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Potted tropical ornamental tolerance to multiple PRE herbicides

Nathan S. Boyd[1] and Shawn Steed[2]

[1]Associate Professor, University of Florida, Gulf Coast Research and Education Center, Balm, FL, USA and [2]Environmental Horticulture Production Extension Agent III, University of Florida, Seffner, FL, USA

Research Article

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Nomenclature:
Dimethenamid-P; flumioxazin; indaziflam; isoxaben; oxyfluorfen; pendimethalin; prodiamine; trifluralin; allamanda; *Allamanda schottii* Pohl.; arbicola; *Schefflera arboricola* (Hayata) Merr. 'Trinette'; bird-of-paradise; *Strelitzia reginae* Aiton; cordyline; *Cordyline fruticosa* (L.) A. Chev. 'Red Sister'; croton; *Codiaeum variegatum* (L.) A. Juss. 'Mammy'; firebush; *Hamelia patens* Jacq.; hibiscus; *Hibiscus rosa-sinensis* L. 'Painted Lady'; ixora; *Ixora coccinea* L. 'Maui Red'; philodendron; *Philodendron selloum* K. Koch; plumbago; *Plumbago auriculata* Lam. 'Dark Blue'; stromanthe; *Stromanthe sanguinea* Sond. 'Triostar'.

Keywords:
Broadleaf; container weed control; potting soil; preemergence

Author for correspondence:
Nathan S. Boyd, University of Florida, Gulf Coast Research and Education Center, 14625 County Road 672, Balm, FL 33598.
(E-mail: nsboyd@ufl.edu)

Abstract

Weeds are difficult to control in potted tropical ornamentals, especially when plants are kept for extended time periods at a nursery. Management is complicated by the lack of tolerance data for many tropical species. Experiments were conducted in 2015, 2016, and 2017 at the Gulf Coast Research and Education Center in Balm, FL, to evaluate tolerance of stromanthe, croton, philodendron, arbicola, cordyline, ixora, plumbago, allamanda, bird-of-paradise, firebush, and hibiscus to granular applications of indaziflam, flumioxazin, pendimethalin + oxyfluorfen, pendimethalin + dimethenamid-P, trifluralin + oxyfluorfen + isoxaben, and trifluralin + isoxaben, and liquid applications of prodiamine + isoxaben and dimethenamid-P. Indaziflam, pendimethalin + oxyfluorfen, and trifluralin + oxyfluorfen + isoxabin were safe for use on all evaluated ornamentals except stromanthe. Dimethenamid-P and pendimethalin + oxyfluorfen were safe on all evaluated ornamentals except allamanda. Flumioxazin damaged philodendron and bird-of-paradise but was safe on all other ornamentals tested. Trifluralin + isoxaben and prodiamine + isoxaben were safe on hibiscus, firebush, and bird-of-paradise, but prodiamine + isoxaben damaged allamanda. We have identified multiple PRE herbicides that can safely be used on multiple tropical ornamentals grown in containers.

Introduction

Florida is the second largest producer of greenhouse and nursery ornamental plants in the nation behind California (USDA 2019) with an estimated wholesale value of $2.753 billion in 2015 (Hodges et al. 2017). The value of tropical plants and palms produced in Florida nurseries for use in the state and export were estimated at $591.6 million (Hodges et al. 2017). Major production areas of the state for these crops include Miami-Dade, Broward, Palm Beach, Orange, and Hillsborough counties. Many of the woody, tropical ornamentals are grown in a nursery for at least 1 yr before being sold. Consequently, weed control is critical, especially in tropical or subtropical environments, where weeds can quickly compete with nursery crop plants.

Weed control is challenging in container-grown, ornamental crops due in part to the lack of registered POST herbicides and high crop species diversity (Stewart et al. 2007). Growers historically relied on hand weeding due to the lack of weed management tools, with costs in Florida estimated to exceed $8,889 ha^{-1} in 1974 before herbicides had been widely adopted (Weatherspoon and Currey 1975). In Alabama, 32 container nurseries were surveyed in 1990, and hand-weeding costs were estimated at $608 to $1,401 ha^{-1} following an average of three PRE herbicide applications per crop (Gilliam et al. 1990). The primary herbicides applied were oxyfluorfen + pendimethalin, oxyfluorfen + oryzalin, and oxadiazon. More recently, Mathers (2003) reported that nurseries spend as much as $9,900 ha^{-1} on hand removal of weeds. Data on the economic losses due to weeds in potted ornamentals are limited, but estimates have been as high as $17,300 ha^{-1} (Case et al. 2005).

