Off-Target Injury to Southern Landscape Species Following Aminocyclopyrachlor Applications[1]

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Abstract

Aminocyclopyrachlor is an herbicide for broadleaf weed control that has recently come under scrutiny following reports of injury to landscape ornamentals across the upper Midwestern United States. This herbicide has been shown to provide excellent weed control in warm-season turfgrasses at much lower use rates than that used for cool-season turf, but data are lacking concerning its safety to landscape ornamentals in southern U.S. regions. Parallel studies were conducted in Dallas and Huntsville, TX, locations to evaluate off-target injury effects on sixteen ornamentals and trees commonly used in southern landscapes. In March 2012, just prior to the spring growth flush, aminocyclopyrachlor was applied to potted plants at 0, 0.5, 1, 2, or 4× rates as either as granular [0, 14, 28, 56, or 112 g ai·ha^{-1} (0.013, 0.03, 0.05, and 0.10 lbs ai·A^{-1})] or liquid [0, 11.2, 22.4, 44.8, or 89.6 g ai·ha^{-1} (0.01, 0.02, 0.04, 0.08 lbs ai·A^{-1})] formulations. For the next 8 weeks, plants were evaluated for injury to new growth. Injury was observed in 9 of the 16 species used, but was generally mild to moderate in nature. Species exhibiting the greatest sensitivity to aminocyclopyrachlor included loblolly pine (*Pinus taeda*), viburnum (*Viburnum odoratissimum*), nandina (*Nandina domestica* 'Compacta'), and camellia (*Camellia japonica*). Extent of injury was not different between granular or liquid formulations, but was less severe at the Dallas location. Results of the study indicate sensitivity within some southern landscape ornamentals to aminocyclopyrachlor.

Index words: aminocyclopyrachlor, herbicide injury, landscape plants and trees.

Species used in this study: Asiatic jasmine (*Trachelospermum asiaticum* Sieb. & Zuch. 'Tricolor'); camellia (*Camellia japonica* '*Shishigashira*' L.); crape myrtle (*Lagerstroemia x fauriei* L. 'Natchez'); eldarica pine (*Pinus eldarica* Medw.); Formosan azalea (*Rhododendron indicum* Sweet 'Formosa'); Italian cypress (*Cupressus sempervirens* L.); Blue Point juniper (*Juniperus chinensis* 'Blue Point' L.); Leyland cypress (*Cupressocyparis leylandii* Dallim. & A.B. Jacks.); live oak (*Quercus virginiana* Mill.); loblolly pine (*Pinus taeda* L.); nandina (*Nandina domestica* 'Compacta'); Shumard red oak (*Quercus shumardii* Buckley); sweet viburnum (*Viburnum odoratissimum* Ker Gawl.); Texas lantana (*Lantana horrida* Hayek); privet (*Ligustrum japonicum*); variegated pittosporum (*Pittosporum tobira* 'Variegata').

Significance to the Nursery Industry

Aminocyclopyrachlor is a lawn and turfgrass herbicide that has been associated with injury in landscape ornamentals in the upper Midwestern United States, particularly on conifers. In this Texas study, we found that aminocyclopyrachlor, even when applied at lower rates than those recommended for the Midwest, has the potential to cause injury to a wide range of southern-adapted ornamentals and should be used with caution or avoided altogether around such vegetation. Out of the sixteen species evaluated, loblolly pine, viburnum, nandina and camellia showed the greatest sensitivity, with injury being more noticeable in the more humid, cooler and wetter site (Huntsville, TX, closer to the coast) than in the more dry and hot environment (Dallas, TX).

Introduction

Aminocyclopyrachlor (6-amino-5-chloro-2-cyclopropyl-4-pyrimidinecarboxylic acid or DPX-MAT 28) has been developed as a broad-spectrum herbicide for diverse uses such as range, non-cropland, industrial sites, lawn, golf course, forestry, and pasture (4, 5). The E.I. Dupont Company began producing aminocyclopyrachlor for the lawn and golf course market as Imprelis® Herbicide in both granular and aqueous solution starting in the Fall of 2010 (1). Aminocyclopyrachlor has been shown to provide effective control over a wide range of annual and perennial broadleaf weeds at low use rates (1, 3, 5, 9, 12, 15). Aminocyclopyrachlor is absorbed by leaves and roots and translocated to meristematic regions of the plant where activity produces a response pattern similar to other synthetic-auxin herbicides (1, 2, 11). It is considered a 'safe' pesticide due to low-risk to human health and non-target organisms.

