Imazapic-Based Herbicide Systems for Peanut and Factors Affecting Activity on Florida Beggarweed

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ABSTRACT

Field studies were conducted over 3 yr to evaluate imazapic, applied either alone or combined with other commonly used herbicides for peanut weed control. Imazapic applied early postemergence alone at 71 g/ha provided excellent weed control, maximum yields, and optimum economic returns. Variations of this treatment—such as half rate of imazapic applied alone, tank mixed with other herbicides, or supplemented with other herbicides—frequently had equivalent weed control and yield. However, these variations did not improve economic return. Greenhouse studies evaluated Florida beggarweed control as influenced by weed age, imazapic rate, and application type. The three application types were foliage only, soil only, and soil plus foliage. Control was independent of application type when Florida beggarweed seedlings were less than 20 d old. The soil-only application did not adequately control older seedlings. Foliage-only and foliage plus soil application were equally effective. Averaged across all other factors, imazapic was less effective controlling seedlings older than 20 d. At this age, seedlings produced trifoliate rather than unifoliate leaves. Absorption of ^{14}C-imazapic by unifoliate and trifoliate leaves was equivalent. However, translocation was greater in unifoliate leaves. Reduced translocation by trifoliate foliage contributes to imazapic tolerance of older Florida beggarweed seedlings.

Key Words: Economic returns, herbicide absorption, herbicide translocation imazapic, weed control.

Paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) was first registered for peanut (*Arachis hypogaea* L.) in 1988. Paraquat can be broadcast applied between peanut emergence and 28 d later. It controls several broadleaf and grass species (Wehtje *et al.*, 1986). Tank mixing paraquat with other herbicides such as 2,4-DB [4-(2,4-dichlorophenoxy) butanoic acid] and/or bentazon [3-(1-methylethyl)-1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide] improves control of paraquat-tolerant species such as bristly starbur (*Acanthospermum hispidium* DC.), coffee senna (*Cassia occidentalis* L.), prickly sida (*Sida spinosa* L.), and smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb]. Furthermore, bentazon reduces paraquat-induced peanut injury since both paraquat and bentazon are mutally antagonistic toward foliar absorption. Paraquat tank mixed with 2,4-DB and/or bentazon is used extensively for peanut weed management (Wehtje *et al.*, 1992; Wilcut *et al.*, 1994b).

Imazethapyr {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid}, an imidiazolinone herbicide, was registered for peanut in 1991. Imazethapyr controls a diversity of weed species including bristly starbur, coffee senna, eclipta (*Eclipta prostrata* L.), prickly sida, and spurred anoda [*Anoda cristata* (L.) Schlecht] (Wilcut *et al.*, 1991a,b). Both yellow (*Cyperus esculentus* L.) and purple nutsedge (*C. rotundus* L.) are controlled by imazethapyr (Swann, 1993), however, control can be variable (Richburg *et al.*, 1993, 1994). Imazethapyr can be applied either preplant incorporated, preemergence, or postemergence (Wilcut *et al.*, 1991a,b; 1994a,b). Grey *et al.* (1995) reported that tank-mixed combinations of paraquat and imazethapyr applied early postemergence, followed by various other treatments, generally resulted in optimum net returns. Conversely, systems in which imazethapyr was applied alone generally had lower economic returns.

In 1996, imazapic {($\pm$)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imadazol-2-yl]-5-methyl-3-pyridine carboxylic acid} became the second member of the imidazolinone herbicide group to be registered in peanut. Imazapic is similar to imazethapyr with respect to species controlled and flexibility of application. However, relative to imazaethapyr, imazapic is more effective on Florida beggarweed [*Desmodium tortuosum* (SW.) DC] (Wilcut *et al.*, 1996) and control of both yellow and purple nutsedge is more consistent (Swann, 1994). Richburg *et al.* (1994) applied imazapic to yellow and purple nutsedge with selective soil only, foliar only, and/or foliar plus soil exposure. Control was excellent and independent of the application type, indicating that imazapic was absorbed by both foliage and roots of target weeds. Dotray and Keeling (1997) reported that imazapic was consistently more effective than imazethapyr when applied postemergence to progressively larger purple nutsedge.

