M. and K. D. Reese. 1993. Effect of soil type and pH on persistence and carryover of imidazolinone herbicides. Weed Technol. 7:452-458.

Malik, N. D., E. Cole, A. L. Darwent, and J. R. Moyer. 1988. Imazethapyr (Pursuit) – a promising new herbicide for forage legumes. Forage Notes 32:42-45.

Mangels, G. 1991. Behavior of the imidazolinone herbicide in soil - A review of the literature. p. 191-209. *In* D. L. Shaner and S. L. O'Connor, eds. The Imidazolinone Herbicides. CRC Press, Boca Raton, FL.

Miller, S. D. and H. P. Alley. 1987. Weed control and rotational crop response with AC 222,293. Weed Technol. 1:29-33.

Mills, J. A. and W. W. Witt. 1989. Efficacy, phytotoxicity, and persistence of imazaquin, imazethapyr, and clomazone in no-till double-crop soybeans (*Glycine max*). Weed Sci. 37:353-359.

Monks, C. D. and P. A. Banks. 1991. Rotational crop response to chlorimuron, clomazone, and imazaquin applied the previous year. Weed Sci. 39:629-633.

Nester, P. R. and W. J. Grichar. 1993. Cadre combinations for broadleaf weeds control in peanut. Proc. South. Weed Sci. Soc. 46:317.

Renner, K. A., W. F. Meggitt, and D. Penner. 1988. Response of corn (*Zea mays*) cultivars to imazaquin. Weed Sci. 36:625-628.

Richburg, J. S., III, J. W. Wilcut, and G. R. Wehtje. 1993. Toxicity of foliar and/or soil applied AC 263,222 to purple (*Cyperus rotundus*) and yellow nutsedge (*C esculentus*). Weed Sci. 42:398-402.

Richburg, J. S., III, J. W. Wilcut, D. L. Colvin, and G. R. Wiley. 1996. Weed management in southeastern peanut (*Arachis hypogaea*) with AC 263,222. Weed Technol. 10:145-152.

Tickes, B. R. and K. Umeda. 1991. The effect of imazethapyr upon crops grown in rotation with alfalfa. Proc. Western Soc. Weed Sci. 44:97.

Walsh, J. D., M. S. Defelice, and B. D. Sims. 1993. Soybean (*Glycine max*) herbicide carryover to grain and fiber crops. Weed Technol. 7:625-632.

Wilcut, J. W., F. R. Walls, Jr., and D. N. Norton. 1991a. Imazethapyr for broadleaf weed control in peanuts (*Arachis hypogaea*). Peanut Sci. 18:26-30.

Wilcut, J. W., F. R. Walls, Jr., and D. N. Norton. 1991b. Weed control, yield, and net returns using imazethapyr in peanuts (*Arachis hypogaea*). Weed Sci. 39:238-242.

Wilcut, J. W., E. F. Eastin, J. S. Richburg, III, W. K. Vencill, F. R. Wells, and G. Wiley. 1993. Imidazolinone systems for southern weed management in resistant corn. Abstr. Weed Sci. Soc. Am. 33:5.

Wilcut, J. W., J. S. Richburg, III, E. F. Eastin, G. R. Wiley, F. R. Walls, Jr., and S. Newell. 1994a. Imazethapyr and paraquat systems for weed management in peanut (*Arachis hypogaea*). Weed Sci. 42:601-607.

Wilcut, J. W., J. S. Richburg, III, G. Wiley, F. R. Walls, Jr., S. R. Jones, and M. J. Iverson. 1994b. Imidazolinone herbicide systems for peanut (*Arachis hypogaea*). Peanut Sci. 21:23-28.

Wilcut, J. W., A. C. York, and G. R. Wehtje. 1994c. The control and interaction of weeds in peanut (*Arachis hypogaea*). Rev. Weed Sci. 6:177-205.

Wilcut, J. W., A. C. York, W. J. Grichar, and G. R. Wehtje. 1995. The biology and management of weeds in peanut (*Arachis hypogaea*). pp. 207-244. *In* H. E. Pattee and H. T. Stalker (eds). Advances in Peanut Science. Amer. Peanut Res. Educ. Soc., Inc., Stillwater, OK.

Wixson, M. B. and D. R. Shaw. 1992. Effects of soil-applied AC 263,222 on crops rotated

This research was supported by grants from the National Peanut Board administered by The Texas Peanut Producers Board.

with soybean (*Glycine max*). Weed Technol. 6:276-279.

York, A. C. and J. W. Wilcut. 1995. Potential for Cadre and Pursuit applied to peanuts to carryover to cotton in North Carolina and Georgia. Proc. Beltwide Cotton Conf. 1:602.

York, A. C., J. W. Wilcut, C. W. Swann, D. L. Jordan, and F. R. Walls, Jr. 1995. Efficacy of imazethapyr in peanut (*Arachis hypogaea*) as affected by time of application. Weed Sci. 43:107-116.

This research was supported by grants from the National Peanut Board administered by The Texas Peanut Producers Board.