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Response of Two Alligatorweed Biotypes to Quinclorac

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ABSTRACT

Greenhouse studies evaluated the influence of foliar applications of quinclorac (3,7-dichloro-8-quinolinecarboxylic acid) on two morphologically distinct alligatorweed biotypes. Quinclorac was applied at 0.3 and 0.6 kg/ha to well-rooted plants that had been cut back and allowed to regrow for two, four, or six weeks to simulate treatment at different stages of regrowth. Herbicide damage and overall effects on growth were significantly greater in the slenderstem than in the broadstem biotype, probably reflecting greater leaf surface are per unit of shoot biomass in the slenderstem biotype. Regrowth from roots and rhizomes was similar for both biotypes, and no herbicide symptoms were observed on the new growth, suggesting poor basipetal translocation. The relative growth rates of slenderstem alligatorweed were reduced sigificantly more than those of the broadstem biotype following either root or leaf treatment. The results of this study suggest that certain alligatorweed biotypes may be more tolerant to herbicides than others and may provide a partial explanation for the variability observed in the response of alligatorweed to herbicides.

Key words: Alternanthera philoxeroides, herbicide resistance, morphology, growth.

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INTRODUCTION

Alligatorweed, *Alternanthera philoxeroides* (Mart.) Griseb. has been very difficult to manage with herbicides. Early studies with compounds such as sodium or potassium arsenite and sodium or potassium chlorate reported top kill, but rapid regrowth occurred from underwater stems (Penfound 1940, zur Burg et al. 1962, 1967). Systemic herbicides developed since the 1940's have been only partially effective because of limited translocation to the underground and underwater biomass (Weldon 1960, Anonymous 1968, Julien and Broadbent 1980). Poor herbicide translocation in alligatorweed has been attributed to several factors. Zur Burg et al. (1961) indicated that abnormal growth of root cell primordia at the nodes blocked vascular tissues and prevented herbicide translocation. Axillary buds seem partially resistant to herbicides, apparently because of the lack of direct connection to the parent plant's vascular system (Zur Burg et al. 1967). Pate et al. (1965) reported that dichlobenil (2,6-dichlorobenzonitrile) and dicamba (2-methoxy-3,6-dichlorobenzoic acid) produced herbicidal activity in axillary buds of alligatorweed only when the vascular tissues between the axillary buds and the stems were well differentiated. Studies using radiolabelled 2,4-D (2,4-dichlorophenoxyacetic acid) (Earle et al. 1951) and glyphosate [*N*-(phosphonomethyl)glycine] (Tucker et al. 1986) showed that basipetal translocation of herbicides was very low, suggesting that a physiological barrier to herbicide translocation may exist in alligatorweed. In a subsequent study, 17 percent of leaf-applied imazapyr (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-phyridinecarboxylic acid) was recovered in the root system eight days after treatment in contrast to only one percent of glyphosate (Tucker et al. 1987).

Evidence exists that at least two morphologically distinct forms of alligatorweed are present in the United States (Quimby et al. 1976, Kay and Haller 1982). These forms exist in geographically-isolated areas and maintain their morphological integrity when cultured under identical conditions. Results of laboratory growth studies (Quimby et al. 1976, Kay and Haller 1982), differences in isozyme patterns (Wain and Martin 1984), and differences in response to a plant growth regulator, brassinolide (2*a*, 3*a*, 22*a*-tetrahydroxy-24*a*-methyl-B-homo-7-oxa-5*a*-cholestan-6-one) (author's unpublished data), suggest that these morphologically distinct forms may represent physiologically distinct biotypes. These and other physiological differences could be responsible for the wide variation in the response of alligatorweed to herbicides under field conditions as noted previously by Spencer (1967). To date, no studies have been conducted to compare the response of morphologically distinct alligatorweed biotypes to herbicides.

Quinclorac recently was introduced by BASF Corporation for weed control in rice and is indicated by the manufacturer to have activity on alligatorweed. The objective of this study was to determine whether or not two morphologically distinct alligatorweed biotypes would respond similarly to quinclorac application.

