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Growth Stage and Time of the Year Effects on Nursery Crop Tolerance to Diuron[1]

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Abstract

Four experiments were conducted to evaluate the tolerance of three landscape crops to over the top spray applications of diuron. Rates ≥ 0.56 kg ai/ha (0.5 lb ai/A) provided excellent (100%) yellow woodsorrel control regardless of the time of year the treatment was made. Diuron applications ≤ 1.12 kg ai/ha (1.0 lb ai/A) in fall and spring caused slight to no injury to dormant abelia, barberry, and spirea. Plants leafed out normally in the spring after application and there was no difference in growth 180 days after treatment (DAT). Application at 2.24 kg ai/ha (2.0 lb ai/A) caused slight to no injury on abelia, moderate injury to spirea, and severe injury to barberry by the following spring. Spring application to actively growing abelia and spirea caused slight to moderate injury from which plants treated with ≤ 0.56 kg ai/ha (0.5 lb ai/A) completely recovered by 90 DAT. Abelia treated with 1.12 kg ai/ha (1.0 lb ai/A) were slightly injured 90 DAT, and spirea were moderately injured 90 DAT. Abelia and spirea treated with 2.24 kg ai/ha (2.0 lb ai/A) were severely injured with many dead plants 60 DAT. Actively growing barberry treated with 0.28 kg ai/ha (0.25 lb ai/A) remained moderately injured by 90 DAT. Rates ≥ 0.56 kg ai/ha (0.5 lb ai/A) caused death to actively growing barberry by 60 DAT.

Index words: container production, postemergence oxalis control.

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

Species used in this study: Edward Goucher Abelia (*Abelia* x 'Edward Goucher'), Crimson Pygmy Barberry (*Berberis thumbergii atropurpurea* 'Crimson Pygmy'), Anthony Waterer Spirea (*Spiraea* x *bumalda* 'Anthony Waterer'), Yellow woodsorrel (*Oxalis stricta* L.).

Significance to the Nursery Industry

Results of this research indicate diuron has potential to control yellow woodsorrel when applied postemergence over the top to dormant abelia, barberry, 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 provides growers with an alternative to hand-weeding, especially when container-grown plants are emerging from over-wintering and yellow woodsorrel, a perennial weed that, while present throughout summer, grows best in spring and fall.

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 alternative weed control methods to reduce costs and produce an economically competitive weed free crop. In the past, growers desired herbicides with 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, e.g., hairy bittercress (*Cardimine hirsuta* L) (2, 3), prostrate spurge (*Chamaesyce prostrata* Ait.) (4), or yellow woodsorrel (*Oxalis* spp. L) (16). With postemergence herbicides in particular, many growers are willing to accept limited crop injury. Eliminating a hand weeding process may be an acceptable (cost effective) trade-off for limited crop injury from which the crop recovers in a short time period.

One area where postemergence-applied herbicides have potential is when nursery crops are emerging from over-wintering. Conditions in late winter frequently favor development of winter weeds such as yellow woodsorrel and hairy 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 situation 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 hairy bittercress. Gallery at 1.12 kg ai/ha (1.0 lb ai/A) provided excellent control of small and intermediate size hairy bittercress, and a rate of 2.24 kg ai/ha (2.0 lb ai/A) provided excellent control of larger, flowering hairy bittercress (3). Other research demonstrated Roundup (glyphosate) and Finale (glufosinate) could control prostrate spurge 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 yellow woodsorrel (*Oxalis stricta* L.) has been conducted in the Southeastern United States. Yellow woodsorrel is a perennial weed that, while present throughout summer, grows best in spring and fall. A 1990 survey of nurserymen reported that yellow woodsorrel was considered to be among the most difficult to control weeds in container-grown nursery crops (10). While preemergence herbicide applications provide adequate control of *Oxalis* spp. and other weeds from seed, no method is 100 percent effective (6, 14). Hand weeding is difficult due to weeds prolifically seeding and by favorable growing conditions in container nurseries (8). Research by

[1]Submitted for publication on March 10, 2006; in revised form September 8, 2006.