While a range of cool season turfgrasses exhibit good tolerance to aminocyclopyrachlor (1, 18), considerable research has also examined warm season turf tolerance to aminocyclopyrachlor, and data have been mixed. While zoysiagrass (*Zoysia japonica* Steud.) has been reported to tolerate labeled rates (0.053 kg·ha^{-1}), some injury has been reported following applications to buffalograss (*Buchloe dactyloides*), St. Augustinegrass (*Stenotaphrum secundatum* (Walt.) Kuntze), and bermudagrass (*Cynodon dactylon* (L.) Pers. X *C. transvaalensis* Burtt Davy) (3, 6, 8). Microscopic examination of St. Augustinegrass injury from aminocyclopyrachlor revealed effects on new growth including abnormal location and development of the apical meristem, damaged vascular tissues, and disorganized root development (7). Despite these issues, recent data suggest that aminocyclopyrachlor can offer effective control of many southern weeds at much lower use rates than those previously used for cool-season systems (18), so the potential may exist for future use in southern climates.

In the summer of 2011, The United States Environmental Protection Agency (EPA) received several claims that aminocyclopyrachlor may have injured certain species of

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Table 1. Botanical name, common name, location, and pot size of plant material.

Botanical name	Common name	Pot size (gal)	
		Dallas	Huntsville
Camellia japonica 'Shishigashira'	Shi-Shi camellia	—	3
Cupressocyparis leylandii	Leyland cypress	15	3
Cupressus sempervirens	Italian cypress	15	3
Juniperus chinensis 'Blue Point'	Blue Point juniper	5	—
Lagerstroemia x *fauriei* 'Natchez'	Natchez crape myrtle	3	3
Lantana horrida	Lantana	1	1
Ligustrum japonicum	Privet	—	3
Nandina domestica 'Compacta'	Compact nandina	3	3
Pinus eldarica	Eldarica pine	15	—
Pinus taeda	Loblolly pine	—	3
Pittosporum tobira 'Variegata'	Variegated pittosporum	3	1
Quercus shumardii	Shumard red oak	3	3
Quercus virginiana	Live oak	15	3
Rhododendron indicum 'Formosa'	Formosan azalea	3	—
Trachelospermum asiaticum	Asiatic jasmine	1	1
Viburnum odoratissimum	Sweet viburnum	3	3

evergreen trees, primarily in midwest and northern states (http://www.epa.gov/pesticides/regulating/imprelis.html). In August 2011, the EPA issued a stop sale order to the E.I. Dupont Company for Imprelis® Herbicide. Because of its prior limited use in southern regions, these reports emphasize the importance of evaluating tree and ornamental tolerance to aminocyclopyrachlor for southern landscapes. While significant amounts of data have been compiled with regard to weed control efficacy for warm-season turf, published ornamental tolerance data continue to be largely unavailable. The objective of this study was to evaluate injury potential following liquid and granular application of aminocyclopyrachlor to ornamental plants common to warm, humid regions of the United States.

Materials and Methods

Parallel field studies were conducted at Texas A&M AgriLife Research and Extension Center in Dallas, TX, as well as at Sam Houston State University, Huntsville, TX, during the spring of 2012. In total, sixteen containerized ornamental species were evaluated, ten of which were used at each location (Table 1). The plant materials, consisting of evergreen and deciduous trees, evergreens, deciduous shrubs, and groundcovers, were acquired from two commercial nurseries, Landmark Nurseries, Coppell, TX, and Magnolia Gardens Nursery, Waller, TX (Dallas and Huntsville studies, respectively). Each trial was arranged as a randomized complete block design, with 4 blocks per treatment (with 2 plants per each experimental unit). The specimens varied with regard to pot size and age, but herbicide treatments rates were adjusted to account for any differences in container diameter (Table 1). The growing medium in all species was composted pine bark, with tests indicating pH ranging from 4.9 to 6.1, and averaging 5.3.