MATERIALS AND METHODS

Two greenhouse studies (spring and summer) were conducted in 1989 to evaluate the responses of two morphologically distinct alligatorweed biotypes to quinclorac. A broadstem biotype (terminology after Kay and Haller 1982) originally collected from Tangipahoa, Louisiana (designated BSA), and a slenderstem biotype originally collected from Bryant's Swamp near Bladenboro, North Carolina (designated SSA), were grown hydroponically in small pools in a greenhouse during the fall and winter of 1988 using a full-strength modified Hoagland's nutrient (Quimby and Kay 1977).

Foliar application tests. Prior to the initiation of each test, five 10-cm stem cuttings of either BSA or SSA were placed into 15-cm pots containing Metromix 220®[2] potting medium. The pots were placed into hydroponic culture in pools as described above to allow the plant cuttings to establish a good root system prior to treatment. During the first test (April 10 to June 5, 1989), plants were cut back to the surface of the substrate either 4 or 8 weeks prior to treatment and allowed to regrow. This was done to simulate two different stages of plant regrowth (4 and 8 weeks) from the root/rhizome system, which occurs in the field during the early and late spring in each growing season. A 2-week regrowth stage was added during the second test (August 1 to September 19, 1989) to simulate very early season growth. Plants were maintained at 30 ± 3 C under a natural photoperiod throughout the rooting period and for the duration of both studies.

When the plants had reached the proper growth stage (i.e., 2, 4, or 8 wks. regrowth), they were placed into a spraying cabinet at the BASF laboratory at Research Triangle Park, North Carolina, and treated with quinclorac at rates of 0.3 or 0.6 kg a.i./ha. BAS 009 002S surfactant (1.25% v/v) was used with the quinclorac (this is the surfactant contained in the commercial quinclorac formulation, Facet®)[3]. A 1.25% solution of Rodeo®[4] (glyphosate) + 0.5% Induce®[5] surfactant was used as a positive control to compare the response of the plants to that with a known herbicide. Treated plants and controls were placed in the greenhouse for observation. Five pots of untreated plants also were clipped at the surface of the substrate at this time, dried at 70 C for 48 hr, and weighed to estimate the shoot biomass at the outset of the test period. At the time of treatment, all plants had formed a complete leaf canopy over the surface of the pots. Subirrigation was used instead of top watering throughout the study to minimize the downward movement of the herbicide into the root zone and facilitate evaluation of basipetal translocation. Weekly, 100 ml of nutrient solution was added to each pot by subirrigation.

Plant injury was rated visually (0 to 5 scale, where 0 = no damage and 5 = complete kill) one, two, and four weeks after treatment. Injury rating is defined as zero for controls. Above-ground biomass was harvested four weeks

[2]Metromix 220 is a registered trademark of Grace Horticultural Products Co.

[3]Facet is a registered trademark of BASF Corp.

[4]Rodeo is a registered trademark of Monsanto, Inc.

[5]Induce is a registered trademark of Helena Chemical Co.

after treatment. Terminal cuttings (10-cm) from herbicide-damaged stems were placed into test-tubes containing tap water and maintained in a growth chamber for 10 days under a 16-hr photoperiod and 30/25 C day/night temperatures to determine stem viability. The remaining above-ground biomass was separated into live and dead tissues, dried, and weighed as described previously. Stem cuttings used for the stem viability test were dried and weighed after the evaluation period, and dry weights were added to the total biomass. The pots containing the root systems were left in the greenhouse and watered via subirrigation for four additional weeks to observe regrowth. All regrowth was harvested, dried, and weighed as described above.

These tests were established in a completely randomized factorial design having 2 biotypes, 2 or 3 (test 2) growth stages, and three herbicide rates with five replicates per treatment. Growth data and visual ratings were subjected to an analysis of variance using a three-way interactive model. The controls were not included in the analysis of visual herbicide injury symptoms, as control ratings were arbitrarily set as zero and had 0 variance.