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Holt and Chism (12) reported 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 adequate control. Another herbicide with potential to provide postemergence control for *Oxalis* species is diuron (11, 13). A Georgia grower found that over the top applications of diuron provided excellent yellow woodsorrel control with slight to no injury on camellia (Mark Crawford, personal communication). Diuron and other photosynthesis inhibiting herbicides are widely used and labeled for use on winter dormant alfalfa (7, 18). Data from prior work showed that diuron provided excellent yellow woodsorrel control with slight to no injury on camellia and liriope (16). We speculated that no injury was observed because the plants were dormant at the time of treatment. The objective of this study was to evaluate nursery crop tolerance to diuron based on the time of year and plant growth stage.

Materials and Methods

Four experiments were conducted at Auburn University, AL, to evaluate diuron (Direx 4L) (Griffin LLC, Valdosta, GA) for nursery crop tolerance based on time of application. Treatments for all experiments 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^2 (20 psi) and calibrated to deliver 340 liter/ha (40 gal/A). Substrate used in all experiments consisted of pine bark: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), 2.9 kg (5.0 lb) of dolomitic limestone, and 0.9 kg (1.5 lb) of Micromax (Scotts Co.). Treatments included diuron at 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. Non-ionic surfactant (X-77, Loveland Industries, Greely, CO) at 0.25% (v/v) was also included. All plants were grown in full sun. Unless otherwise noted all experiments had 8 replications per treatment arranged in a completely randomized design (CRD) with nursery crop species grouped separately. Data collected included visual nursery crop injury ratings at 15, 21, and 30 days after treatment (DAT), and then monthly thereafter until 150 DAT. The visual rating scale used was from 1 to 10, where 1 equaled no injury and 10 equaled plant death (9). Growth indices ((height + widest width + perpendicular width) / 3) were taken at 180 DAT. In all four experiments, barberry had a natural infestation of yellow woodsorrel. Yellow woodsorrel sizes ranged from 5 to 6 cm tall (some flowers) in Expt. 4 to 14 to 20 cm tall (flowering and setting seed) in Expts. 1, 2 and 3. Visual yellow woodsorrel control (0 = no control and 100 = complete control) was rated at 7, 14 and 21 DAT. All data were analyzed with regression analysis and Dunnett's test where appropriate (15).

Experiment 1 was treated on November 28, 2001. All plants were potted from liners in the spring. Spirea (*Spiraea* x *bumalda* 'Anthony Waterer') and abelia (*Abelia* x 'Edward Goucher') was grown in full gallons, and barberry (*Berberis thumbergii atropurpurea* 'Crimson Pygmy') was grown in trade gallon containers. At the time of treatment, plants had no new growth and were entering dormancy. Overhead irrigation (0.3 in, 0.76 cm) resumed the day after treatment application (18 hours after treatment).

Experiment 2 was treated on March 15, 2002. One-year-old plants similar to those used in experiment one were used. Abelia was not actively growing at the time of treatment. Spirea was dormant, retained only a few lower leaves and had no leaf buds breaking. Barberry was leafless, and had very tight latent buds. At 30 DAT plants were top dressed with 8.0 grams of Osmocote 17N–3.1P–10K. In addition to rain of about 0.25 in (0.64 cm) 12 hours after treatment, overhead irrigation (0.3 in, 0.76 cm) resumed the day after treatment application (18 hours after treatment).

Experiment 3 was treated on October 15, 2002. All plants were potted from liners in the spring (March) and there was no new growth at the time of treatment. Overhead irrigation (0.3 in, 0.76 cm) resumed the day after treatment application (16 hours after treatment).

Experiment 4 was treated on March 12, 2003. One-year-old plants were treated and all species had 10 replications per treatment. At the time of treatment, abelia had active terminal growth, while barberry and spirea had opening leaf buds with some leaves partially expanded. Overhead irrigation (0.3 in, 0.76 cm) was withheld until 6 hours after treatment.

Results and Discussion

Influence of diuron on abelia. Diuron applied to dormant abelia in November 2001 (Expt. 1) and abelia in March 2002 prior to active growth (Expt. 2) caused no injury or effects on growth indices at 180 DAT (data not shown). Applications of diuron in October 2002 to abelia at the end of a growth flush caused only slight injury with a quadratic rate response at 21, 30, and 60 DAT (Table 1). Injury to abelia was observed only at the 2.24 kg ai/ha (2.0 lb ai/A) and was charac-

Table 1. Growth stage and injury rating of abelia treated with diuron.

