# Postemergence Oxalis Control with Diuron: Minimizing Crop Injury with Timely Irrigation[1]

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## Abstract

Experiments were conducted to evaluate tolerance of container nursery crop tolerance and yellow woodsorrel (*Oxalis stricta*) control with postemergence applied diuron as influenced by timely overhead irrigation. Intent was to identify an interval between application and irrigation that may reduce crop injury without compromising oxalis control. Diuron was applied at a common rate of 1.0 lb ai/A to oxalis and two nursery crops (*Camellia sasanqua* 'Alabama Beauty' camellia, and *Rhododendron indicum* 'G.G. Gerbing', azalea). Treatments consisted of irrigation at 1, 2, 4, 8, 12, 24, or 48 hr after application. Oxalis control was equivalent whether treated plants were irrigated within either 1 hr or 48 hr after application. Camellia exhibited no visible injury regardless of treatment. Azaleas exhibited diuron-induced injury, however injury was reduced if plants were irrigated within 1 hr of diuron application. $^{14}$C-diuron was used to determine the absorption rate of foliar-applied diuron into oxalis, camellia and azalea. Absorption by oxalis was relatively rapid, and reached a maximum (~68% of applied) within 8 hr after application. Camellia and azalea absorbed a smaller percentage of the amount applied, and absorption was more protracted over time compared to oxalis. Azalea absorbed slightly more than camellia. Diuron has potential for use as an over-the-top application for postemergence oxalis control and timely irrigation has the potential to reduce injury to sensitive crops.

**Index words:** *Oxalis stricta*, Direx, herbicide, weed control, container production, nursery crops.

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

**Species used in this study:** Camellia (*Camellia sasanqua* 'Alabama Beauty') , Azalea (*Rhododendron indicum* 'G.G. Gerbing'); and yellow woodsorrel (*Oxalis stricta* L.).

### Significance to the Nursery Industry

Postemergence weed control in container grown nursery crops is becoming increasingly important to producers due largely to increasing labor costs. Oxalis or yellow wood sorrel (*Oxalis stricta*) is a serious problem in many regions of the United States, especially with container grown crops emerging from winter protection. Previous research has shown that diuron has the potential to control oxalis when applied postemergence over-the-top to dormant camellia (*Camellia japonica* 'Pink Icicle'), liriope (*Liriope muscari* 'Big Blue') and spirea (*Spiraea* x *bumalda* 'Anthony Waterer'). However in some cases slight crop injury resulted from the application of diuron, and injury was more severe with actively growing crops. This research indicated that irrigation at 1 hr after diuron application reduced diuron-induced injury without compromising oxalis control.

### Introduction

Preemergence herbicides and hand weeding are the two primary methods of weed control in container nursery crops (7). However, supplemental hand weeding is usually required because preemergence herbicide programs generally do not provide complete control (8). Due to increasing labor costs, growers are seeking alternatives to hand weeding. Postemergence-active herbicides applied 'over-the top' of container-grown nursery crops would provide a labor-saving option. Traditionally, growers would accept this type of application only if it provided broad-spectrum weed control combined with no crop injury. Due to economic considerations, many growers are now willing to accept some injury provided it is limited to the early portion of the crop cycle and the crop rapidly grows past the injury. The ability of postemergence-applied herbicides to control a single weed species with minimal landscape crop injury has been previously demonstrated. Recent studies have shown isoxaben (Gallery 75DF), which is typically used as a preemergence herbicide, effectively controlled hairy bittercress (*Cardamine hirsuta*) when applied postemergence (1, 2).

Oxalis is a weed problem common in the southeast and has been identified as being difficult to control by many growers (7). Due to the ideal growing conditions provided in container nursery production systems, oxalis can be a problem year round (5). Recent studies demonstrated that postemergence-applied diuron (Direx 4L) provided excellent control of oxalis. Simpson *et al*. (9) applied diuron without a surfactant at rates ranging from 0.14 to 1.12 kg ai/ha (0.125 to 1.0 lb ai/A) to container grown: camellia (*Camellia japonica* 'Pink Icicle'), liriope (*Liriope muscari* 'Big Blue') and spirea (*Spiraea* x *bumalda* 'Anthony Waterer'). Diuron caused no more than slight injury, while providing at least 74% oxalis control. In subsequent studies, diuron (surfactant added) was applied to three different sizes of oxalis, i.e. small 3 to 9 cm (1.2–3.5 in) tall, medium 13 to 15 cm (5.1–5.9 in) tall, and large 20 to 30 cm (7.9–11.8 in) tall. Control was at least 90% regardless of oxalis size with rates of ≥0.56 kg/ha (0.5 lb ai/A). Ahrens *et al.* and Barolli *et al.* (3, 4) applied diuron to the following crops while actively growing: Japanese painted fern (*Athyrium*