Comparison of leaf and stem characteristics. An additional 10 stems of each biotype were collected from the greenhouse stock cultures to determine possible differences in leaf areas per unit weight of shoots. Stems for this procedure were clipped at the base of the internode below the sixth fully-expanded leaf pair. This position was chosen because it represents the limit of nonsenescent leaf tissue (leaves below this point frequently have abscised in natural or greenhouse populations). Leaves were removed, and leaf areas were measured using a Lambda®,[6] leaf area meter. Lengths of stems and internodes also were measured. Tissues were dried and weighed as described above. Differences between the means were separated using a T-test.

Foliar versus root uptake. Another test was conducted during the spring of 1990 to address questions concerning the route of quinclorac uptake and translocation in these biotypes. Stem cuttings (as described above) were rooted for two weeks in the greenhouse in flasks containing 250 ml of full-strength nutrient solution. Quinclorac was applied either in the nutrient solution or to a single leaf to evaluate root uptake and foliar uptake, respectively. The concentration applied in the nutrient solutions for the root uptake study was 0.4 mg/l (total of 0.1 mg available in each flask containing 250 ml solution). This treatment concentration was determined on the basis of the theoretical concentration (w/v) occurring in the water column if the herbicide was applied at 0.6 kg/ha and was evenly distributed in the upper 15 cm of the water column (roughly equivalent to the depth of the plow layer in a terrestrial application). The exposure rate for foliar uptake was determined similarly on the basis of the amount of herbicide theoretically striking the surface of an upper leaf having a surface area of five cm^2 if 0.6 kg a.i./ha had been applied. A 10-microliter aliquot of a suspension containing a total of 30 micrograms quinclorac was applied with a syringe as a series of ten small droplets, five along each side of the midvein in the center of the leaf lamina of a single leaf from the third fully expanded leaf pair. The treated leaf always was on the longer of the two shoots arising from the apical node of the stem cutting. This shoot henceforth will be designated as the primary shoot. The shorter of the two shoots arising from the apical node of the stem cuttings will be designated as the secondary shoot. Each treatment was replicated five times. The diameters of the nodes immediately above (designated node + 1) and below (node − 1) and adjacent to (node 0) this leaf pair was measured for all plants on the date of treatment and again at harvest. A rubber band was lopped over the leaf to mark the location of the third fully-expanded leaf pair at time 0 for both foliar and root-absorbed herbicide tests to facilitate the relocation of this position for subsequent observations. An additional five replicates were harvested at the outset to determine initial biomass and allow subsequent calculation of relative growth rates (RGR), using the formula $(W_1 - W_0) / (W_0 \times D)$, where W_0 = g dry weight at time 0, W_1 = g dry weight at harvest, and D = the number of days until harvest. Plants were separated into original stem cuttings, roots, leaves, and stems, dried, and weighed for growth determinations. Data were subjected to an analysis of variance, and treatment means were separated using the Duncan's Multiple Range procedure (Steele and Torrie 1960).

RESULTS AND DISCUSSION

Foliar application tests. The two biotypes used in this study (BSA and SSA) differ substantially morphologically when grown under identical conditions in either the field or greenhouse. Internodal diameter, length, and cavity size are larger on the broadstem (BSA) than on the slenderstem (SSA) biotype. The leaves of BSA are longer, narrower, and acutely pointed in contrast to the broader and more rounded leaves of SSA.

Visual symptoms of quinclorac treatment included defoliation, leaf malformation, epinasty of the younger portions of the stems, swelling of nodes, partial kill of the terminal buds and stems, and extensive callous tissue development apically and along the internodes. These symptoms are quite similar to those induced by application of phenoxy herbicides such as 2,4-D on alligatorweed (Solymosy 1967) and other plants (Ashton and Crafts 1973, Klingman and Ashton 1982, Ross and Lembi 1985). Leaf malformation has been noted previously in studies evaluating quinclorac for broadleaf weed control in broccoli (Herbst and Derr 1988). Damage symptoms were distinctly more pronounced on SSA than BSA in both tests. These symptoms also appeared to be slightly greater on both biotypes following treatment in August.

