Diuron: Postemergence Oxalis Control in Container-grown Plants[1]

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Abstract

Three experiments were conducted to evaluate the effectiveness of postemergence applied diuron (Direx 4L) for oxalis control and crop safety in container nursery crops. The first experiment, treated on March 15, 2001, evaluated diuron at 0.14, 0.28, 0.56, and 1.12 kg ai/ha (0.125, 0.25, 0.5, and 1.0 lb ai/A) rates without a surfactant and provided a maximum of 74% oxalis control in liriope and 57% in camellia. Diuron caused slight to no injury on 'Pink Icicle' camellia, 'Anthony Waterer' spirea and 'Big Blue' liriope which dissipated completely by 60 DAT. Experiment two, treated on April 6, 2001, used higher rates and included a surfactant. Diuron provided excellent oxalis control at rates ≥ 0.56 kg ai/ha (0.5 lb ai/A) by 21 days after treatment (DAT) and reduced oxalis shoot fresh weight (SFW) and shoot dry weight (SDW) by ≥ 95%. Unlike the first experiment, no injury was observed on either liriope or camellia. Experiment three, treated on April 15, 2001, evaluated diuron rate and oxalis size on oxalis control. At 9 DAT a significant diuron rate × oxalis size interaction occurred, but at 15 and 21 DAT only diuron rate affected oxalis control for the sizes of oxalis tested. At 21 DAT, rates of 0.56 kg ai/ha (0.5 lb ai/A) and higher provided excellent oxalis control. These data indicate that diuron provides excellent oxalis control when applied postemergence in tolerant nursery crops.

Index words: diuron, herbicide, container production, weed control.

Herbicide used in this study: Direx 4L (diuron), 3-(3, 4-dichlorophenyl)-1, 1-dimethyl urea.

Species used in this study: Camellia (*Camellia japonica* 'Pink Icicle'); 'Big Blue' liriope (*Liriope muscari* L.H.B.); 'Anthony Waterer' spirea (*Spiraea* x *bumalda* 'Anthony Waterer'); and Yellow wood sorrel (*Oxalis stricta* L.).

Significance to the Nursery Industry

Oxalis is a difficult to control weed in container nurseries; thus growers are often forced to resort to hand removal. Results of this research indicate diuron has potential to control oxalis when applied postemergence over-the-top to dormant camellia, liriope and spirea at rates as low as 0.56 kg ai/ha (0.5 lb ai/A), while causing slight to no crop injury when applied as an over–the-top spray before active growth of the nursery crop begins. Diuron may provide growers with an alternative to hand-weeding, especially when container-grown nursery crops are emerging from over-wintering and oxalis, a cool season weed, is problematic. Additional work is evaluating other landscape crops for tolerance to diuron and time of application.

Introduction

Consumers demand weed free container grown plants. Labor for hand weeding of containers is expensive and increasingly difficult to find. With increasing costs and declining profit margins, growers have been forced to search for nontraditional weed control methods to reduce costs and produce an economically competitive weed free crop. In the past, growers demanded that herbicides have broad-spectrum control and crop safety. However, many growers now accept herbicides that have tolerance in a few crops or that control a single weed species, i.e., bittercress (*Cardimine hirsuta* L), spurge (*Chamaesyce prostrata* Ait.), or oxalis (*Oxalis spp.* L). Many growers are also willing to accept limited crop injury from herbicides that effectively control weeds; in particular, if the resultant injury is early in the crop cycle and the crop completely recovers in a short time period. This is especially true with herbicides that control weeds postemergence; thus, possibly eliminating a hand weeding process at some point in the production cycle.

One area where postemergence-applied herbicides have potential is when nursery crops are emerging from over-wintering. Frequently, conditions in late winter favor development of winter weeds, such as oxalis and bittercress (8), while the nursery crop is still dormant, but the winter weed is actively growing. A postemergence herbicide with selective tolerance could provide growers economic relief from a crop that requires hand weeding. Recent research has demonstrated success with postemergence weed control in container-grown nursery crops. Studies by Altland, et al., (2, 3) evaluated Gallery (isoxaben) for postemergence control of bittercress. Bittercress control was influenced by Gallery rate and bittercress size, control was greater on smaller, non-flowering bittercress. Gallery at 1.12 kg ai/ha (1.0 lb ai/A) was required for excellent control of small and intermediate size bittercress, and a rate of 2.24 kg ai/ha (2.0 lb ai/A) was required for excellent control of larger, flowering bittercress. Other research demonstrated Roundup (glyphosate) and Finale (glufosinate) could control prostrate spurge (*Chamaesyce prostrata* Ait.) when applied at 1.8 kg ai/ha (1.6 lb ai/A) and 1.12 kg ai/ha (1.0 lb ai/A) respectively, with minimal injury to two liriope cultivars (4).