Two herbicide formulations, granular and liquid, were tested at four rates: 0,14, 28, 56, or 112 g ai·ha^{-1} (0.013, 0.03, 0.05, and 0.10 lbs ai·A^{-1}) (granular) and 0, 11.2, 22.4, 44.8, or 89.6 g ai·ha^{-1} (0.01, 0.02, 0.04, 0.08 lbs ai·A^{-1}) (liquid) (Table 2). Granular herbicides were weighed and applied by hand using a shaker jar, while liquid herbicides were measured and evenly distributed across surface of the growing medium in pots via syringe. Irrigation was supplied to water in herbicides immediately after applications were made to initiate the trial.

At Dallas, three rows of field pipe with impact sprinkler heads were used for irrigating plants, with irrigation provided three times weekly to supply 100% of reference ET (ET_o) replacement, based on an on-site weather station. At Huntsville, pots were monitored daily and hand-watered so as to keep the growing medium continually moist and prevent

Table 2. Treatment formulations and rates used in the trials.

Treatment	Formulation[z]	Product rate	Active substance concentration	Active substance rate
		g·m^{-2}	W:W	g ai·ha^{-1}
Control	N/A	0	0	0
0.5×	GR	7.6	0.018	14
1×	GR	15.2	0.018	28
2×	GR	30.4	0.018	56
4×	GR	60.8	0.018	112
		mL·m^{-2}		
0.5×	AS	25.1	0.0045	11
1×	AS	50.2	0.0045	22
2×	AS	100.4	0.0045	45
4×	AS	200.8	0.0045	90

[z]GR is granular and AS is aqueous solution.

Table 3. **Weather conditions for the Dallas and Huntsville, TX, trials. Data are for the 8 week study period at each location and were obtained from onsite weather stations.**

	Total ET_o mm	Avg. max temp C	Avg. min temp C	Avg. solar radiation $MJ \cdot m^{-2}$	Total rainfall mm	Avg. windspeed kph
Dallas	300	27	18	17.4	56	13.1
Huntsville	195	25	15	16.1	183	2.9

substrate drying. More detailed climatic data for both trials have been provided (Table 3).

Herbicide applications were made on March 1, 2012, at the more southeastern location of Huntsville, and on March 26, 2012, at the Dallas location. Injury data (0–10: 0 = no damage, 1–3 = mild damage, 4–6 = moderate damage, 7–9 = severe damage, and 10 = dead plant) were visually determined on terminal growth of all species at 2-week intervals for 8 weeks following application.

Analysis of variance revealed a significant location main effect ($P \leq 0.05$), so data were presented separately for each location. Herbicide formulation (granular vs. liquid) main effects were not significant; therefore means were pooled across herbicide formulations for the purposes of performing means separations tests. Due to the non-parametric nature of the injury rating data (0–10 scale used for rating injury), injury rating data were transformed to ranks and analyzed with the procedures Proc Rank and Proc Mixed (SAS Institute, 2010) respectively. Means treatment separations were generated with the macro PDMIX800 with $\alpha = 0.05$ (14).

Results and Discussion

Nine of the 16 species used in the study exhibited significantly higher levels of injury than untreated controls in the new growth by the end of the 8 week trial (Tables 4 and 5) at either one or both locations. Seven species failed to exhibit any injury during the trial period, including azalea, crape myrtle, Asiatic jasmine, lantana, pittosporum, Shumard oak, and live oak. All other species showed some degree of injury, generally mild to moderate in nature (0–5), but never reaching levels that were deemed severe.

Dallas site. In the Dallas study, only three of the 13 species exhibited injury symptoms by the conclusion of the 8 week trial (Table 4). These species included 'Blue Point' juniper, Italian cypress, and viburnum. At this location, only mild injury symptoms (1 out of 10) were generally observed, appearing as early as 4 WAT in viburnum, but not until 8 WAT in juniper and Italian cypress. Injury symptoms in viburnum (Fig. 1) primarily exhibited as distorted terminal growth, occurred with both liquid and granular formulations, and did not appear to be rate-dependent, with injury appearing at both 1× and 4× rates. Italian cypress and 'Blue Point' juniper did not show injury until 8 WAT, and with these species, injury was expressed under nearly all rates and formulations. No other significant injury was noted at the Dallas location by the conclusion of the 8 week trial. It should be noted, however, that during tear-down of the trial ~12 WAT, nandina plants were noted as showing injury as distorted terminal leaves within the 4× rate treatments, but this had not been observed during the 8 week study period. Thus, damage expression may have been delayed beyond the period of this trial in some species. Distortion of new terminal growth is characteristic of synthetic auxin herbicides, which have been found to translocate in the xylem and phloem and accumulate in the meristems (7).