There are few registered POST herbicides for ornamentals, and growers rely on PRE herbicides followed by hand removal of escapes. There are other effective management practices that are incorporated as a component of an integrated weed management program, such as fertilizer placement (Saha et al. 2019) and the use of mulch materials (Marble et al. 2019), but PRE herbicides remain a core component of all management programs.

A variety of PRE herbicides have been evaluated for a range of ornamentals such as grasses (Neal and Senesac 1991) and ferns (Stamps 1992). However, there is almost no published information on susceptibility of container-grown, tropical ornamentals to PRE herbicides due to the niche market of these crops. With limited tolerance data, growers rely on hand labor for weed control, which as previously noted is expensive. The objective of this research was to evaluate the tolerance of multiple container-grown, tropical ornamentals to a range of PRE herbicides currently registered for other ornamental crops that have an open label that contains a statement that the herbicide may be used "at own caution" on additional species not listed on the label.

Table 1. Herbicide treatments and estimated costs of herbicides evaluated for PRE weed control in potted tropical ornamentals at the Gulf Coast Research and Education Center, Balm, FL, in 2015, 2016, and 2017.

Common name	Trade name	Rate	Manufacturer	Price[a]
		kg ai ha^{-1}		\$ ha^{-1}
Indaziflam	Spect(i)cle® G[b]	0.05	Bayer Environmental Science, Cary, NC 27513	919
Indaziflam	Spect(i)cle® G[b]	0.10	Bayer Environmental Science, Cary, NC 27513	1,838
Flumioxazin	Broadstar™	0.42	Valent U.S.A. Corporation, Walnut Creek, CA 94569	722
Flumioxazin	Broadstar™	0.84	Valent U.S.A. Corporation, Walnut Creek, CA 94569	1,444
Dimethenamid-P	Tower®	1.68	BASF Corporation, Research Triangle Park, NC 27709	183
Dimethenamid-P	Tower®	3.36	BASF Corporation, Research Triangle Park, NC 27709	366
Pendimethalin + oxyfluorfen	OH2®	1.12 + 2.24	Everris NA Inc., Dublin, OH 43016	593
Pendimethalin + oxyfluorfen	OH2®	2.24 + 4.48	Everris NA Inc., Dublin, OH 43016	1,186
Dimethenamid-P + pendimethalin	Freehand 1.75G®	1.68 + 2.24	BASF Corporation, Research Triangle Park, NC 27709	884
Dimethenamid-P + pendimethalin	Freehand 1.75G®	3.36 + 4.48	BASF Corporation, Research Triangle Park, NC 27709	1,768
Trifluralin + oxyfluorfen + isoxaben	Showcase®	4.48 + 0.56 + 0.56	Dow AgroSciences LLC, Indianapolis, IN 46268	835
Trifluralin + oxyfluorfen + isoxaben	Showcase®	8.96 + 1.12 + 1.12	Dow AgroSciences LLC, Indianapolis, IN 46268	1,670
Trifluralin + isoxaben	Snapshot®	4.48 + 1.12	Dow AgroSciences LLC, Indianapolis, IN 46268	973
Trifluralin + isoxaben	Snapshot®	8.96 + 2.24	Dow AgroSciences LLC, Indianapolis, IN 46268	1,946
Prodiamine + isoxaben	Gemini 3.7 SC	1.67 + 1.14	Everris NA Inc., Dublin, OH 43016	622
Prodiamine + isoxaben	Gemini 3.7 SC	3.34 + 2.28	Everris NA Inc., Dublin, OH 43016	1,244

[a]Prices are based on quotes from distributors in 2019.
[b]Spect(i)cle® G and Marengo® G have the same active ingredient at the same concentration. Marengo® G is marketed for weed control in production ornamentals, shade houses, hoop houses, and hardscapes, whereas Spect(i)cle® G is primarily marketed for landscapes.

Materials and Methods

General Methodology

All experiments occurred at the Gulf Coast Research and Education Center in Balm, FL. A complete list of herbicides and herbicide rates used in the following experiments are listed in Table 1. Granular herbicides were evenly applied over the plants using a handheld shaker. Leaves were lightly shaken following application to remove granules. Liquid herbicides were applied using a handheld CO_2-pressurized sprayer equipped with TeeJet® 8002VS nozzles (TeeJet Technologies, Springfield, IL, USA 62703). The herbicides were applied in 187 L ha^{-1} of water at 241 kPa. All pots were irrigated with overhead irrigation immediately following herbicide application.