Exposure to quinclorac reduced total shoot biomass and percent new growth, and increased percent dead tissue in both biotypes (Tables 1 and 2). There were no significant three-way interactions in these tests. Interaction between biotype and herbicide rate was highly significant ($P > F = 0.001$). Differences between biotypes were more pronounced on plants treated at the later stages of growth in both tests ($P > F = 0.05$). This pattern probably is a function of greater leaf surface area for absorption of the

[6]Lambda is a registered trademark of Li-Cor, Inc.

TABLE 1. VISUAL INJURY AND GROWTH OF BROADSTEM (BSA) AND SLENDERSTEM (SSA) ALLIGATORWEED BIOTYPES IN THE GREENHOUSE FOLLOWING QUINCLORAC APPLICATION. DATA SHOWN ARE FOR THE TEST CONDUCTED IN THE SPRING OF 1989.[1]

Treatment	Biotype	Growth Stage	4-wk Visual Ratings	Biomass	% New Growth	% Dead	Regrowth
Control	BSA	4 wks	**[2]	25.3 (4.4)	71.8 (4.2)	1.7 (0.8)	1.2 (0.3)
0.3 kg/ha			2.2 (0.3)	15.2 (4.1)	51.1 (13.5)	8.8 (3.1)	0.6 (0.4)
0.6 kg/ha			2.2 (0.3)	15.3 (2.6)	53.2 (7.6)	13.9 (3.0)	0.3 (0.0)
Control	SSA	4 wks	**	14.7 (3.9)	68.9 (11.6)	0.1 (0.3)	1.4 (0.2)
0.3 kg/ha			3.1 (0.2)	6.8 (1.1)	36.5 (9.8)	27.1 (6.0)	1.1 (0.1)
0.6 kg/ha			3.6 (0.4)	5.4 (1.4)	18.1 (18.8)	46.7 (10.8)	0.8 (0.1)
Control	BSA	8 wks	**	32.7 (14.3)	56.3 (20.5)	1.8 (1.7)	1.7 (0.5)
0.3 kg/ha			2.3 (0.3)	23.3 (5.8)	46.3 (11.4)	7.1 (2.6)	0.6 (0.3)
0.6 kg/ha			2.4 (0.4)	26.1 (10.9)	45.0 (29.4)	12.1 (3.0)	0.3 (0.2)
Control	SSA	8 wks	**	21.4 (2.9)	60.2 (5.5)	0.7 (0.7)	1.4 (0.3)
0.3 kg/ha			3.1 (0.2)	8.1 (1.4)	–6.1 (18.4)	30.3 (5.3)	1.0 (0.2)
0.6 kg/ha			3.4 (0.5)	7.8 (1.2)	–9.5 (17.8)	32.1 (8.9)	0.6 (0.2)

[1]All data are the means of 5 replications; values in parentheses are one standard deviation. Visual ratings are on the scale of 0 to 5, where 0 = no damage and 5 = complete kill. All biomass and growth data are reported as g dry weight. Data for glyphosate are not shown, as plants were consistently killed by the treatment.
[2]Controls not included in the analysis of visual data as ratings are arbitrarily set as zero (variance = 0).

herbicide in the larger (i.e., older) plants but also might represent differences in translocation. Herbicide damage and growth responses within each biotype were somewhat variable and probably reflected the normal variation in plant growth as observed in the plants clipped for the initial biomass at the outset of the tests. Glyphosate gave essentially complete kill of both the shoots and the root/rhizome systems at all stages of growth in both tests (data not shown). Regrowth following quinclorac treatment was significantly reduced in the 8-week-old plants of both biotypes in the first test but not in the second test. Regrowth from glyphosate-treated plants was negligible in both tests (data not shown). These data suggest that basipetal translocation of quinclorac was poor and that differences in regrowth probably were not biologically significant. This would be consistent with the route of absorption of quinclorac, which occurs largely through the root system (Pearson and Carter 1986; Stovicek and Penner 1986), even though some absorption may occur through other portions of the plant (Reeves et al. 1986; Wegener and Muller 1988).