Huntsville site. Results from the Huntsville trial revealed greater levels of injury across the species, with 8 of the 13 species exhibiting significant levels of injury (Table 5). While injury was slightly more severe than in the Dallas study (1–6 of 10), injury was generally mild to moderate in nature, and again, no significant difference was observed between liquid or granular formulation. Similar to Dallas, injury was noted in viburnum (Fig. 1) and Italian cypress, but also in Leyland cypress, live oak, nandina, loblolly pine (Fig. 2), camellia, and privet. Also, most injured species showed a trend toward greater injury with increasing rates of aminocyclopyrachlor in the Huntsville location. Table 6 provides a relative sensitivity ranking based on the observations from both studies.

While a number of factors could be responsible for this, previous research and anecdotal field observations following use of aminocyclopyrachlor have indicated somewhat sporadic and variable injury expression. The greater extent

Table 4. **Dallas mean injury ratings at the end of the 8 week study. Visual rating scale of 0–10, with 0 = no damage, 5 = moderate damage, 10 = dead plant. Means followed by the same letter within each column are not significantly different based on LSD (P = 0.05).**

Formulation	Azalea	Juniper 'Blue Point'	Crape myrtle	Elderica pine	Italian cypress	Asiatic jasmine	Lantana	Leyland cypress	Live oak	Nandina	Pitto-sporum	Shumard oak	Viburnum
Control	0.00A	0.25C	0.00A	0.00A	0.00C	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00C
0.5 GR	0.00A	0.75B	0.00A	0.00A	1.00B	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	1.00B
0.5 AS	0.00A	1.00A	0.00A	0.00A	1.00B	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	1.00B
1 GR	0.00A	1.00A	0.00A	0.00A	1.00B	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	1.00B
1 AS	0.00A	1.00A	0.00A	0.00A	1.00B	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	1.00B
2 GR	0.00A	1.00A	0.00A	0.00A	1.00B	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	1.00B
2 AS	0.00A	1.00A	0.00A	0.00A	1.00B	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	1.25A
4 GR	0.00A	1.00A	0.00A	0.00A	1.00B	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	1.00B
4 AS	0.00A	1.00A	0.00A	0.00A	1.25A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	0.00A	1.00B
Significance	ns	*	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	*
P-value		.0001			.0001								.0001

Table 5. **Huntsville mean injury ratings at the end of the 8 week study. Visual rating scale of 0–10, with 0 = no damage, 5 = moderate damage, 10 = dead plant. Means followed by the same letter within each column are not significantly different based on LSD (P = 0.05).**

Formulation	Camellia	Crape myrtle	Loblolly pine	Italian cypress	Asiatic jasmine	Lantana	Leyland cypress	Privet
Control	0.00E	0.00A	0.00D	0.00D	0.00A	0.00A	0.00F	0.00D
0.5 GR	0.75E	0.00A	0.75BC	1.50C	0.00A	0.00A	1.25DE	0.00D
0.5 AS	0.87E	0.00A	0.25CD	0.75C	0.00A	0.00A	1.12DE	0.00D
1 GR	2.25D	0.00A	1.50B	3.12B	0.00A	0.00A	1.62D	0.00D
1 AS	0.62E	0.00A	0.87B	1.50C	0.00A	0.00A	0.75E	0.25D
2 GR	3.75CD	0.00A	4.37A	4.75A	0.00A	0.00A	3.37B	0.87C
2 AS	4.25BC	0.00A	4.87A	3.25B	0.00A	0.00A	2.62C	0.75BC
4 GR	5.75AB	0.00A	6.50A	4.87A	0.00A	0.00A	4.50A	2.62A
4 AS	6.50A	0.00A	6.00A	3.87AB	0.00A	0.00A	4.12AB	2.62AB
Significance	*	ns	*	*	ns	ns	*	*
P-value	.0001		.0001	.0001			.0001	.0001