Imazapic is currently the most costly herbicide registered in peanut. Imazapic at the recommended registered rate of 71 g/ha typically costs 68.40 \$/ha, excluding application cost. Comparable cost of paraquat is 6.90 \$/ha. Because combinations of imzaethapyr and paraquat were more effective than imazaethapyr alone (Grey *et al.*, 1995), tank mixing a reduced rate of imazapic with paraquat may provide an economical alternative to imazapic applied alone at the full registered rate. Wilcut *et al.* (1995) speculated that lower rates of imazapic applied in a tank mixture with paraquat and bentazon may be equally effective as full rates applied alone. The first objective of this study was to evaluate and compare performance and economic returns of weed control sys-

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tems utilizing imazapic applied either alone or in various combinations with paraquat and/or other herbicides.

Several of the published reports concerning Florida beggarweed control with imazapic have noted a lack of consistency across years and/or locations (Richburg *et al.*, 1995, 1996; Wilcut *et al.*, 1996). Differential rainfall was hypothesized as a possible explanation (Wilcut *et al.*, 1996). In addition, peanut producers have observed that imazapic looses efficacy as Florida beggarweed seedlings mature.

Given the inconsistent preformance of imazapic on Florida beggarweed, our second objective was to determine the relative importance of foliar versus root adsorption of imazapic by Florida beggarweed seedlings and to evaluate control as influenced by selective application and seedling age. The final objective was to compare the imazapic absorption/translocation between unifoliate and trifoliate leaves of Florida beggarweed using radiotracer techniques.

Materials and Methods

Field Studies. Field experiments were conducted over 3 yr (1995 to 1997) at the Wiregrass Substation of Auburn Univ., located at Headland, AL. Soil was a Dothan loamy sand (fine-loamy, siliceous, thermic Kandiudults) with 91% sand, 6% silt, 3% clay, 0.5% organic matter, and pH 6.5. Different test areas were used each year. Experimental sites were moldboard plowed and disked in the spring following a winter cover crop of rye (*Secale cereale* L.). Pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] was applied at 1.1 kg ai/ha preplant incorporated over entire test area 1 d before planting and incorporated to a depth of approximately 7 cm to control annual grasses which are generally not controlled by imazapic. Test areas were naturally infested with Florida beggarweed, sicklepod [*Senna obtusifolia* (L.) Irwin and Barneby], and bristly starbur which are common in southeastern Alabama. Peanut cv. Florunner was planted at 123 kg/ha on 20 April, 25 April, and 5 May during 1995, 1996, and 1997, respectively. Rows were spaced 91 cm apart. All other pest management decisions and cultural practices were in accordance with recommendations of the Alabama Coop. Ext. Serv. Individual plots were four rows wide and 6.1 m long. All treatments were applied either 1 or 3 mo after planting. These application timings are herein referred to as early postemergence (EPOST) and postemergence (POST), respectively. Florida beggarweed, sicklepod, and bristly starbur germinate throughout the growing season, usually in 'flushes' following rainfall and/or soil disturbance (Cardina and Hook, 1989). However, at 1 mo after planting the majority of the Florida beggarweed plants had approximately four unifoliate true leaves and did not exceed 10 cm in height. At 3 mo, Florida beggarweed plants had 12 to 15 trifoliate leaves and were approximately 35 cm in height. At 1 mo after planting the majority of the sicklepod and bristly starbur plants had two to five true leaves. Both weed species were slightly above the peanut canopy at 3 mo. Yellow nutsedge was approximately 4 and 10 cm in height at 1 and 3 mo after planting, respectively. All herbicide treatments were applied with a tractor-mounted compressed air sprayer equipped with flat fan nozzles discharging 140 L/ha.