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*niponicum* ‘Pictum’), creeping juniper (*Juniperus horizontalis* ‘Wiltoni’), azalea (*Rhododendron* ‘Stewartstonian’), bigleaf hydrangea (*Hydrangea macrophylla* ‘Merritts Supreme’), pee gee hydrangea (*Hydrangea paniculata* ‘Grandiflora’), bog rosemary (*Andromeda polifolia*), dwarf burning bush (*Euonymus alatus* ‘Compactus’) and clematis (*Clematis* x *jackmanii*). These researchers noted that overhead irrigation soon after application tended to reduce any diuron-induced crop injury. This led to the hypothesis that a timely irrigation shortly after application may improve crop tolerance without compromising oxalis control.

Specific objectives of this research were to first determine the ideal time interval between diuron application and irrigation that meet the combined criteria of reducing diuron-induced injury on a sensitive species without compromising oxalis control. A second objective was to monitor the foliar sorption of diuron into oxalis and selected landscape crops using radiotracer techniques. Intent was to discover if differential rates of sorption between the target weed and the landscape crop would indicate the potential for enhanced weed-crop selectivity through timely irrigation.

## Materials and Methods

All experiments were conducted at the Patterson greenhouse complex of Auburn University, Department of Horticulture. Oxalis seed were sown in January 2004 in 7.6 cm (3 in) containers and thinned to one uniform-sized oxalis per container. The medium used was a 6:1 (v:v) pine bark:sand amended with 2.3 kg (5 lb) of dolimitic lime, 6.4 kg (14 lb) of Polyon 17N–2.2P–9.13K (Polyon 17–5–11, Pursell Industries, Sylacauga, AL) and 0.68 kg (1.5 lb) of Micromax (The Scotts Co., Marysville, OH). At time of treatment, approximately five weeks after seeding, oxalis plants were 8–12 cm (3.1–4.7 in) wide and 4–6 cm (1.6–2.4 in) tall. Diuron was applied at 1.12 kg ai/ha (1.0 lb ai/A) using Direx 4L. Agri-Dex, a non-ionic adjuvant, was included at 0.25% v:v. Treatments were applied using an enclosed-cabinet, track sprayer (DeVries Manufacturing, Hollandale, MN), equipped with a single 11002 spray tip, and was calibrated to deliver 284 liters/ha (30 gal/A). Treatment application was at 7:00 A.M. Immediately after application all plants were transported to a double layer polyethylene greenhouse.

Diuron-treated plants were subsequently irrigated at 1, 2, 4, 8, 12, 24, or 48 hr after application. Irrigation was 0.64 cm (0.25 in), and was accomplished with an overhead impact sprinkler (Rain Bird 2045PJ). Each treatment-irrigation time interval was assigned to 7 single pot replicates. Subsequent to all irrigation treatments, plants were arranged in a completely randomized experimental design. Visual ratings on percent injury were taken at 14, 21 and 28 days after treatment (DAT) on a scale of 0 to 100 where 0 = no injury and 100 = dead plants. At 28 DAT shoot fresh and dry weights were taken for oxalis. This experiment was conducted three times in 2004 with initiation dates of February 23, March 19 and April 6 respectively. There were no differences among experimental repetitions; consequently data were pooled across all three repetitions for further analysis and presentation.

Two container grown nursery crops: *Rhododendron indicum* ‘G.G. Gerbing’ and *Camellia sasanqua* ‘Alabama Beauty’ were used to evaluate crop injury. Azaleas were in 7.6 cm (3 in) pots and camellias in 10.2 cm (4 in) pots at time of treatment. Diuron rate, spray volume and irrigation intervals were identical to that previously described for oxalis. Treatments were replicated 7 and 6 times for azalea and camellia, respectively. Visual ratings were taken at 14, 21, 28 and 120 DAT on a scale of 0 to 100 where 0 = no injury and 100 = dead plants. Azaleas were transplanted into 2.8 liter (trade gallon) containers and camellias were transplanted into #1 (1 gal) containers at 28 DAT. Growth indices were taken for both species at 120 and 240 DAT. Azalea and camellia studies were conducted twice with treatment initiation dates of March 19 and April 6 respectively. Results were consistent among dates; consequently data were pooled for further analysis and presentation.