Limited research evaluating postemergence control of *Oxalis stricta* L. has been conducted in the southeastern United States. Oxalis is generally considered to be a cool season weed but may occur throughout the entire growing

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season under over-head irrigation in many parts of the United States. A 1990 survey of nurserymen reported that oxalis was considered to be among the most difficult to control in containers (10). While preemergence herbicide applications provide adequate control of oxalis, no method is 100 percent effective (7, 15). Hand-weeding is difficult due to the weed prolifically seeding and favorable growing conditions in container nurseries (8). Research by Holt and Chism (12) found the growth regulator napthaleneacetic acid (NAA) could be used to control *Oxalis corniculata* L. Several landscape crops had tolerance to NAA applications; however, impractical rates of 8.4 kg ai/ha (7.5 lb ai/A) were required to provide excellent control. Another herbicide with potential to provide postemergence oxalis control is diuron (11, 13). A Georgia grower discovered, in a non-scientific trial, that diuron provided excellent control of oxalis postemergence with little to no injury on container-grown camellias. The objective of this study was to evaluate diuron for postemergence oxalis control, and tolerance of selected nursery crops to diuron.

Materials and Methods

Three experiments were conducted at Auburn University, AL, to evaluate diuron (Direx 4L Griffin Chemical Co. Griffin, GA) for nursery crop tolerance and postemergence oxalis control. Treatments were applied with a CO_2 backpack sprayer equipped with an 8004 flat fan nozzle. Applications were made with a pressure of 1.41 kg/cm (20 psi) and calibrated to deliver 340 liters/ha (40 gal/A). The substrate used in all experiments consisted of pinebark:sand (7:1, v/v) amended per m^3 (yd^3) with 8.3 kg (14 lb) of Osmocote 17N–3.1P–10K (17N–7P–12K, Scotts Co., Marysville, OH), 3.9 kg (5.0 lb) of dolomitic limestone, and 0.9 kg (1.5 lb) of Micromax (Scotts Co.). All data were analyzed with regression analysis and Dunnett's test or Duncan's multiple range test where appropriate (16).

Experiment 1. On March 15, 2001, one-year-old camellia (*Camellia japonica* 'Pink Icicle') grown in 47% shade in trade gallon containers, one-year-old liriope (*Liriope muscari* 'Big Blue') grown in full sun in square 10.2 cm (4 in) containers, and spirea (*Spiraea* x *bumalda* 'Anthony Waterer') grown in full sun in 3.8 liter (#1) containers were evaluated for diuron tolerance. Spirea were potted from liners three days prior to treatment. Camellia and Liriope each contained native uniform populations of oxalis (*Oxalis stricta*) [7–12 cm (2.8–4.7 in) tall, flowering, with a few seed pods present]. Treatments included four rates of diuron (0.14, 0.28, 0.56, and 1.12 kg ai/ha) (0.125, 0.25, 0.5, and 1.0 lb ai/A) and a non-treated control. At the time of treatment, camellia and liriope were dormant, while spirea liners were actively growing. All treatments consisted of eight single-plant replications in a completely randomized design (CRD) with species grouped separately. Irrigation was withheld after application for about 20 hours. Data collected included visual oxalis control ratings from 0 to 100 (0 = no control and 100 = complete control) at 15 and 21 days after treatment (DAT), oxalis shoot fresh weight (SFW) and dry weight (SDW) at 21 DAT, as described by Frans, et al. (9). Nursery crop injury ratings from 1 to 10 (1 = no injury and 10 = plant death) were determined on 15 and 21 DAT and monthly thereafter for six months. Liriope and spirea SFW and SDW were recorded seven months after treatment. All plants with a crop injury rating greater than three were considered unmarketable.