Comparison of the two biotypes at the same stages of growth indicated that growth inhibition by quinclorac was significantly greater on SSA than BSA (Tables 1 and 2).

TABLE 2. VISUAL INJURY AND GROWTH OF BROADSTEM (BSA) AND SLENDERSTEM (SSA) ALLIGATORWEED BIOTYPES IN THE GREENHOUSE FOLLOWING QUINCLORAC APPLICATION. DATA SHOWN ARE FOR THE TEST CONDUCTED IN THE SUMMER OF 1989.[1]

Treatment	Biotype	Growth Stage	4-wk Visual Ratings	Biomass	% New Growth	% Dead	Regrowth
Control	BSA	2 wks	**[2]	10.0 (1.6)	87.1 (2.1)	3.1 (1.1)	0.2 (0.2)
0.3 kg/ha			2.5 (0.6)	4.7 (1.1)	71.8 (7.6)	17.0 (7.5)	0.5 (0.1)
0.6 kg/ha			2.3 (0.3)	4.6 (1.0)	71.7 (5.8)	11.2 (3.4)	0.4 (0.2)
Control	SSA	2 wks	**	4.3 (0.8)	88.5 (2.1)	9.3 (4.1)	0.4 (0.1)
0.3 kg/ha			3.2 (0.4)	1.4 (0.4)	61.0 (17.1)	40.8 (25.4)	0.5 (0.2)
0.6 kg/ha			3.3 (0.3)	1.5 (0.3)	67.6 (5.9)	48.7 (12.8)	0.4 (0.1)
Control	BSA	4 wks	**	26.6 (3.5)	66.1 (0.4)	2.8 (1.0)	0.1 (0.1)
0.3 kg/ha			3.1 (0.5)	17.0 (3.0)	46.5 (8.9)	22.0 (10.8)	0.2 (0.3)
0.6 kg/ha			2.7 (0.4)	20.7 (4.5)	55.4 (9.8)	14.8 (3.2)	0.1 (0.0)
Control	SSA	4 wks	**	14.9 (14.1)	67.7 (10.5)	4.7 (2.0)	0.2 (0.0)
0.3 kg/ha			3.7 (0.4)	10.7 (4.7)	31.3 (24.2)	53.6 (18.6)	0.1 (0.1)
0.6 kg/ha			3.3 (0.4)	13.0 (3.2)	47.6 (12.6)	41.6 (7.3)	0.1 (0.0)
Control	BSA	8 wks	**	54.1 (6.9)	59.9 (5.0)	1.3 (0.5)	0.2 (0.1)
0.3 kg/ha			3.2 (0.4)	27.3 (6.6)	16.7 (25.5)	16.0 (6.8)	0.1 (0.1)
0.6 kg/ha			2.9 (0.2)	28.7 (6.4)	22.1 (19.1)	9.3 (2.6)	0.1 (0.0)
Control	SSA	8 wks	**	34.9 (7.6)	49.5 (14.7)	3.3 (0.9)	0.2 (0.1)
0.3 kg/ha			3.6 (0.5)	17.3 (8.5)	–13.7 (43.8)	38.2 (15.7)	0.1 (0.1)
0.6 kg/ha			3.1 (0.2)	23.2 (4.7)	25.5 (14.2)	23.9 (6.0)	0.1 (0.1)

[1]All data are the means of 5 replications; values in parentheses are one standard deviation. Visual ratings are on the scale of 0 to 5, where 0 = no damage and 5 = complete kill. All weight data are reported as g dry weight. Data for glyphosate are not shown, as almost complete kill occurred on all plants.
[2]Controls not included in the analysis of visual data as ratings are arbitrarily set as zero (variance = 0).

