# Weed Control

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# Minimum Duration of Diuron Exposure for Oxalis Control

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**Index Words:** *Oxalis stricta*, Direx, herbicide, postemergence weed control

**Significance to Industry:** While preemergence herbicides are the primary methods of weed control used by growers, they are not 100% effective. Uncontrolled weeds reduce growth and salability of the crop and become a source of inoculum for future weed infestations. As a result, growers have become more interested in using postemergence applied herbicides. However, few postemergence herbicides are labeled for container nursery crops. This research shows that properly applied, diuron could be a postemergence herbicide option for growers to control oxalis in container crops.

**Nature of Work:** Nursery crops are quickly becoming the most valuable agricultural commodity in the southeast. Weeds present at the time of sale reduce the value of the crops. The decrease in value can be attributed to reduced aesthetics and reduced growth (3) due to weed competition. Most growers use two methods of weed control, preemergence herbicides and hand weeding. However preemergence herbicides are not 100% effective and hand weeding is very expensive (5, 6). Postemergence herbicides are now receiving more attention. In the past, many growers demanded that postemergence herbicides have broad spectrum control with no damage to crops. With the increasing costs in hand weeding, growers are now willing to accept selective control of certain weed species and some crop injury. However, any injury must occur early in the crop cycle, and the crop must recover completely and quickly. *Oxalis stricta* is a perennial weed which spreads rapidly by seed. In a survey of nurserymen it was identified as being very difficult to control in container crops (5). Normally *Oxalis* thrives in the cool season, however Cross and Skroch reported (4) oxalis can be a major problem year round under certain nursery production systems. Simpson et al. (7) showed that diuron provided excellent oxalis control and that crop tolerance was good with dormant nursery crops. However injury occurred if crops were actively growing. Other work evaluating diuron as a preemergence herbicide has shown that nursery crop tolerance is improved with overhead irrigation soon after diuron application (1, 2).
The objective of this study was to determine the minimum time duration of diuron exposure between application and irrigation to result in postemergence oxalis control. This information would facilitate the utilization of overhead irrigation to rinse the diuron from the crop thus reducing potential crop injury yet not compromising phytotoxcity to the oxalis.

**Materials and Methods:** This experiment was conducted in Auburn, Alabama in 2004. Oxalis were seeded and grown in 7.5cm (3in) containers and thinned leaving one uniform sized oxalis plant per container. The substrate used was a 6:1(v:v) aged pine bark:sand amended with 2.3kg (5lb). of dolimitic lime, 6.4kg (14lb) of Osmocote 18-2.6-9.8 and 0.68kg (1.5lb) of Micromax. At time of treatment, approximately five weeks after seeding, oxalis plants were 8-12cm wide and 4-6cm tall. Direx 4L (diuron) at 1lb ai/A (1.1kg ai/ha) plus 0.25%

Agridex -non ionic surfactant were applied to the oxalis using a spray chamber. The chamber was calibrated to deliver 30 gal/A (284 l/ha) with an 11002 nozzle. Application was at 7:00 A.M. Treatments consisted of irrigation intervals of 0.5, 1, 2, 4, 8, 12, 24, and 48 hours after diuron application with 7 replications for each treatment. Plants were irrigated with a Rain Bird (2045PJ) impact sprinkler head, which was calibrated to deliver 0.25in (0.64cm) in approximately 20 minutes. Plants were placed in a greenhouse in random design. Visual estimates of on percent injury were recorded 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 measured. Crop tolerance was evaluated for azalea (*Rhododendron indicum* 'G. G. Gerbing') and camellia (*Camellia sasanqua* 'Alabama Beauty') liners. Each species was transplanted into four inch containers. Substrate and treatments were the same as described above. Visual evaluations were conducted 14, 21, and 28 DAT. This experiment was conducted three times. Oxalis was included in all three repetitions while azalea and camellia were in the later two. Results were consistent and data were pooled for further analysis and presentation. To asses long-term crown growth, azaleas and camellias were transplanted into trade gallon containers 30 days after treatment and growth measurements will be taken monthly for 180 days.