Plants identical to ones used in the previously-described irrigation timing study were used in a foliar absorption study. Procedures for determining herbicide foliar sorption using radiotracer techniques have been described in more detail elsewhere (6, 11, 12). This experiment was conducted concomitantly with 2nd and 3rd repetitions of the irrigation timing study, and included oxalis, azalea and camellia. A 0.5-ml (0.017 oz) sub-sample of the spray suspension as previously-described was retained and supplemented with $^{14}C$-diuron so that the final concentration of diuron and radioactivity was 3, 000 mg/liter and 0.2 MBq/2 µl, respectively. Single 2 µl, drops of this $^{14}C$-diuron suspension was applied to the target plants, i.e. oxalis, azalea and camellia using a micro applicator. For oxalis, a recently-formed, but fully-expanded leaf was selected. Droplets were applied to the middle leaflet of the selected leaf. For azalea and camellia, mature leaves were selected that were full sized and had been produced during the previously-season’s growth. Droplets were applied to the center of the selected leaf, but not on the midvein. For all species, experimental units consisted of individual plants.

Plants treated with $^{14}C$-diuron were harvested at the same schedule as used in the previously-described timed irrigation study, i.e. either 1, 2, 4, 8, 12, 24 or 48 hr after treatment. For oxalis, the treated leaflet was removed from the plant and placed into a 20-ml (0.68 oz) scintillation vial which contained 1 ml (0.034 oz) of a water/methanol solution [50:50 (v/v)]. The vial was then agitated with a swirling motion for 30 sec to remove any unabsorbed diuron. After removing the leaflet, 10 ml (0.34 oz) of scintillation fluid was added into the vial in preparation for counting. Treated leaflet was retained, dried at 45C (113F) for 24 hr, combusted at 358C (900F) in a biological tissue oxidizer, and recovered radioactivity quantified through scintillation spectrometry (10). For each experimental unit, radioactivity from both the wash and the combusted tissue were summed, the portion recovered in the tissue was then expressed as a percentage of this total, which represented the amount of adsorption. Typically, the quantity of $^{14}C$ recovered in the wash and tissue sums to 94 to 103% of amount applied. No effort was made to separate between parent diuron and potential metabolities.

For azalea and camellia, a 1 cm (0.39 in) cork borer was used to remove the site to which the herbicide droplet had been placed. These disks of leaf tissue were treated in a manner identical to that previously described for the treated oxalis leaflet. A completely random design with 6 single-plant replicates for each harvest time was used. The experiment was repeated. Data were subjected to ANOVA using the general linear model procedure in SAS.

## Results and Discussion

Oxalis control at 14 DAT was not influenced by any irrigation treatment. Irrigating within 1 hr of treatment resulted

Table 1. **The influence of irrigation timing after diuron application on postemergence oxalis control.**

| Irrigation[z] (hr) | Oxalis control | | | | |
|---|---|---|---|---|---|
| | Visual rating (%) | | | Weight (g) | |
| | 14 DAT[y] | 21 DAT | 28 DAT | SFW | SDW |
| 1 | 39[x]a[w] | 62a | 71a | 0.48a | 0.13a |
| 2 | 50a | 75a | 80a | 0.23a | 0.09a |
| 4 | 46a | 72a | 73a | 0.46a | 0.11a |
| 8 | 48a | 67a | 64a | 0.62a | 0.14a |
| 12 | 42a | 61a | 64a | 0.58a | 0.17a |
| 24 | 51a | 70a | 74a | 0.36a | 0.11a |
| 48 | 54a | 70a | 72a | 0.37a | 0.10a |
| Non-treated | 2b | 5b | 4b | 3.34b | 0.93b |

[z]Irrigation timing, hours after diuron application.

[y]DAT = days after treatment, SFW = shoot fresh weight (g), SDW = shoot dry weight (g).

[x]Percent oxalis control, where 0% = no injury and 100% = plant death.

[w]Means within a column followed by the same letter are not significantly different (Duncan's Multiple Range Test: ÿ = 0.05).

in similar control to waiting 48 hr after diuron application (Table 1). Oxalis control tended to increase through 28 DAT, but irrigation timing had no effect on oxalis control. Shoot fresh and dry weights followed similar trends. Overall level of oxalis control observed was lower than that previously reported by Simpson *et al*. (9). Control in their study ranged from 95 to 98% control at 21 DAT while control in this study ranged from 61 to 75% at 21 DAT. A partial explanation may be surfactant selection. Surfactant rate was identical for both studies; however, Simpson *et al*. used X-77 while Agri-Dex was used in this study. Simpson *et al.* (9) established that contact foliar activity is the predominant factor in the efficacy of postemergence-applied diuron on yellow woodsorrel; however, root-based absorption did contribute to the overall efficacy. The impact of root-based absorption on control in this study cannot be determined.

