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Oat (*Avena sativa*) Response to Imazapic Residues[1]

ERIC P. PROSTKO, TIMOTHY L. GREY, ROBERT N. MORGAN, and JERRY W. DAVIS[2]

Abstract: Three field trials were conducted in south Georgia under irrigated conditions in 2002/2003 and 2003/2004 to evaluate the effects of imazapic residues on oat growth and yield. Imazapic at 70 g ai/ha was applied during the first weeks of May, June, July, August, and September to bare soil. No additional tillage was performed after the herbicide application. Oats (cv. Coker 227) were planted the first week of October. Oat plant populations were not reduced by any timing of imazapic. Generally, oat plant heights and forage yields were reduced when imazapic was applied in August and September (1–2 mo before planting). Grain yields were not reduced by any timing of imazapic. Results of these tests suggest that the current 18-mo rotational restriction for oats following an application of imazapic could be reduced to 4 mo.

Nomenclature: Imazapic; oats, *Avena sativa* L. 'Coker 227'.

Additional index words: Carryover, crop rotations, herbicide persistence, imidazolinone, plant-back restrictions.

Abbreviations: DAP, days after planting.

INTRODUCTION

Imazapic is a postemergence herbicide registered for use in peanut (*Arachis hypogaea* L.) (Anonymous 2005a). Peanut tolerance to this herbicide is adequate, and imazapic provides excellent control of many common and troublesome weeds (Dotray and Keeling 1997; Dotray et al. 2001; Grichar and Nester 1997; Richburg et al. 1994, 1995a, 1995b, 1996; Webster et al. 1997; Wilcut et al. 1996). Since its introduction in 1996, imazapic has become one of the most popular herbicides used in peanut weed management systems. It has been estimated that in Georgia, approximately 64% of all hectares planted with peanut are treated with this herbicide (N. Smith, personal communication, 2004).

One problem that limits imazapic's use is its potential to injure rotational crops. In Texas, imazapic at 70 g/ha reduced rice (*Oryza sativa* L.) yield by 25% when applied the year before to soybean [*Glycine max* (L.) Merr.] (Grymes et al. 1995). In Georgia, imazapic at 35 g/ha reduced cotton (*Gossypium hirsutum* L.) yield an average of 34% the year after treatment regardless of application method (York and Wilcut 1995). In North Carolina, imazapic applied preplant incorporated at 140 g/ha in peanut delayed cotton maturity and reduced yield by 44% the following year (York et al. 2000). Field observations also suggest that certain vegetable crops such as watermelon (*Citrullus lanatus* L.) and cabbage (*Brassica oleracea* L.) are highly susceptible to imazapic residues (A. S. Culpepper, personal communication, 2004).

Oats are presently grown on 32,000 ha in Georgia (Anonymous 2005b). The current rotation restriction for planting oats following an application of imazapic is 18 mo. Other small grains, such as wheat (*Triticum aestivum* L.) and rye (*Secale cereal* L.), require only a 4-mo rotation interval (Anonymous 2005a). Because no information has been documented to support this discrepancy between the small grains, the objective of this research was to determine whether oats could be planted earlier than 18 mo after an application of imazapic.

MATERIALS AND METHODS

Field trials were conducted in 2002/2003 and 2003/2004 at the Ponder Research Station located near Tifton, GA, and in 2003/2004 at the Southwest Georgia Branch Experiment Station near Plains, GA. The soil type at the Ponder Research Station was a Tifton sand (fine-loamy, kaolinic, thermic Plinthic Kandiudults) with 96% sand, 2% silt, 2% clay, and 1.2% organic matter, pH 6.0. The soil type at the Southwest Experiment Station was a Greenville sandy loam (fine, kaolinitic, thermic Rhodic Kandiudults) with 71% sand, 13% silt, 16% clay, and <1% organic matter, pH 6.0.

Imazapic at 70 g ai/ha was applied the first weeks of

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[2] First through third authors: Associate Professor, Assistant Professor, and Former Assistant Professor, respectively, Department of Crop & Soil Sciences, The University of Georgia, P.O. Box 1209, Tifton, GA 31794; fourth author: Agricultural Research Statistician, University of Georgia, 1109 Experiment Street, Griffin, GA 30223. Corresponding author's E-mail: eprostko@uga.edu.

Table 1. Total rainfall plus irrigation amounts from May through September.

Month	Tifton 2002	Tifton 2003	Plains 2003
	cm		
May	10	10	15
June	7	18	12
July	18	23	14
August	13	15	15
September	14	14	9
Total	62	80	65
Average rainfall[a]	54	54	52

[a] Average rainfall for May through September for Tifton, 1912–2003; and Plains, 1956–2003.