Crotons, Philodendrons, and Stromanthe

Experiments were conducted in 2015 to evaluate multiple PRE herbicides for efficacy and safety on stromanthe, croton, and philodendron. The experiment was set up as a randomized complete block design in four blocks and then repeated. Each replicate was a single potted ornamental. All ornamentals were potted by a commercial grower in 3.785-L pots filled with 20% peat, 20% 1.9 cm pine bark, 50% 2.54 cm pine bark, 5% composted bark, and 5% compost manufactured by Reliable Peat Company (Leesburg, FL). The potting soil also contained 907 g of minor nutrients, 72 g bifenthrin granular insecticide, and 907 g gypsum per 0.76 m^3 amended to a pH of 6.0 to 6.5. Philodendrons were seedling liners, stromanthe were rooted rhizomes, and crotons were unrooted cuttings from Costa Rica. Pots were transported to GCREC 30 d after potting on March 25, 2015. Upon arrival, 14 ml of a time-release fertilizer (Nutricote 18-6-8 100 day; Florikan ESA, Sarasota, FL) was added to each pot. The first herbicide treatments were applied on April 1, 2015, followed by the second application on May 27, 2015 (~8 wk after treatment [WAT]).

Arbicola, Cordyline, Ixora, and Plumbago

Experiments were conducted in 2015 to evaluate multiple PRE herbicides for efficacy and safety on arbicola, cordyline, ixora, and plumbago. The experiment was set up as a randomized complete block design in four blocks and then repeated. Each replicate was a single potted ornamental. All ornamentals were potted in 3.785-L pots filled with 55% peat and 45% pine bark. (Harrells Inc., Lakeland, FL 33815). The potting soil also contained minor nutrients and 454 g dolomite per 0.76 m^3. All pots also received 14 ml of time-release fertilizer (Nutricote 18-6-8 100 day; Florikan ESA). Each herbicide treatment was applied twice, with the first application on March 28, 2016, followed by the second application on June 9, 2016 (~9 WAT).

Allamanda, Bird-of-Paradise, Firebush, and Hibiscus

Experiments were conducted in 2017 to evaluate efficacy and crop safety of multiple PRE herbicides on allamanda, bird-of-paradise, firebush, and hibiscus. The experiment was set up as a randomized complete block design in five blocks and then repeated. Each replicate was a single potted ornamental. All ornamentals were potted in 3.785-L pots filled with 25% Florida Peat and 75% 1.9 cm bark (Reliable Peat Company). The potting soil also contained minor nutrients and 454 g dolomite per 0.76 m^3. Plants were fertilized with slow-release fertilizer (Nutricote 18-6-8 as needed; Florikan ESA). Each herbicide treatment was applied twice, with the first application on March 14, 2017, followed by the second application on May 17, 2017 (~9 WAT).

Data Collection

Data collection consisted of visual damage ratings at 4 wk after the first herbicide application and damage ratings at 2, 4, and 8 wk after the second herbicide application. Damage ratings were based on a 0 to 100 scale, where 0 was no damage and 100 was complete shoot death. Plant heights and plant widths at the widest point were measured the day before herbicide applications and at 8 wk after the first and second herbicide applications.

Data Analysis

The data were analyzed in SAS (SAS, Cary, NC 27513) using Proc Mixed, with block as the random factor. Damage ratings, heights, and plant widths were analyzed using the repeated statement, and

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Table 2. The height and width (widest point) of potted tropical ornamentals immediately before applying PRE herbicides at the Gulf Coast Research and Education Center, Balm, FL.

Species	Height	SE	Diameter	SE
	cm		cm	
Allamanda	12.0	0.30	14.2	0.41
Arbicola	11.5	0.20	—	—
Bird of paradise	7.91	0.44	11.6	0.19
Cordyline	27.8	0.38	—	—
Croton	21.70	0.22	24.0	0.25
Firebush	9.1	0.39	13.5	0.31
Hibiscus	22.9	0.42	21.0	0.39
Ixora	6.7	0.15	—	—
Philodendron	23.3	0.26	30.8	0.37
Plumbago	10.7	0.19	—	—
Stromanthe	22.3	0.51	33.5	0.41

Table 3. Herbicide damage and weed density in three potted tropical ornamentals following PRE herbicide applications at the Gulf Coast Research and Education Center, Balm, FL, in 2015.