Herbicide Treatments. EPOST treatment options consisted of (a) none, (b) paraquat at 0.14 kg ai/ha, (c) imazapic at 36 g/ha, (d) imazapic at 71 g/ha, (e) paraquat + imazapic (tank mixture) at 36 g/ha, and (f) paraquat + imazapic at 71 g/ha. POST treatment options were (a) none, (b) 2,4-DB at 0.60 kg ae/ha, (c) paraquat + 2,4-DB, and (d) paraquat + 2,4-DB + bentazon at 0.3 kg ai/ha. When herbicide combinations were used, they were applied as tank mixtures. All treatments included a nonionic surfactant [X-77, a mixture of alkylarypolyoxyethylene glycols, free fatty acids, and isopropanol (Loveland Industries Greeley, CO) at 0.25% (v/v). Individual treatments consisted of a factorial arrangement of the six EPOST and four POST treatment options. Experimental design was a randomized complete block with four replications.

Visual estimates of percent weed control were collected in late August on a scale of 0 to 100% which represented no control and complete control, respectively. The center two rows of all plots were harvested in early September using conventional peanut-harvesting machinery. Plot data on inputs and yield were evaluated using enterprise budgets developed by the Alabama Coop. Ext. Serv. for nonirrigated peanut production. This spreadsheet-based budget was modified to calculate income above variable costs on an individual plot basis. Herbicide prices were based upon quotes obtained from local dealers. Herbicide costs (excluding application cost) were imazapic (71 g/ha) $68.40/ha, paraquat $6.90/ha, bentazon $9.30/ha, and 2,4-DB $11.70/ha. Calculations of income above variable costs were based on the peanut crop marketed at a 3:1 ratio of quota to additionals, with an assumed valued of 700 and 350 $/ton, respectively. Grade, as determined from a composite sample of harvested peanuts, was consistent with grades from our area for each year that the test was conducted.

Data were subjected to analysis of variance and tested for year by treatment interactions. Data were pooled where appropriate and treatment means were separated by appropriate LSD values at the 0.05 level.

Greenhouse Studies. Experiments were conducted with approximate day and night temperatures of 32 and 24 C, respectively. Supplemental lighting was used to obtain a 16-hr photoperiod. Soil, which had been collected from the site of the field studies as described above, was air dried and sieved to a particle size of ≤ 5 mm. Florida beggarweed seed, collected from the field test site, were seeded into flats. Upon germination, seedlings were transplanted to 1000-mL styrofoam cups at a rate of four seedlings/cup. Seeding was repeated on a 10-d schedule to obtain plants with staggered ages at the time of treatment.

Treatments consisted of a factorial arrangement of five imazapic rates (18, 35, 54, 71, and 87 g/ha), four ages of Florida beggarweed (10, 20, 30, and 40 d old), and three types of application (soil only, foliar only, and soil plus foliar). The foliar only application was obtained by placing a 1-cm layer of charcoal on the soil surface 1 d prior to spraying. Charcoal was removed the day after herbicide application. Soil only application was obtained by calculating the amount of imazapic solution that would reach the soil surface based upon the surface area of the cup. This amount of herbicide spray solution was diluted into 10 mL of water and evenly pipetted onto the soil surface. Seedling height, number of nodes, and leaves (unifoliate and trifoliate) for each age grouping were noted prior to treatment. A moving-belt sprayer, calibrated to deliver 140 L/ha at 220 kPa was used to apply the foliar only and the foliar plus soil applications. Plants were not watered for 1 d after treatment, subsequently all treatments were surface watered to avoid foliage wetting on an as-needed basis.

A completely random experimental design with five single-cup replicates for each treatment was used. The entire experiment was repeated over time, and data were pooled since results did not vary. Data were subjected to an analysis of variance. Main effect and treatment means were separated by LSD ($P \leq 0.05$).

Absorption and Translocation. A solution was prepared that contained both formulated and ^{14}C-imazapic, with imazapic and radiation concentrations of 38 µg/mL and 800,000 dpm/mL, respectively. Resulting specific activity of imazapic was 2230 dpm/mM. Total imazapic concentration was equivalent to the spray solution in which imazapic was applied at 71 g/ha in the aforementioned greenhouse study.