Experiment 2. On April 6, 2001, one-year-old camellia grown in 47% shade and liriope (same varieties as the first experiment) grown in full sun, both in trade gallon containers also containing native uniform populations of oxalis [6–13 cm (2.4–5.1 in) tall, flowering, and seed pods present], were treated with four rates of diuron (0.28, 0.56, 1.12, and 2.24 kg ai/ha) (0.25, 0.5, 1.0, and 2.0 lb ai/A) and a non-treated control. This experiment represents an increase in the diuron rate used and included non-ionic surfactant (X-77, Loveland Industries, Greely, CO) at 0.25% (by vol). At the time of treatment, camellia and liriope were just beginning to emerge from dormancy. All treatments consisted of eight single-plant replications in a CRD with species grouped separately. Irrigation was withheld until the next day (about 16 hours). Data was collected in a similar manner to Experiment 1.

Experiment 3. Three sets of 50 trade gallon containers filled with substrate and placed in full sun were over-seeded with 25 oxalis seed each at two week intervals beginning in late February. At the time of treatment, small oxalis were 3–9 cm (1.2–3.5 in) tall and 7–10 cm (2.8–3.9 in) wide, with some flowering. Medium oxalis were 13–15 cm (5.1–5.9 in) tall and 17–22 cm wide (6.7–8.7 in), with flowers, and starting to set seed. Large oxalis were 20–30 cm (7.9–11.8 in) tall and 20–30 cm (7.9–11.8 in) wide, with flowers and many seed pods. On April 30, 2001, the three oxalis sizes were treated in a factorial arrangement with four rates of diuron (0.28, 0.56, 1.12, and 2.24 kg ai/ha) (0.25, 0.5, 1.0, and 2.0 lb ai/A) and a non-treated control arranged in a CRD. There were eight single pot replications per treatment combination. A non-ionic surfactant was included (X-77) at 0.25% (by vol). Irrigation was withheld until the following day (approximately 16 hours). Data collected included visual oxalis control ratings 9, 15, and 21 DAT, and oxalis SFW and SDW 21 DAT.

Results and Discussion

Experiment 1. At 21 DAT diuron caused only slight injury to liriope. Injury was characterized as marginal chlorosis on some leaf tips (Table 1). However, by 60 DAT all visual injury had dissipated, and only a slight difference in liriope SFW and SDW compared to non-treated plants was detected seven months after treatment. With oxalis control in liriope, maximum control was achieved with the 1.12 kg ai/ha (1.0 lb ai/A) rate, which provided 74% oxalis control at 21 DAT, and 79% reduction in oxalis SFW (Table 2). Oxalis control increased linearly with increasing diuron rate. By 21 DAT diuron caused slight but significant initial injury to camellia with injury increasing linearly with increasing diuron rate. Injury was characterized by marginal chlorosis on leaf tips. In camellia, maximum oxalis control was achieved with the 1.12 kg ai/ha (1.0 lb ai/A) rate, which provided 57% oxalis control at 21 DAT, and 62% reduction in oxalis SFW. Oxalis control increased linearly with increasing diuron rate. By 60 DAT all camellia had completely outgrown signs of visual injury. Moderate control ratings were attributed to the absence of surfactant in the spray for this experiment. In spirea, diuron caused only slight injury to all treated plants by 21 DAT with injury increasing linearly with increasing diuron rate (Table 3). Injury was characterized by marginal chlorosis of leaves. However, plants fully recovered by 60 DAT and were considered marketable by the end of the study. Seven

Table 1. Effect of diuron on injury to container-grown 'Big Blue' liriope, 'Anthony Waterer' spirea and 'Pink Icicle' camellia in Experiment 1.