		Herbicide damage[a]		
Herbicide	Rate	Croton	Philodendron	Stromanthe
	kg ai ha^{-1}		%	
Nontreated	—	0	2 ab	18 b
Indaziflam	0.05	0	2 ab	21 ab
Indaziflam	0.10	0	2 ab	28 a
Flumioxazin	0.42	0	3 ab	26 ab
Flumioxazin	0.84	0	3 a	24 ab
Dimethenamid-P	1.68	0	2 ab	20 ab
Dimethenamid-P	3.36	0	1 b	23 ab
Pendimethalin + oxyfluorfen	1.12 + 2.24	0	2 ab	28 a
Pendimethalin + oxyfluorfen	2.24 + 4.48	0	2 ab	22 ab
Dimethenamid-P + pendimethalin	1.68 + 2.24	0	1 b	20 ab
Dimethenamid-P + pendimethalin	3.36 + 4.48	0	3 ab	18 b
Trifluralin + oxyfluorfen + isoxaben	4.48 + 0.56 + 0.56	0	2 b	28 a
Trifluralin + oxyfluorfen + isoxaben	8.96 + 1.12 + 1.12	0	2 ab	20 ab
P-value		0.9849	0.0006	<0.0001

[a]Damage ratings are an average of ratings taken 2, 4, and 8 wk after the first and second herbicide applications. Means within a column followed by different letters are significantly different at $P < 0.05$.

means are compared using the LSMEANS statement in SAS for means comparisons. Data were tested for normality and constant variance before analysis.

Results and Discussion

Croton, Philodendron, and Stromanthe

Plant heights and widths at herbicide application are reported in Table 2. None of the herbicides evaluated stunted any of the ornamentals tested in this study. Plant height and width of all species at 8 wk after the first and second herbicide applications were not significantly different from those of the nontreated control (data not shown). There were no time by treatment interactions on damage ratings, so damage ratings are averaged over time (Table 3). No damage was observed on any of the crotons throughout the trial. Minor flumioxazin damage was observed on the philodendrons, but damage ratings were not significantly different from those for the nontreated control. Damage consisted of necrotic tissue at the base of petioles when herbicide granules were trapped. Damage symptoms remained visible until leaf senescence and drop due to natural plant growth. The stromanthe plants used in the study had necrotic patches on the leaves due to an unknown fungal pathogen with necrosis on 18% of the leaf tissue based on visual estimates in the nontreated controls (Table 3). Significantly more necrotic leaf tissue was observed on stromanthe where indaziflam, pendimethalin + oxyfluorfen, and trifluralin + oxyfluorfen + isoxaben were applied at the lower rate, but damage was not observed when the herbicide rate was doubled. The reason for this is unknown. We cannot be certain how healthy stromanthe plants would respond to indaziflam, pendimethalin + oxyfluorfen, and trifluralin + oxyfluorfen + isoxaben, but our results indicate that these products may cause damage. Further research is recommended.

Arbicola, Cordyline, Ixora, and Plumbago

None of the herbicides evaluated in this study affected plant growth in terms of height and width. The height and width of all species at 8 wk after the first and second herbicide applications were not significantly different from those of the nontreated control. There were no time by treatment interactions on damage ratings, so damage ratings are averaged over time. All herbicides caused little to no significant damage on arbicola, ixora, and plumbago (Table 4). Flumioxazin damage was noted on some cordyline plants, although ratings were not significantly different from those for the nontreated control. The damage occurred where granules were

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Table 4. Herbicide damage and weed density in four potted tropical ornamentals following PRE herbicide applications at the Gulf Coast Research and Education Center, Balm, FL, in 2016.

Herbicide	Rate	Herbicide damage[a]			
		Arbicola	Cordyline	Ixora	Plumbago
	kg ai ha^{-1}	%			
Nontreated	—	0	0	0	2
Indaziflam	0.05	0	0	0	2
Indaziflam	0.10	0	5	0	4
Flumioxazin	0.42	0	14	0	1
Flumioxazin	0.84	0	27	0	1
Dimethenamid-P	1.68	0	0	0	0
Dimethenamid-P	3.36	0	0	0	0
Pendimethalin + oxyfluorfen	1.12 + 2.24	0	5	0	5
Pendimethalin + oxyfluorfen	2.24 + 4.48	0	4	0	5
Dimethenamid-P + pendimethalin	1.68 + 2.24	0	0	0	3
Dimethenamid-P + pendimethalin	3.36 + 4.48	0	0	0	1
Trifluralin + oxyfluorfen + isoxaben	4.48 + 0.56 + 0.56	0	0	0	2
Trifluralin + oxyfluorfen + isoxaben	8.96 + 1.12 + 1.12	0	0	0	3
P-value[b]		—	—	—	—

[a]Damage ratings are an average of ratings taken 2, 4, and 8 wk after the first and second herbicide applications. Means within a column followed by different letters are significantly different at $P < 0.05$.
[b]Data could not be normalized due to the large number of zeros and therefore were not analyzed.