This solution was applied as a single 5-mL drop to the youngest fully-expanded unifoliate leaf of a 20-d-old plant, or to the center leaflet of youngest fully-expanded trifoliate leaf of a 30-d-old plant. Lanolin was used to attach 3-mm-diameter 'O' rings to the leaf surface to keep constant the amount of leaf surface area in contact with the solution. Lanolin is commonly used for this purpose in absorption studies (Yamaguchi and Crafts, 1958). Treated plants were harvested 48 h after treatment. The 'O' ring was removed and a 1-cm-diameter cork borer was used to remove the disk of leaf/leaflet tissue that encompassed the treated site. This disk was rinsed 30 sec with 1 mL H_2O:methanol (90:10 v/v) to remove unabsorbed imazapic. Scintillation fluid was added to this rinsate and radioactivity was quantified by liquid scintillation spectrometry. The remainder of the treated leaf or leaflet was collected, along with adjacent leaflets of trifoliate leaf. All tissues above the treated leaf (i.e., younger leaves and the terminal bud) were collected. All plant parts were oven dried for 48 hr at 40 C, weighed, and combusted in a biological sample oxidizer. Radioactivity from these samples also was quantified by liquid scintillation spectrometry and expressed on a dpm/mg basis. Preliminary trials by the authors (data not shown) indicated that recovery of the applied radioactivity was ≥ 96%. It was unknown whether recovered radioactivity represented unaltered imazapic or metabolites. A completely random experimental design with six replications was used. Data were subjected to analysis of variance and means compared by a t-test at the $P = 0.05$ level.

Results and Discussion

Field Studies—Weed Control. No year by treatment interactions were detected in Florida beggarweed, sicklepod, and bristly starbur control data. Consequently, these data were pooled across years (Table 1). Control of all three species was influenced by both the EPOST and POST treatments, and by the EPOST-POST interaction. This interaction probably can be attributed to the synergistic-type improvement in control that was frequently obtained when EPOST and POST options were sequentially combined.

Imazapic (71 g/ha) was the most effective EPOST treatment applied alone. This treatment controlled Florida beggarweed, sicklepod, and bristly starbur ≥ 90% (Table 1). Neither tank mixing the imazapic with paraquat nor following with any of the POST treatments improved control of these species. Comparable weed control could be obtained with either imazapic (35 g/ha), paraquat, or paraquat + imazapic (35 g/ha), provided they were supplemented with a suitable POST application. For example, control of bristly starbur and sicklepod was ≥ 90% when any of these three EPOST options were supplemented with 2,4-DB POST. To achieve > 89% control of Florida beggarweed, these three EPOST options had to be supplemented with paraquat + bentazon POST. Furthermore, all three broadleaf species were controlled ≥ 84% with only paraquat + bentazon + 2,4-DB applied POST.

The 1997 data for yellow nutsedge control are presented separately from the 1995-96 data (which were pooled) due to year by treatment interactions (Table 2). Yellow nutsedge control in both the 1995-96 and 1997 data was influenced by EPOST, POST, and sequential treatments. In 1995-96, ≥ 85% control was obtained with the following three EPOST treatments applied alone: imazapic (71 g/ha), imazapic (35 g/ha) + paraquat, and imazapic (71 g/ha) + paraquat. With these treatments, the addition of a POST applications did not improve

Table 1. Broadleaf weed control as influenced by early postemergence- and postemergence-applied treatments in peanut at Headland, AL (data pooled over 1995, 1996, and 1997)[a].