Herbicide	Rate (kg ai/ha)	Liriope				Spiraea			Camellia
		15 DAT[z]	21 DAT	SFW[u] (g)	SDW (g)	21 DAT	SFW (g)	SDW (g)	21 DAT
Diuron	0.14	1.0a[xy]	2.1b	71ab	18.7ab	2.0b	248.3a	105.5a	1.0a
Diuron	0.28	1.3a	2.4b	70ab	18.3ab	1.9b	239.4ab	96.4ab	2.1a
Diuron	0.56	1.4ab	2.6b	61b	16.6b	1.7b	221.4ab	95.1ab	2.1a
Diuron	1.12	1.0a	2.5b	63b	16.2b	2.2c	193.0b	82.8b	2.5a
Significance[w]		NS[v]	NS	NS	NS	L*	L**	L**	NS
Non treated control		1.0a	1.0a	70ab	18.1ab	1.0a	231.1ab	93.2ab	1.0a

[z]DAT, SFW and SDW, days after treatment, shoot fresh weight and shoot dry weight, respectively.
[y]Where 1 = no injury and 10 = plant death.
[x]Means followed by same letter are not significantly different (Duncan's Multiple Range Test: $\alpha = 0.05$).
[w]Indicates if there was a rate response to Direx.
[v]NS and L represent not significant and linear respectively; * indicates significance at the 0.05 level.

months after treatment, spirea SFW and SDW decreased linearly with increasing diuron rate. However, spirea SFW and SDW were not different compared to non-treated plants with the exception of the 1.12 kg ai/ha (1.0 lb ai/A) rate. Oxalis control in liriope grown in full sun was higher than oxalis control in camellia grown in 47% shade. While not compared statistically, oxalis control was likely influenced by the amount of sunlight they received, which is supported by laboratory research where substituted urea-induced phytotoxicity was light dependent (5).

Experiment 2. At 21 DAT liriope and camellia plants treated with diuron had reduced oxalis growth compared to non-treated plants (Table 2). Rates of 0.56 kg ai/ha (0.5 lb ai/A) and higher provided excellent oxalis control (95 to 100%) in liriope and caused 95% or greater reductions of oxalis SDW, compared to non-treated plants. Oxalis control in liriope responded quadratically to increasing diuron rates. Rates of 0.56 kg ai/ha (0.5 lb ai/A) and higher provided good-to-excellent oxalis control (83 to 99%) in camellia, and caused 96% or greater reductions of oxalis SDW, compared to non-treated plants. Oxalis control in camellia responded linearly to increasing diuron rates. Unlike the first experiment, diuron did not injure either liriope or camellia. Improvement in oxalis control over the first experiment was attributed to the surfactant addition. This concurs with data reported by Singh et al. (18) and Hill et al. (11), who reported use of surfactants increased the postemergence activity of diuron by up to 70%.

Table 2. Effect of postemergence applied diuron on oxalis control in container-grown liriope and camellia.

Herbicide	Rate (kg ai/ha)	Oxalis in liriope			Oxalis in camellia		
		21 DAT[y]	SFW (g)	SDW (g)	21 DAT	SFW (g)	SDW (g)
Experiment 1[z]							
Diuron	0.14	28[x]	9.9	1.1	17	11.5	1.2
Diuron	0.28	35	6.1	0.6	28	11.5	0.9
Diuron	0.56	49	5.6	0.6	44	7.3	0.6
Diuron	1.12	74	2.3	0.3	57	6.0	0.4
Significance[w]		L***[v]	L***	L**	L***	L*	L*
Non-treated		0	10.6	1.6	0	15.6	1.9
Experiment 2							
Diuron	0.28	50	9.2	0.1	64	5.5	0.8
Diuron	0.56	95	1.7	0.0	83	1.5	0.2
Diuron	1.12	98	1.7	0.0	98	0.7	0.0
Diuron	2.24	100	0.0	0.0	99	0.0	0.0
Significance		Q***	Q***	NS	L*	L*	L*
Non-treated		0	23.2	2.4	0	28.7	4.3

[z]Experiment 1 treated on 03/15/2001 without surfactant, and Expt. 2 treated on 04/06/01 with 0.25% (v/v) X-77 surfactant.
[y]DAT, SFW and SDW, days after treatment, shoot fresh weight and shoot dry weight, respectively.
[x]Where 0% = no injury and 100% = plant death.
[w]Indicates if there was a rate response to diuron.
[v]NS, L, and Q represent not significant, linear and quadratic responses, respectively.
*,**,*** indicates significance at the 0.05, 0.01,and 0.001 level, respectively.

Table 3. Effect of diuron on injury to container-grown 'Anthony Waterer' spirea in Experiment 1.