May, June, July, August, and September to bare soil in 2-m by 8-m plots. The herbicide treatments were arranged in a randomized complete block design with four replications and were applied with a CO_2-powered backpack sprayer calibrated to deliver 140 L/ha at 207–276 kPa. After the herbicide was applied, no additional soil tillage operations were performed and the plots were maintained weed-free using multiple applications of glyphosate. Rainfall plus irrigation data for the months of May through September are listed in Table 1. During the first week of October, oats (cv. Coker 227) were no-till drilled in 20-cm rows at a seeding rate of 140 kg/ha. Oat fertilization, insect, and disease management decisions were made on the basis of local Cooperative Extension Service recommendations.

Subjective visual crop injury ratings were obtained using a scale of 0 = no injury to 100% = complete crop death. Visual injury symptoms from imazapic included a combination of crop stunting and loss of vigor. Oat plant populations were obtained 7 to 10 d after planting (DAP) by counting the number of emerged plants per meter of row. Oat plant heights were obtained before harvesting for either forage or grain. Forage yields were obtained in December and January using mechanical forage harvesting equipment but were combined for statistical analysis. Forage cutting height was 8 cm, and total forage yields were converted to kilograms of dry matter/hectare. Grain yields were obtained in May using mechanical harvesting equipment, and yields were adjusted to 12% moisture.

All data were analyzed using Statistical Analysis Systems Proc Mixed procedures in a randomized complete block (SAS 1999). Variables that had significant test by treatment interactions were subjected to a one-way analysis of treatment within each level of test. Imazapic timing of application and test location were considered fixed effects, while replication was considered a random effect. Mean separation for main effects and interactions were obtained by Fisher's LSD at $P > 0.05$.

RESULTS AND DISCUSSION

Visual Crop Injury Symptoms. Treatment by location interactions for visual injury ratings were significant, thus the data are presented by location (Table 2). At the Tifton location in 2002/2003, only the August and September timings of imazapic caused significant visual injury to oat at both rating dates. At the 28 DAP rating, the June timing also caused significant visual injury but was only 6%. At this same location in 2003/2004, only the September application of imazapic caused significant visual injury to oat. At the Plains location in 2003/2004, both the August and September timings of imazapic consistently caused significant crop injury symptoms. At this location, the September timing was more injurious than the August timing. It is interesting to note that in 2003/2004, injury symptoms from the August and September timings of imazapic were greater at the Plains location than at the Tifton location. The soil type at Plains has 14% more clay than the soil type at Tifton. In previous studies conducted with imazapic on similar

Table 2. Fall oat visual injury from imazapic applied to bare soil.[a]

Imazapic timing	Tifton 2002–2003[b] 28 DAP[c]	Tifton 2002–2003 62 DAP	Tifton 2003–2004 21 DAP	Tifton 2003–2004 55 DAP	Tifton 2003–2004 118 DAP	Plains 2003–2004 21 DAP	Plains 2003–2004 41 DAP	Plains 2003–2004 111 DAP
	%							
Nontreated	0 d	0 c	0 b	0 b	0 b	0 d	0 d	0 c
May	3 cd	0 c	0 b	0 b	0 b	0 d	0 d	0 c
June	6 abc	4 bc	0 b	3 b	0 b	0 d	0 d	0 c
July	4 bcd	5 bc	0 b	6 b	5 b	11 c	19 c	4 c
August	8 ab	9 ab	0 b	8 b	6 b	25 b	45 b	19 b
September	10 a	14 a	25 a	53 a	26 a	49 a	80 a	61 a

[a] Imazapic applied at 70 g ai/ha for each application timing. Means within a column followed by the same letter are not different according to Fisher's Protected LSD test at $P > 0.05$.

[b] Oats planted October 2, 2002, October 1, 2003, and October 2, 2003 for Tifton 2002–2003, Tifton 2003–2004, and Plains 2003–2004, respectively.

[c] Abbreviation: DAP, days after planting.