TABLE 3. COMPARISON OF THE LEAF AND STEM CHARACTERISTICS OF BROADSTEM (BSA) AND SLENDERSTEM (SSA) ALLIGATORWEED BIOTYPES.[1]

Characteristic	Biotype		Significance
	SSA	BSA	
Shoot biomass, g	0.43 ± 0.15	1.29 ± 0.42	**
Total leaf area, cm^2	77.4 ± 21.9	101.8 ± 24.9	*
Average size of leaves, cm^2	4.5 ± 1.2	5.3 ± 1.3	NS
Leaf weight, g	0.21 ± 0.08	0.40 ± 0.13	**
Specific leaf weight, mg/cm^2	2.6 ± 0.4	3.8 ± 0.7	**
Stem length, cm	25.4 ± 5.3	32.1 ± 6.1	*
Stem weight, g	0.23 ± 0.08	0.90 ± 0.33	**
Specific stem weight, mg/cm	8.7 ± 1.7	27.5 ± 7.6	**
Average internode length, cm	3.3 ± 0.6	3.7 ± 0.6	NS
Leaf area:shoot biomass ratio	184.0 ± 24.0	83.0 ± 21.0	**
Leaf area:stem length ratio	3.0 ± 0.5	3.3 ± 0.9	NS
Leaf area:stem weight ratio	358.0 ± 75.0	126.0 ± 51.0	**

[1]Data shown are the means ± 1 standard deviation, where n = 10. Means were compared using a T-Test procedure; means designated with * and ** indicate significance at alpha = 0.05 and 0.01, respectively; NS = not significant.

Significantly greater reduction occurred in total shoot biomass and percent new growth of SSA at the later growth stage in the first experiment. Percent dead tissue also was significantly greater in SSA than BSA at all growth stages in both tests. These biotypic differences in response were reflected in the visual ratings, which effectively integrate quantitative effects on biomass with plant appearance.

Comparison of leaf and stem characteristics. It is uncertain whether or not differences in the responses of these two alligatorweed biotypes to foliar applications of quinclorac are the results of morphological variation or innate physiological differences. A comparison of shoot cuttings taken from untreated, greenhouse-grown plants of both biotypes (Table 3) suggests that biotypic differences in response to quinclorac may partly reflect differences in leaf area ratios (leaf area per unit of shoot biomass), which were greater for SSA than for BSA. Seasonal differences in light quality and photoperiod also affect both the morphology and growth of alligatorweed and may have caused some of the observed differences between the two tests. Differences in results between the two experiments also appear to reflect the innate variability of alligatorweed growth, as substantial varition in plant size was observed within each biotype at the outset of both tests.

Foliar versus root uptake. There were no significant differences between the two biotypes with respect to the time interval until the appearance of epinasty and nodal swelling following either leaf or root treatment with quinclorac in this experiment (data not shown). Both nodal swelling and epinasty appeared more slowly in secondary shoots than in primary shoots following leaf treatment, in contrast to the more rapid and uniform appearance of symptoms in both shoots following root treatment. The appearance of epinasty following quinclorac treatment was slower than that reported previously (several hours) for alligatorweed following 2,4-D applications (Solymosy 1967). The two-week duration of this experiment was not sufficiently long for the development of the tumorous growths and callous tissues observed in the two previous tests.