	Postemergence treatments			
Early postemergence treatments	None	2,4-DB	Paraquat + bentazon	Paraquat + bentazon + 2,4-DB
g/ha	% control			
Florida beggarweed				
None	0	39	53	86
Imazapic (35)	68	78	89	90
Imazapic (71)	90	94	94	96
Paraquat	39	56	84	89
Para+imazapic (35)	65	81	91	94
Para+imazapic (71)	92	95	96	97
Sicklepod				
None	0	79	66	91
Imazapic (35)	84	97	96	96
Imazapic (71)	98	97	99	97
Paraquat	76	96	89	97
Para+imazapic (35)	87	95	91	97
Para+imazapic (71)	95	97	99	99
Bristly starbur				
None	0	66	57	84
Imazapic (35)	81	90	96	98
Imazapic (71)	94	93	98	98
Paraquat	60	93	90	96
Para+imazapic (35)	64	92	89	97
Para+imazapic (71)	89	92	96	96

[a]$LSD_{0.05}$ values for the comparison of any two treatment means is 15, 13 and 15 for Florida beggarweed, sicklepod, and bristly starbur, respectively. Paraquat and bentazon were applied at 0.14 and 0.28 kg ai/ha, respectively. 2,4-DB was applied at 0.56 kg ae/ha. All treatments included a nonionic surfactant at 0.25% (v/v); '+' indicates a tank mixture.

Table 2. Yellow nutsedge control as influenced by early postemergence- and postemergence-applied treatments in peanut at Headland, AL (data pooled over 1995, 1996, and 1997)[a].

Early postemergence treatments	Postemergence treatments			
	None	2,4-DB	Paraquat + bentazon	Paraquat + bentazon + 2,4-DB
g/ha	% control			
1995 and 1996				
None	0	8	73	49
Imazapic (35)	75	76	89	86
Imazapic (71)	90	82	92	92
Paraquat	71	76	71	80
Para+imazapic (35)	87	82	82	75
Para+imazapic (71)	85	87	91	91
1997				
None	0	47	44	95
Imazapic (35)	96	95	96	99
Imazapic (71)	99	99	99	74
Paraquat	62	49	99	99
Para+imazapic (35)	98	99	98	94
Para+imazapic (71)	99	99	99	98

[a]$LSD_{0.05}$ for the comparison of any two treatment means is 7 for the 1995-1996 data and 11 for the 1997 data. Paraquat and bentazon were applied at 0.14 and 0.28 kg ai/ha, respectively. 2,4-DB was applied at 0.60 kg ae/ha. All treatments included a nonionic surfactant at 0.25% (v/v); '+' indicates a tank mixture.

Table 3. Yield as influenced by early postemergence- and postemergence-applied treatments in peanut at Headland, AL[a].

Early postemergence treatments	Postemergence treatments			
	None	2,4-DB	Paraquat + bentazon	Paraquat + bentazon + 2,4-DB
g/ha	kg/ha			
1995 and 1996				
None	2750	3260	3420	3740
Imazapic (35)	4530	4500	4710	4760
Imazapic (71)	4490	4820	4510	4840
Paraquat	3570	4500	4350	4630
Para+imazapic (35)	4410	4430	4470	4840
Para+imazapic (71)	4740	4880	4460	4510
1997				
None	2360	2830	2630	3150
Imazapic (35)	3000	3120	3350	3400
Imazapic (71)	3730	3630	3560	3420
Paraquat	3370	3080	3310	3010
Para+imazapic (35)	3170	3290	3190	3270
Para+imazapic (71)	3460	3010	2970	2470

[a]$LSD_{0.05}$ for the comparison of any two treatment means is 480 for the 1995-96 data and 370 for the 1997 data. Paraquat and bentazon were applied at 0.14 and 0.28 kg ai/ha, respectively. 2,4-DB was applied at 0.60 kg ae/ha. All treatments included a nonionic surfactant at 0.25% (v/v); '+' indicates a tank mixture.

control. Comparable control (≥ 86%) was obtained also with imazapic (35 g/ha) applied EPOST, provided this was followed by either of the two bentazon-containing POST treatments.

Yellow nutsedge control ≥ 96% was obtained in 1997 with all imazapic-containing EPOST treatments, regardless of the imazapic rate. Addition of a sequential POST treatment was not warranted. Comparable control (≥ 99%) was obtained also with paraquat applied alone EPOST, if followed with either of the two bentazon-containing treatments applied POST.

Inspection of all data reveals that consistent and adequate control (= 90%) of all three broadleaf species and yellow nutsedge was obtained with imazapic alone, applied EPOST at 71 g/ha. Comparable control was obtained frequently with the less effective EPOST treatments provided they were followed with an appropriate POST treatment.