Herbicide	(kg ai/ha)	15 DAT[z]	21 DAT	60 DAT	215 DAT	SFW (g)	SDW (g)
Diuron	0.14	1.3[y]	2.0[x]	1.0	1.0	248.3	105.5
Diuron	0.28	1.3	1.9[x]	1.0	1.0	239.4	96.4
Diuron	0.56	1.4[x]	1.7[x]	1.0	1.0	221.4	95.1
Diuron	1.12	1.3	2.2[x]	1.0	1.0	193.0[x]	82.8[x]
Significance[w]		NS[v]	L*	NS	NS	L**	L**
Non-treated		1.0a	1.0	1.0	1.0	231.1	93.2

[z]DAT, SFW and SDW, days after treatment, shoot fresh weight and shoot dry weight, respectively.
[y]Where 1 = no injury and 10 = plant death.
[x]Injury rating significantly higher than non-treated (Dunnett's Test: $\alpha = 0.05$).
[w]Indicates if there was a rate response to diuron.
[v]NS, and L represent not significant and linear responses, respectively.
*,** indicates significance at the 0.05 and 0.01 level, respectively.

Table 4. Effect of diuron rate and oxalis size on postemergence oxalis control Experiment 3.

		Visual oxalis control (%)[z]					
		Diuron rate (kg ai/ha)					
	Oxalis size	Non-treated	0.28	0.56	1.12	2.24	Significance[w]
9 DAT[y]	small (3 to 9 cm)	0a[x]	52a	100a	92a	91a	L**, Q**[v]
	medium (13 to 15 cm)	0a	38a	68b	60b	78b	L**
	large (20 to 30 cm)	0a	40a	50c	68b	62b	L***,Q***
15 DAT	small (3 to 9 cm)	0a	39a	100a	100a	100a	L***,Q***
	medium (13 to 15 cm)	0a	44a	94b	96a	100a	L***,Q***
	large (20 to 30 cm)	0a	56a	93b	98a	99a	L***,Q***
21 DAT	small (3 to 9 cm)	0a	22a	100a	100a	100a	L***,Q***
	medium (13 to 15 cm)	0a	36a	92a	100a	100a	L**,Q***
	large (20 to 30 cm)	0a	52a	100a	100a	100a	L***,Q***

[z]Where 0% = no injury and 100% = plant death.
[y]Days after treatment.
[x]Means followed by same letter in a column are not significantly different within a given date. (Duncan's Multiple Range Test: $\alpha = 0.05$).
[w]Indicates if there was a rate response to diuron.
[v]L, and Q represent linear and quadratic responses, respectively.
,* indicates significance at the 0.01and 0.001 level, respectively.

Experiment 3. A diuron rate × oxalis size interaction was detected at 9 DAT. However, at 15 and 21 DAT only diuron rate affected oxalis control (Table 4). Among all oxalis sizes, there were linear and/or quadratic rate responses to diuron at 9, 15, and 21 DAT. Initially diuron injury to oxalis was characterized by leaf chlorosis and curling followed by complete desiccation. By 15 DAT rates greater than 0.56 kg ai/ha (0.5 lb ai/A) provided excellent (96–100%) oxalis control over all three oxalis sizes. The 0.28 kg ai/ha (0.25 lb ai/A) rate provided low weed control (22–52%), 21 DAT, with oxalis recovering from injury. These data are in contrast to those reported by Altland et al. (3) with bittercress, where smaller non-flowering bittercress were controlled with Gallery at 0.56 kg ai/ha (0.5 lb ai/A) while mature flowering bittercress required 2.24 kg ai/ha (2.0 lb ai/A) for adequate control.

In summary, these data show that diuron provides excellent oxalis control when applied postemergence in tolerant nursery crops. Additional crop tolerance may be achieved when plants are not actively growing (i.e., late fall or early spring), or as reported by Ahrens et al. (1) and Barolli et al. (6) by irrigating soon after application is made. These differ from research conducted by Kumar and Singh (13) who obtained only minimal control (60% with 1.5 kg ai/ha) with diuron on a related species (*Oxalis latifolia* L.) in field experiments. Looman and Van Kuik (14) reported diuron provided lasting preemergence control when applied as a granular formulation with tolerance in several nursery crops. Therefore, diuron application for postemergence oxalis control may also provide some residual preemergence oxalis control. Diuron, more commonly used as a directed or preemergence applied herbicide in cotton and in fruit orchards, is not currently registered for use in nursery crops.

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