Table 5. Herbicide damage on four potted tropical ornamentals following PRE herbicide applications at the Gulf Coast Research and Education Center, Balm, FL, in 2017.[a]

Herbicide	Rate	Herbicide damage[a]			
		Allamanda	Bird of paradise	Firebush	Hibiscus
	kg ai ha^{-1}	%			
Nontreated	—	0 f	13 bc	0 e	0
Indaziflam	0.05	2 ef	4 d	0 e	0
Indaziflam	0.10	0 f	3 d	1 e	0
Flumioxazin	0.42	2 ef	9 bcd	27 c	0
Flumioxazin	0.84	1 ef	23 a	66 a	0
Dimethenamid-P	1.68	13 bcd	8 cd	10 de	0
Dimethenamid-P	3.36	46 a	4 cd	39 b	0
Pendimethalin + oxyfluorfen	1.12 + 2.24	11 de	4 d	0 e	0
Pendimethalin + oxyfluorfen	2.24 + 4.48	2 ef	8 cd	3 e	0
Dimethenamid-P + pendimethalin	1.68 + 2.24	22 bc	18 ab	14 d	0
Dimethenamid-P + pendimethalin	3.36 + 4.48	7 def	11 bcd	44 b	0
Trifluralin + oxyfluorfen + isoxaben	4.48 + 0.56 + 0.56	2 ef	9 bcd	3 e	0
Trifluralin + oxyfluorfen + isoxaben	8.96 + 1.12 + 1.12	1 ef	6 cd	0 e	0
Trifluralin + isoxaben	4.48 + 1.12	1 ef	6 cd	0 e	0
Trifluralin + isoxaben	8.96 + 2.24	1ef	10 bcd	0 e	0
Prodiamine + isoxaben	1.67 + 1.14	13 cd	3 d	17 cd	0
Prodiamine + isoxaben	3.34 + 2.28	23 b	4 cd	58 a	0
P-value		<0.0001	0.0002	<0.0001	—

[a]Damage ratings for allamanda and firebush are averaged across damage observed at 4 and 8 wk after the second application due to the lack of damage observed in earlier ratings, and damage ratings for bird-of-paradise and firebush are averaged across all damage ratings. Means within a column followed by different letters are significantly different at $P < 0.05$.

trapped and persisted for extended periods of time and would likely be a concern for growers.

Allamanda, Bird-of-Paradise, Firebush, and Hibiscus

Dimethenamid-P at both rates, 1.68 + 2.24 kg ha^{-1} pendimethalin + dimethenamid-P, 1.12 +2.24 pendimethalin + oxyfluorfen, and both rates of prodiamine + isoxaben caused significantly greater allamanda damage than seen in the nontreated control (Table 5). All plants recovered by the end of the experiment, but given the high rate of damage, we conclude that dimethenamid-P is not safe for use on allamanda. In addition, the lack of damage observed when isoxaben was mixed with other active ingredients would suggest that prodiamine was the source of the damage in isoxaben and prodiamine mixes. The remainder of the herbicides did not cause damage. None of the herbicides caused significant levels of damage in bird-of-paradise plants, but the 23% damage observed following flumioxazin applications at the highest rate is a concern, because the damaged tissue did not recover and resulted in leaf senescence. Both rates of flumioxazin, 3.36 kg ha^{-1} dimethenamid-P, pendimethalin + dimethenamid-P, and prodiamine + isoxaben caused significant firebush damage when compared with the nontreated control, and the damage tended to increase with application rate. Damage symptoms persisted throughout the duration of the trial. All other herbicides were safe for use. None of the herbicides evaluated damaged hibiscus. Porter (1996) also reported that isoxaben was safe on hibiscus.

Our results clearly indicate that established tropical ornamentals in containers are not damaged by a wide range of PRE herbicides when applied under conditions similar to those established for the experiments. This information will provide growers with new weed management tools for tropical ornamentals.

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