Field Studies—Yield and Net Returns. Year-by-treatment interactions required that the 1997 yield and net return data be reported separately from the 1995 and 1996 data, which were pooled (Table 3). The uniqueness of the 1997 data can be partially attributed to rainfall distribution. June through August rainfall for 1995, 1996, and 1997 was -7, +28, and -23%, respectively, of the historical average of 37 cm (data not shown).

Yield in 1995-96 was influenced by both the EPOST and POST treatments and by the EPOST-POST interaction (Table 3). In 1995-96, highest yields (4400 to 4880 kg/ha) were obtained with all treatments that included imazapic EPOST (either rate) and paraquat EPOST followed by either of the two POST options that contained 2,4-DB.

Yield in 1997 was influenced only by EPOST-applied treatments (Table 3). Highest yields (3360 to 3730 kg/ha) were obtained with (a) imazapic at 71 g/ha EPOST (with or without any POST treatment), (b) imazapic at 35 g/ha EPOST followed by paraquat + bentazon + 2,4-DB POST, and (c) imazapic (71 g/ha) + paraquat EPOST with no POST treatment.

Economic return in 1995-96 was influenced by the EPOST and POST treatments and by the EPOST-POST interaction (Table 4). Economic return tended to reflect yield. Highest returns (1331 to 1535 $/ha) were obtained with the following systems: (a) imazapic EPOST (either rate), with or without any POST treatment; (b) paraquat EPOST, followed by either of the two POST treatment that contained 2,4-DB; (c) imazapic (35 g/ha) + paraquat EPOST, followed by either of the two POST options that contained bentazon; and (d) imazapic (71 g/ha) + paraquat EPOST, either alone or followed by 2,4-DB POST.

In 1997, economic returns were influenced by herbicides applied EPOST, POST, and by the treatment interaction. Of the treatment combinations included, highest numerical return (961 $/ha) were obtained with an EPOST application of imazapic (71 g/ha). All remaining systems returned less.

Imazapic applied EPOST alone at 71 g/ha was consistently associated with comprehensive weed control, maximum yield, and economic returns across all years. Frequently, variations of this treatment, such as a half rate of imazapic applied alone or various sequential herbicide applications, had equivalent weed control and yield. Yet, these variations

Table 4. Economic returns as influenced by early postemergence- and postemergence-applied treatments in peanut at Headland, AL[a].

Early postemergence treatments	Postemergence treatments: None	2,4-DB	Paraquat + bentazon	Paraquat + bentazon + 2,4-DB
g/ha	$/ha			
1995 and 1996				
None	510	772	821	1006
Imazapic (35)	1406	1385	1481	1497
Imazapic (71)	1346	1511	1340	1508
Paraquat	920	1415	1310	1461
Para+imazapic (35)	1236	1329	1350	1533
Para+imazapic (71)	1469	1535	1283	1304
1997				
None	309	546	435	698
Imazapic (35)	597	661	773	786
Imazapic (71)	961	590	589	425
Paraquat	831	669	782	615
Para+imazapic (35)	688	744	681	716
Para+imazapic (71)	800	559	528	260

[a]$LSD_{0.05}$ for the comparison of any two treatment means is 204 for the 1995-96 data and 109 for the 1997 data. Paraquat and bentazon were applied at 0.14 and 0.28 kg ai/ha, respectively. 2,4-DB was applied at 0.60 kg ae/ha. All treatments included a nonionic surfactant at 0.25% (v/v); '+' indicates a tank mixture.

offered no improvement with respect to economic return. Thus, our original hypothesis of the viability of a half rate of imazapic supplemented with other herbicides as an alternative to imazapic applied alone at the full registered rate is proven false. In the Southeastern U.S., imazapic offers the most comprehensive weed control currently available.