Formulation	Live Oak	Nandina	Pittosporumm	Viburnum	Shumard oak
Control	0.00C	0.00F	0.00B	0.00D	0.00A
0.5 GR	0.00C	0.00F	0.00B	3.14BC	0.00A
0.5 AS	0.00C	0.25EF	0.20AB	1.37CD	0.00A
1 GR	0.25BC	0.62EF	0.00B	4.25B	0.00A
1 AS	0.00C	1.00DE	1.40AB	2.00C	0.00A
2 GR	0.62BC	2.00CD	2.00A	5.62A	0.00A
2 AS	0.50B	2.62BC	0.00B	4.5AB	0.00A
4 GR	1.25A	4.25AB	0.00B	5.12A	0.00A
4 AS	1.25A	5.00A	0.00B	4.87A	0.00A
Significance	*	*	ns	*	ns
P-value		.0001	.2450	.0001	

of injury observed in Huntsville suggests that various factors may contribute to damage following application in these species. Because all species were potted in a similar pine bark substrate, it seems unlikely that there would have been any potting media influences on differences in herbicide activity.

One factor that may have contributed to differences in observed injury severity between the two trials was growing conditions. Weather station data from the Huntsville study during the 56-day trial period showed average high/low temperatures during the trial of 25/15C (77/59F), with 16.11 MJ·m^{-2} solar radiation, 183 mm (7.2 in) rainfall, and 2.9 mph

Fig. 1. Distorted leaf margins on new growth of Viburnum following aminocyclopyrachlor granular application at the 4× rate. Image was taken at conclusion of the 8 week trial.

Fig. 2. Distorted terminal growth of loblolly pine following aminocyclopyrachlor granular application at the 2× rate. Image was taken at conclusion of the 8 week trial.

Table 6. Final sensitivity assessment, based on both locations, for ornamentals used including description of symptom expression.

Species	Sensitivity to MAT28	Injury description
Azalea	Low	
'Blue Point' juniper	Low to Moderate	
Camellia	Moderate	Distorted, necrotic margins of new leaves
Crape myrtle	Low	
Eldarica pine	Low	
Italian cypress	Low to moderate	Chlorotic/necrotic, wavy margins of new growth
Asiatic jasmine	Low	
Lantana	Low	
Leyland cypress	Low to moderate	Chlorotic/necrotic, wavy margins of new growth
Privet	Low	
Live oak	Low	
Loblolly pine	Moderate	Distorted, twisted, necrotic meristems
Nandina	Moderate	Rolled, necrotic margins of new leaves
Pittosporum	Low	
Shumard oak	Low	
Viburnum	Moderate	Distorted lamina with necrotic margins of new leaves

average wind speed, with a resultant potential evapotranspiration (ETo) during the period of 195 mm (7.7 in). Contrast this to Dallas, which received average high/low temps of 27/18C (80/64F), 17.35 MJ·m^{-2} solar radiation, 56 mm (2.2 in) rainfall, and 8.2 mph average windspeed, with a resultant ETo of 300 mm (11.8 in) during the study period (Table 3). The warmer, windier, and generally drier conditions at the Dallas location created higher evaporative demand and intermittent soil moisture stress which may not have been alleviated by the 3× weekly irrigation events. As a result, periodic wilt prior to irrigation events was observed during the Dallas study. Compared to Huntsville, it is possible that these conditions could have contributed to suppressed uptake and translocation of the herbicide, contributing to the less-severe injury observed at Dallas. Specific data on relationship between soil moisture and aminocyclopyrachlor efficacy are limited, however environmental conditions can influence herbicide absorption, translocation, and metabolism (13), and greater activity of the herbicide has been reported following application to wet rather than dry turf (10).

While some of the species used in the study consistently exhibited good apparent tolerance to aminocyclopyrachlor, it is clear that this compound, regardless of formulation, has the potential to cause injury to a wide range of southern adapted ornamentals. Therefore, aminocyclopyrachor should be used with caution or avoided altogether around susceptible vegetation. Injury to trees and shrubs following use of aminocyclopyrachlor has been reported in the upper Midwest United States, most notably on evergreen species including white pine. Based on the relatively short-term observations over this 8 week study, it also poses a risk to a range of southern landscape trees and shrubs at the rates used here.

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