Rate kg ai/ ha	Not actively growing				GI[y]
	21 DAT[z]	30 DAT	60 DAT	150 DAT	180 DAT
0.28	1.0[x]	1.0	1.0	1.0	68.2
0.56	1.0	1.0	1.0	1.0	67.6
1.12	1.1	1.3	1.3	1.0	61.2[w]
2.24	1.3	1.6[w]	1.8[w]	1.0	66.1
Non treated	1.0	1.0	1.0	1.0	64.5
Significance[v]	Q*	Q***	Q***	NS	Q*

Rate kg ai/ ha	Active growing state				
	15 DAT	21 DAT	30 DAT	60 DAT	90 DAT
0.28	1.7	1.2	1.2	1.1	1.2
0.56	2.3	1.3	1.2	1.3	1.2
1.12	3.6[w]	3.2[w]	3.4[w]	3.1[w]	2.0[w]
2.24	4.8[w]	5.6[w]	6.6[w]	7.3[w]	7.6[w]
Non treated	1.0	1.0	1.0	1.0	1.0
Significance	L***Q*	L***	L***	L***	L***

[z]Days after treatment.

[y]Growth indices in cm ((height + widest width + perpendicular width) / 3).

[x]1 = no injury and 10 = death.

[w]Injury rating significantly higher than non-treated or GI significanltly lower than non-treated (Dunnett's Test: $\alpha = 0.05$).

[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 2. Growth stage and injury rating of barberry treated with diuron.

Rate kg ai/ ha	Not actively growing					GI[y]
	15 DAT[z]	21 DAT	30 DAT	60 DAT	150 DAT	180 DAT
0.28	1.0[x]	1.8[w]	2.2[w]	3.0[w]	1.0	33.1[w]
0.56	1.0	2.1[w]	4.1[w]	6.4[w]	1.0	31.6
1.12	1.0	2.9[w]	4.9[w]	5.6[w]	1.0	33.5
2.24	1.9[w]	3.0[w]	4.4[w]	6.4[w]	8.8[w]	4.4[w]
Non treated	1.0	1.0	1.0	1.0	1.0	34.5
Significance[v]	L***Q***	L**	L***Q**	L***Q*	Q***	Q**

Rate kg ai/ ha	Not actively growing					GI
	15 DAT	21 DAT	30 DAT	60 DAT	150 DAT	180 DAT
0.28	1.6[w]	2.5[w]	2.6[w]	3.0[w]	1.0[w]	36.4
0.56	2.5[w]	3.4[w]	3.6[w]	4.3[w]	1.0[w]	35.3
1.12	3.1[w]	4.0[w]	5.1[w]	5.3[w]	1.0[w]	35.9
2.24	4.0[w]	5.5[w]	6.4[w]	6.4[w]	9.6[w]	2.9[w]
Non treated	1.0	1.0	1.0	1.0	1.0	37.6
Significance	L***Q***	L***Q***	L***Q***	L***Q***	L*Q***	Q**

Rate kg ai/ ha	Not actively growing					
	15 DAT	21 DAT	30 DAT	60 DAT	90 DAT	150 DAT
0.28	1.0	1.0	1.0	1.0	1.0	1.0
0.56	1.0	1.0	1.0	1.0	1.0	1.0
1.12	1.0	1.0	2.0w	1.4	1.0	1.0
2.24	1.0	2.2w	4.5w	7.6w	7.1w	7.1w
Non treated	1.0	1.0	1.0	1.0	1.0	1.0
Significance	NS	L*	L***	L*Q***	L*Q***	L*Q***

Rate kg ai/ ha	Active growing state					
	15 DAT	21 DAT	30 DAT	60 DAT	90 DAT	150 DAT
0.28	1.0	1.0	1.4	3.3[w]	5.1[w]	—[u]
0.56	1.1	1.3	3.5[w]	9.1[w]	10.0[w]	—
1.12	1.3	1.6	3.8[w]	9.6[w]	10.0[w]	—
2.24	2.2[w]	5.0[w]	6.6[w]	10.0[w]	10.0[w]	—
Non treated	1.0	1.0	1.0	1.0	1.0	—
Significance	L***	L***Q***	L***Q*	L***Q***	L***Q***	

[z]Days after treatment.

[y]Growth indices in cm ((height + widest width + perpendicular width) / 3).

[x]1 = no injury and 10 = death.