Dry biomass production was consistently greater in BSA than in SSA regardless of route of treatment (Table 4). Leaf application of quinclorac resulted in significantly greater reduction of new growth in SSA than BSA, whereas there were no significant differences in new growth between the two biotypes following root treatment. The RGR of SSA controls was significantly greater than that of BSA controls, but there were no significant differences in RGR between the two biotypes after either root or leaf application of quinclorac. The differences in response between the two biotypes are quite clear, if the data are expressed as percent reduction in RGR. The reductions in RGR following leaf and root treatment were 15 and 44 percent, respectively, in BSA; RGR reductions for SSA were 33 and 57 percent, respectively. This clearly supports the evidence from the first two tests which indicated that BSA was more tolerant to quinclorac than SSA. The

TABLE 4. EFFECTS OF QUINCLORAC ON GROWTH RATES AND DRY MATTER PRODUCTION OF BROADSTEM (BSA) AND SLENDERSTEM (SSA) ALLIGATORWEED BIOTYPES WHEN APPLIED TO A SINGLE LEAF OR TO THE ROOT SYSTEM. VALUES SHOWN ARE MEANS OF FIVE REPLICATES ± 1 STANDARD DEVIATION).[1]

Variable	SSA/Control	SSA/Leaf	SSA/Root	BSA/Control	BSA/Leaf	BSA/Root
Stem wt., g	0.71 (0.31) b	0.47 (0.20) c	0.22 (0.07) d	1.63 (0.22) a	1.66 (0.22) a	0.71 (0.23) b
Leaf wt., g	0.36 (0.04) bc	0.28 (0.08) cd	0.17 (0.04) d	0.56 (0.07) d	0.52 (0.12) ab	0.47 (0.24) ab
Root wt.,g	1.24 (0.38) a	1.04 (0.32) ab	0.51 (0.07) d	1.00 (0.15) ab	0.79 (0.09) bc	0.64 (0.14) cd
Biomass, g	2.32 (0.64) b	1.78 (0.45) c	0.90 (0.12) d	3.18 (0.28) a	2.97 (0.33) a	1.82 (0.33) c
New growth (g)	1.59 (0.44) a	0.99 (0.34) b	0.44 (0.10) c	1.65 (0.13) a	1.40 (0.18) a	0.67 (0.26) bc
% new growth	68.40 (3.80) a	54.90 (7.80) b	48.30 (5.00) b	51.90 (3.50) b	47.40 (4.60) b	36.10 (10.40) c
RGR (g/g.day)	0.15 (0.02) a	0.08 (0.02) b	0.06 (0.01) bc	0.07 (0.01) b	0.06 (0.01) bc	0.04 (0.02) c

[1]Means in a row followed by the same letter are not significantly different according to Duncan's Multiple Range procedure (alpha = 0.05).

results of this experiment suggest that root absorption and xylem transport are more important than foliar uptake and phloem transport of quinclorac in alligatorweed and explain the lack of herbicide symptoms on the regrowth in the initial tests. These observations are consistent with those of previous studies with quinclorac on other plants, which indicate that the primary route of uptake would be through the root system (Pearson and Carter 1986). Earlier research also has suggested that herbicide uptake by alligatorweed occurs more readily via the roots than foliar applications (Solymosy 1967). The more rapid responses in both qualitative and quantitative growth characteristics following root treatment as compared with foliar treatment also support the earlier suggestion that biotypic differences in response to foliar applications of quinclorac may have been the result of morphological differences (leaf surface characteristics such as waxes or epidermal hairs) between the biotypes. This conclusion must be accepted with caution, as the actual amount of herbicide entering the plants following root treatment may have been substantially different than that entering the plant via application to a single leaf. Uptake through the roots also may occur more readily than that through the leaves because of the lack of barriers to absorption (cuticular waxes, etc.), which are absent in the roots.

The results of this study suggest that broadstem alligatorweed may be more tolerant to herbicides such as quinclorac than slenderstem alligatorweed and may partly explain the inconsistent patterns of response to herbicides reported previously for alligatorweed. Field testing of quinclorac and other herbicides at locations having different alligatorweed biotypes and experimentation under a wider range of environmental conditions are needed to clearly substantiate differences in herbicide tolerance among alligatorweed biotypes. Micromorphological differences among biotypes which may affect foliar herbicide absorption (cuticle thickness, leaf pubescence, etc.) also should be investigated.

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