Camellia tolerance to diuron was excellent with no visible injury at any time in the study. This is in contrast with previous reports of slight initial diuron injury when applied to 'Pink Icicle' camellia; however, plants had completely outgrown injury symptoms by 60 DAT (9). G.G. Gerbing azaleas were actively growing at time of diuron application and were more sensitive to diuron. Injury occurred with all treatments however irrigation 1 hr after diuron application reduced injury 10 to 15% compared to irrigation 2 hr after diuron application (Table 2). There were no differences in azalea injury at 14, 21 or 28 DAT when irrigated from 8 to 48 hr after diuron application. Similarly there were no differences in azalea injury rating when irrigated 2 to 4 hr after diuron application. No visible injury was evident at 120 DAT. Azalea growth at 120 DAT was similar among the non-treated control and plants that were irrigated 1, 2, 24 and 48 hr after diuron application. At 240 DAT all azaleas had similar growth except those irrigated 24 hr after diuron application, which were slightly smaller. With camellia all plants were similar in size or larger than the non-treated control plants at both 120 and 240 DAT.

The radiotracer study revealed that $^{14}$C-diuron was rapidly absorbed by oxalis reaching near maximum of 68% at 8 hr after application (Fig. 1). Within 1 hr of application, about 35% of the applied $^{14}$C-diuron had been absorbed. In contrast, foliar absorption was much slower in the landscape plants, and the maximum amount absorbed was less compared to oxalis. Azalea and camellia absorbed only 8 and 5% of the amount applied, respectively. Azalea absorption was slightly greater than camellia. Slower uptake is likely related to the thickness of the leaf cuticle. For example the camellia has a thicker leaf cuticle than azalea and absorption was slightly less with camellia. Oxalis, azalea and camellia reached maximum absorption at 48 hr after diuron application, with 70, 48 and 32 % absorbed, respectively. Again no effort was made to determine whether the absorbed $^{14}$C represented parent diuron or a diuron metabolite(s), but with respect to oxalis, its sensitivity to diuron would suggest that recovered $^{14}$C would likely represent parent diuron.

These findings concur with research by Simpson *et al*. (9) indicating oxalis control is likely obtained with irrigation soon after diuron application due to rapid absorption. Azalea injury is likely reduced by irrigation due to slow foliar uptake; therefore, a timely irrigation could remove unabsorbed diu-

Table 2. **The influence of irrigation timing after diuron application on azalea (*Rhododendron indicum* 'G.G. Gerbing') and camellia (*Camellia sasanqua* 'Alabama Beauty')**

| Irrigation[y] (hr) | Azalea rating | | | | Growth indices[z] | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 120 DAT | | 240 DAT | |
| | 14 DAT[x] | 21 DAT | 28 DAT | 120 DAT | azalea | camellia | azalea | camellia |
| 1 | 19[w]e[v] | 21d | 20d | 0 | 21ab | 38a | 35ab | 50a |
| 2 | 31b–e | 36bc | 35bc | 0 | 22ab | 39a | 40ab | 47ab |
| 4 | 29cde | 37bc | 36bc | 0 | 19b | 40a | 36ab | 48ab |
| 8 | 41abc | 41abc | 44ab | 0 | 19b | 36a | 34ab | 46ab |
| 12 | 46ab | 46ab | 50a | 0 | 19b | 37a | 36ab | 46ab |
| 24 | 35a–d | 45ab | 45ab | 0 | 20ab | 39a | 32b | 48ab |
| 48 | 48a | 54a | 53a | 0 | 20ab | 40a | 36ab | 49ab |
| Non treated | 3f | 1e | 2e | 0 | 23a | 38a | 44a | 44b |

[z]Growth indices = height (cm) + 2 perpendicular widths (cm) divided by 3.

[y]Irrigation timing, hours after diuron application.

[x]DAT = days after treatment.

[w]Percent azalea injury, where 0% = no injury and 100% = plant death.

[v]Means within a column followed by the same letter are not significantly different. (Duncan's Multiple Range Test: ÿ = 0.05).

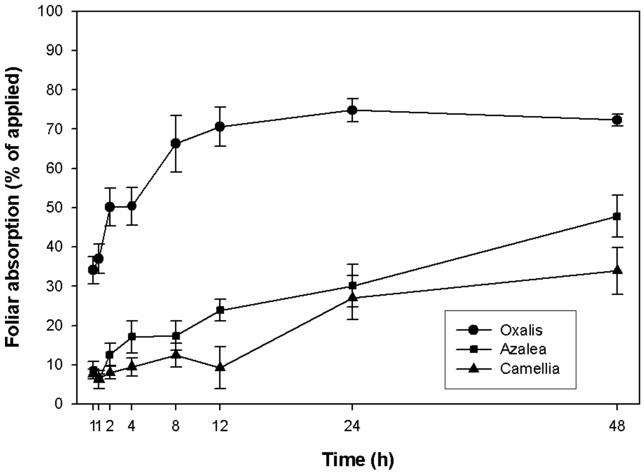


**Fig. 1. Foliar absorption of $^{14}C$ diuron by oxalis, azalea and camellia. Error bars equal standard deviation of individual means.**

ron thus reducing additional absorption. Additional research is needed to evaluate tolerance of diuron and timing of application to nursery crops.

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