[w]Injury rating significantly higher than non-treated or GI significantly lower than non-treated (Dunnett's Test: $\alpha = 0.05$).

[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.

[u]Data at 150 days after treatment noted by '—' indicates all plants except non-treated were dead.

terized by a slight chlorosis on terminal leaves, possibly caused by the leaves' tendency to cup upward and hold the spray solution. However, the following spring there was no observable injury on any abelia. Abelia growth indices responded in a quadratic manner however, growth indices were similar among all diuron treated plants to non-treated plants. Diuron application to actively growing abelia treated in March 2003, caused slight injury at 0.56 kg ai/ha (0.5 lb ai/A) and was characterized by terminal leaf chlorosis. Plants treated with the two lowest rates recovered and were not different from non-treated abelia 60 DAT. However, growers would still be advised to test these rates on a small number of plants to determine if the low rates offer suitable control. Rates of 1.12 kg ai/ha (1.0 lb ai/A) and higher caused moderate injury throughout the test characterized by extensive chlorosis and some leaf senescence. Injury to abelia treated in March with 2.24 kg ai/ha (2.0 lb ai/A) was moderate (4.8) 15 DAT; however by 60 and 90 DAT injury ratings had increased to severe injury (7.3 and 7.6, respectively) characterized by extensive necrosis (die back) and death.

Table 3. Growth stage and injury rating of spirea treated with diuron.

Rate kg ai/ ha	Not actively growing				GI[y] 180 DAT
	21 DAT[z]	30 DAT	60 DAT	150 DAT	
0.28	1.0[x]	1.0	1.0	1.0	46.8
0.56	1.3	1.3	1.3	1.0	40.8
1.12	1.5[w]	1.5[w]	1.2	1.0	44.7
2.24	2.1[w]	2.6[w]	3.5[w]	1.0	42.9
Non-treated	1.0	1.0	1.0	1.0	45.3
Significance[v]	Q***	Q***	Q***	NS	NS

Rate kg ai/ ha	Active growing state				
	15 DAT	21 DAT	30 DAT	60 DAT	90 DAT
0.28	1.0	1.0	1.0	1.3	1.1
0.56	1.0	1.0	1.3	2.4[w]	1.4
1.12	1.0	1.2	2.1[w]	4.3[w]	5.0[w]
2.24	2.0[w]	2.9[w]	6.6[w]	9.5[w]	10.0[w]
Non-treated	1.0	1.1	1.1	1.4	1.9
Significance	L***Q***	L***Q***	L***Q**	L***	L***

[z]Days after treatment.

[y]Growth indices in cm ((height + widest width + perpendicular width) / 3).

[x]1 = no injury and 10 = death.

[w]Injury rating significantly higher than non-treated or GI significantly lower than non-treated (Dunnett's Test: $\alpha = 0.05$).

[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.

Influence of diuron on barberry. Diuron application to dormant barberry in November 2001 caused slight initial injury, which progressed to moderate injury by 60 DAT (Table 2). Injury was characterized by marginal necrosis and early onset of senescence. The following spring (150 DAT), plants treated with 1.12 kg ai/ha (1.0 lb ai/A) or less leafed out normally and were similar to non-treated plants. Barberry treated with 2.24 kg ai/ha was severely injured with numerous dead plants. Growth indices for barberry treated with 1.12 kg ai/ha (1.0 ai/A) or less were similar to non-treated plants. Diuron application in March 2002, caused no injury on barberry treated with 0.56 kg ai/ha (0.5 lb ai/A) or less. Barberry treated with 1.12 kg ai/ha (1.0 ai/A) had slight injury, while plants treated with 2.24 kg ai/ha (2.0 ai/A) exhibited moderate injury by 30 DAT characterized by leaf bud necrosis. At 60 DAT, barberry treated with 1.12 kg ai/ha (1.0 ai/A) had completely recovered, while with plants treated with 2.24 kg ai/ha (2.0 ai/A) had increased to a severe rating. Application of diuron in October 2002 to barberry resulted in slight to moderate injury at 15, 21, and 30 DAT with injury responding linearly and quadratically to diuron rate. Barberry injury was characterized by leaf chlorosis and necrosis, followed by early onset of senescence in plants treated with 1.12 and 2.24 kg ai/ha (1.0 and 2.0 ai/A). The following spring, barberry leafed out normally except for plants treated with 2.24 kg ai/ha (2.0 ai/A) which continued to exhibit severe injury. Only plants treated with 2.24 kg ai/ha (2.0 ai/A) had growth indices lower than non-treated plants at 180 DAT. Actively growing barberry treated in March 2003 had slight initial injury which progressed to severe injury and death on all plants treated with 0.56 kg ai/ha and higher 60 DAT. Plants treated with 0.28 kg ai/ha (0.25 lb ai/A) had moderate injury by 60 DAT. Injury was characterized by partially expanded leaves and buds turning necrotic and stem die back. These data are in contrast to data from Expt. 2 when plants were treated about the same time of the year the previous year. Spring-like weather in late January and February 2003 caused many plants to leaf out sooner than the prior year. The resultant injury to barberry is consistent with research conducted on alfalfa with substituted ureas where dormant alfalfa was not injured and plants that were actively growing at the time of treatment were injured (7, 18). These data suggest that dormant plants have a greater tolerance to diuron than actively growing plants.