Greenhouse Studies. Florida beggarweed control was influenced by imazapic rate, type of application, seedling age, and by all possible two-way interactions of these variables. Examination of the main effects of application method and seedling age (Table 5) revealed that greater control was obtained with the foliar only and foliar plus soil application. However, control was equivalent across all three methods of exposure when seedlings were ≤ 20 d old. Conversely, the soil-only exposure was less effective than foliar only and foliar plus soil applications when seedlings were ≥ 30 d old. Data indicate that imazapic can be absorbed by either the foliage or the roots of Florida beggar-weed. However, foliar entry gains importance as seedlings age. A rate-dependent response to imazapic was evident at all seedling stages (Table 6). At least 88% control was obtained with and foliar plus soil application of 71 g/ha to seedlings ≤ 20 d old.

Table 6. Control of Florida beggarweed with imazapic applied to both foliage and soil, as influenced by seedling age and application rate.

Seedling age	Imazapic rate (g ai/ha): 18	35	54	71	87
d	% control				
10	78[a]	82	91	91	94
20	79	83	86	88	91
30	18	34	44	45	47
40	9	10	12	15	19
Mean[b]	46 D	52 C	58 B	60 B	66 A

[a]$LSD_{0.05}$ for the comparison of any two individual treatment means is 11.

[b]Main effect means followed by the same letter are equivalent according to the appropriate LSD value at the 0.05 level.

Control, as averaged across all other experimental variables, was at least 71% with seedlings ≤ 20 d old (Table 5). Conversely, control did not exceed 41% with seedlings ≥ 30 d old. While the height and number of nodes increased progressively as seedlings matured, the most pronounced difference in seedlings between 20 and 30 d of age was the development of trifoliate leaves.

Absorption and Translocation. Absorption of ^{14}C-imazapic by unifoliate and trifoliate leaves was equivalent and averaged 42% of the amount applied (Table 7). The amount of radioactivity recovered in the 1-cm diameter target area was equivalent between unifoliate and trifoliate leaves. However, amounts of radioactivity recovered in the

Table 5. Control of Florida beggarweed seedlings with imazapic as influenced by seedling age and application method under greenhouse conditions (data pooled over imazapic rate).

Seedling maturity: Age	Height	Nodes	Unifoliate leaves	Trifoliate leaves	Application method: Soil only	Foliar only	Soil and foliar	Mean
d	cm	no.			% control			
10	6	3	5	0	70[a]	73	75	73 A[b]
20	9	5	7	0	69	72	73	71 A
30	18	8	7	2	34	42	48	41 B
40	35	10	9	5	4	14	15	11 C
Mean						43 B	50 A	53 A

[a]$LSD_{0.05}$ for the comparison of any two individual treatment means is 7.

[b]Main effects means followed by the same letter are equivalent according to the appropriate LSD value at the p = 0.05 level.

remainder of the treated leaf/leaflet and in the apical bud was greater when ^{14}C-imazapic had been applied to the unifoliate leaf of a 20-d-old seedling than to a trifoliate leaf of a 30-d-old seedling. Data indicate that, while imazapic absorption by unifoliate and trifoliate leaves is equivalent, translocation away from the immediate area of adsorption in greater in unifoliate leaves. Thus, reduced translocation by trifoliate foliage, but not absorption, contributes to the imazapic tolerance of older seedlings. The authors are unaware of any anatomical and/or physiological differences between unifoliate and trifoliate leaves that would cause this difference.

Table 7. Absorption and translocation of imazapic when applied to unifoliate and trifoliate leaves of Florida beggarweed[a].

	Leaf type[b]	
Foliar tissue	Unifoliate	Trifoliate
	------------dpm/g------------	
1-cm diameter target	338.6	373.8
Remainder of treated leaf/leaflet	4.9 *[c]	1.9
Remaining leaflets	--	1.5
Apical bud	5.6 *	0.7

[a]Amount absorbed was equivalent for unifoliate and trifoliate leaves, averaging 42% of the amount applied.

[b]The unifoliate and trifoliate leaves were the youngest fully expanded leaves of 20- and 30-d-old seedlings, respectively. *indicates that values differ according to t-test at the 0.05 level.

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