Table 3. Oat height response to imazapic applied to bare soil.[a]

Imazapic timing	Tifton 2002–2003[b] 28 DAP	Tifton 2002–2003[b] 62 DAP	Tifton 2003–2004 21 DAP	Tifton 2003–2004 118 DAP	Plains 2003–2004 21 DAP	Plains 2003–2004 111 DAP	Height at grain harvest[b]
	cm						
Nontreated	30 a	36 a	38 a	27 a	35 a	23 a	100 ab
May	32 a	39 a	40 a	28 a	40 a	25 a	96 bc
June	32 a	36 a	37 a	29 a	39 a	26 a	94 c
July	32 a	35 a	33 a	27 a	29 b	23 a	100 ab
August	29 a	37 a	37 a	30 a	21 c	14 b	100 a
September	27 a	33 a	24 b	22 b	13 d	12 b	98 ab

[a] Imazapic applied at 70 g ai/ha for each application timing. Oat height measured just prior to harvest. Means within a column followed by the same letter are not different according to Fisher's Protected LSD test at $P > 0.05$.

[b] Data were analyzed as a mixed model using PROC MIXED test at $P > 0.05$. Variables that had significant test by treatment interactions were subjected to a one-way analysis of treatment within each level of test. PROC MIXED analysis indicated no test by treatment interaction, so data were combined for presentation.

[c] Abbreviation: DAP, days after planting.

soil types, cotton injury was greater on the heavier soil at the Plains location (Grey et al. 2005). It has also been demonstrated that imazaquin and imazethapyr are more persistent in clay soils than in silt loam soils (Loux et al. 1989; Loux and Reese 1993).

Oat Plant Heights. Treatment by location interactions for oat plant heights before forage harvest were significant, so the data are presented separately by location (Table 3). At the Tifton location in 2002/2003, plant heights were not affected by any application of imazapic. At this same location in 2003/2004, plant heights were reduced by the September application of imazapic. At the Plains location in 2003/2004, both the August and September applications of imazapic consistently reduced oat height. When combined over locations, plant heights just before grain harvest were reduced only by the June application of imazapic. However, this height reduction was slight (6%) and probably of little practical significance.

Oat Plant Population and Yield. Treatment by location interactions were not significant for oat plant population and yield, thus the data were combined over locations (Table 4). Imazapic application timing did not affect oat stand. Total forage yields, combined over two harvest dates, were significantly reduced when imazapic was applied in August and September, approximately 1–2 mo before planting. Grain yields were not reduced by any application timing of imazapic. In previous studies, other grass crops such as wheat, rice, corn (*Zea mays* L.), and sorghum (*Sorghum bicolor* L.) were tolerant of imazapic residues (Matocha et al. 2003; Wixson and Shaw 1992).

Numerous degradation and transfer processes influence the persistence of herbicides in the soil. These include biological and abiotic decomposition, soil adsorption, leaching, volatility, runoff, removal by higher plants, and absorption/exudation by plants and animals (Monaco et al. 2002). It is our opinion that the tests described herein were conducted under optimum conditions or worst-case scenarios for inducing herbicide persistence or carryover (i.e., bare-soil applications, minimal soil disturbance after application, and no or limited plant uptake of residues before oat planting). Despite these conditions, the results of our studies suggest that

Table 4. Oat plant population and yield response to imazapic applied to bare soil.[a]

Imazapic timing	Population[b]	Forage yield December[b]	Forage yield January[b]	Forage yield Total[b]	Grain yield[b]
	plants/m of row	kg dry matter/ha			kg/ha
Nontreated	85 a	1,660 ab	890 ab	2,550 a	3,260 a
May	93 a	1,740 a	1,010 a	2,750 a	3,030 a
June	92 a	1,590 abc	950 a	2,540 a	2,940 a
July	88 a	1,380 bc	890 ab	2,270 ab	3,130 a
August	95 a	1,270 c	710 b	1,980 b	3,190 a
September	92 a	650 d	330 c	980 c	3,260 a

[a] Imazapic applied at 70 g ai/ha for each application timing. Data were analyzed as a mixed model using PROC MIXED test at $P > 0.05$. Variables that had significant test by treatment interactions were subjected to a one-way analysis of treatment within each level of test; means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test.

[b] PROC MIXED analysis indicated no test by treatment interaction, so data were combined for presentation.

the current rotation restriction of 18 mo for oats following an application of imazapic is too restrictive. These data indicate that the 4-mo rotation restriction presently registered for wheat and rye would be acceptable for oats.

It is important to note that these studies were conducted under irrigated conditions, and that rainfall plus irrigation totals exceeded the long-term rainfall averages (Table 1). Microbial degradation is the primary degradation mechanism of the imidazolinone herbicides and is favored by warm, moist soil conditions (Mangels 1991). Approximately 56% of hectares in Georgia planted with peanut are irrigated and receive an average of 20 cm supplemental irrigation (K. Harrison, personal communication, 2005). Consequently, the response of oats to imazapic residues under these conditions should be similar to these studies. However, in dry years and dryland fields, it is possible that oats may not respond as reported described herein.

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