Influence of diuron on spirea. Diuron applied to dormant spirea in November 2001 (Expt. 1) and spirea in March 2002 prior to active growth (Expt. 2) caused no injury or effects on growth indices at 180 DAT (data not shown). Spirea treated with diuron in October 2002, were slightly injured by diuron at 21 and 30 DAT (Table 3) characterized by chlorosis on a few leaves, primarily at the 1.12 and 2.24 kg ai/ha (1.0 and 2.0 lb ai/A) rates. Spirea plants leafed out normally in the spring, and there was no difference in growth 180 DAT compared to non-treated plants. For actively growing spirea treated in March 2003, diuron caused slight injury at 21 DAT to plants treated with 1.12 kg ai/ha (1.0 lb ai/A) and severe injury to plants treated with 2.24 kg ai/ha (2.0 lb ai/A) 30 DAT characterized by chlorosis on partially expanded leaves. By 60 and 90 DAT plants treated with 1.12 kg ai/ha (1.0 lb ai/A) retained the same chlorosis; however, plants treated with 2.24 kg ai/ha declined and were severely injured and dead. Although treated on almost the same day of the year as Expt. 2, the plants in Expt. 4 were beginning to actively grow due to spring-like weather in February 2003 whereas plants treated in 2002 (Expt. 2) were not. These data suggest that spirea and abelia have greater tolerance to diuron than barberry.

Yellow woodsorrel control within barberry. Diuron provided excellent yellow woodsorrel control over all four experiments (Table 4). Rates of 0.56 kg ai/ha (0.56 lb ai/A) and higher provided excellent (100%) yellow woodsorrel con-

Table 4. Effect of diuron on oxalis control in container-grown barberry[z].

Rate kg ai/ ha	Days after treatment		
	7	14	21
0.28	35[y]	58	82
0.56	42	77	100
1.12	50	84	100
2.24	66	94	100
Non treated	0	0	0
Significance[x]	L***	L***Q***	L***Q***

[z]Data were pooled over four experiments treated in the fall or spring in 2001–2003.

[y]0 = no control and 100 = complete control.

[x]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.

trol regardless of the time of year 21 DAT. The 0.28 kg ai/ha (0.25 lb ai/A) rate provided good control at (82%) 21 DAT. Analysis revealed no experiment by treatment interactions, therefore data were pooled across all experiments.

In summary, these data show that diuron provides excellent yellow woodsorrel control at 0.56 kg ai/ha (0.5 lb ai/A) when applied postemergence to tolerant nursery crops. The risk of crop injury increases greatly if rates over 1.12 kg ai/ha (1.0 lb ai/A) are applied. 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) by irrigating soon after application is made. Ashton reported that light intensity affected substituted urea phytotoxicity (5). Light intensity is generally lower in winter months and so this may also have an effect on nursery crop tolerance. Other research has shown that the postemergence activity of diuron can be increased with the addition of non ionic surfactant (12, 17). Whether or not surfactant is used may also have an affect on crop tolerance. Prior unpublished work by the authors has shown diuron without surfactant had moderate activity (57 to 74% control with 1.12 kg ai/ha) against yellow woodsorrel. Diuron, more commonly used as a directed or preemergence applied herbicide in cotton, alfalfa and in fruit orchards, is not currently registered for use in nursery crops.

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