**Results and Discussion:** This study shows that irrigating one hour after diuron application has minimal impact on diuron activity on oxalis. There was no significant difference among irrigation intervals at anytime throughout the study (Table 1). Camellia plants were actively growing at the time of diuron application and no visible injury occurred at any time during the study. Azaleas were also actively growing at time of diuron application and were injured in all treatments across all dates; however the least injury occurred with the azaleas irrigated within one hour of application at 28 DAT (Table 1). These data concur work by Ahrens et al. and Barolli et al.,(1,2) who reported that overhead irrigation soon after diuron application for preemergence weed control increased crop tolerance of landscape plants. Additional research is needed to evaluate tolerance of diuron and timing of application to nursery crops.

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

| Irrigation timing(hr) after diuron application | *Oxalis stricta* | | | | | *R. indicum* ‘G.G.Gerbing’ | | |
|---|---|---|---|---|---|---|---|---|
| | 14DAT[z] | 21DAT | 28DAT | SFW | SDW | 14DAT | 21DAT | 28DAT |
| 0.5 | 37 [y] a [x] | 63a | 62a | 0.70a | 0.22a | 24de | 30cd | 29cd |
| 1 | 39a | 62a | 71a | 0.48a | 0.13a | 19e | 21d | 20d |
| 2 | 50a | 75a | 80a | 0.23a | 0.09a | 31b-e | 36bc | 35bc |
| 4 | 46a | 72a | 73a | 0.46a | 0.11a | 29cde | 37bc | 36bc |
| 8 | 48a | 67a | 64a | 0.62a | 0.14a | 41abc | 41abc | 44ab |
| 12 | 42a | 61a | 64a | 0.58a | 0.17a | 46ab | 46ab | 50a |
| 24 | 51a | 70a | 74a | 0.36a | 0.11a | 35a-d | 45ab | 45ab |
| 48 | 54a | 70a | 72a | 0.37a | 0.10a | 48a | 54a | 53a |
| Non treated | 2b | 5b | 4b | 3.34b | 0.93b | 3f | 1e | 2e |

[z]DAT= days after treatment, SFW= shoot fresh weight (g/individual plant), SDW= shoot dry weight(g/individual plant).

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

[x]Means within a column followed by the same letter are not significantly different (Duncan’s Multiple Range Test: $\alpha$=0.05).

# Common Weeds and Weed Management in Australian Nurseries

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**Index Words:** international, Australia, container nurseries, preemergence herbicides

**Significance to the Industry:** Weeds present in Australian container nursery crop production are surprisingly similar to those common in US . In the U.S.A. we are fortunate to have many preemergence herbicides labeled for use in container and field production of ornamental crops. In other countries, growers must battle similar weeds with fewer herbicides. In Australia, container nursery crop growers have only two primary herbicides available – Rout and Ronstar. Innovative, but labor intensive application methods have been devised to direct applications to the potting substrate and not contact foliage of sensitive plants. This allows the use of these herbicides in crops that would not tolerate over the top applications. Also, because they have fewer herbicides on which to rely, Australian growers place a greater emphasis on sanitation and preventing weeds from seeding than do most U.S.A. growers. The weed management practices in Australia demonstrate that it is possible to develop safe and effective weed management programs in herbicide-sensitive crops. Also, based on these experiences I am convinced that U.S.A. growers can place a greater emphasis on sanitation in nursery crop weed management systems.

**Nature of Work:** From March through August 2003, I had the opportunity to visit numerous nurseries, cut flower farms and botanic gardens in New South Wales, South Australia, Victoria and Queensland, Australia. During these visits I surveyed weeds present and interviewed nursery managers, industry development representatives and chemical sales representatives. During these visits I gained an understanding of the common weeds and weed management practices.

**Results and Discussion:** Nursery crop producers in Australia have fewer herbicides available and fewer sources of information on weed management than their US counterparts. For example, they have no extension service to assist them and they have no weed scientists in the public sector working on weed management in nursery crops. The nursery industry in Australia produces plants predominantly in containers. A per-container levy is utilized to fund research and education projects relating to nursery crop production. Although there are no university-based extension specialists, each state has one Nursery Industry Development Officer (NDO) that serves much the same roll. The NDOs are funded in part by the nursery industry.

The majority of the weeds in container nurseries and landscape plantings in Australia were the same as those in the US (Table 1). The few different weed species had closely related relatives that are important in US nurseries. For example: spurges and oxalis present in Australian nurseries were nearly identical to those found in US nurseries but were different species. Additionally, *Crassocephalum crepidioides* (thickhead) was a common species in Australia that looks nearly identical to *Erichtites hieraceifolia* (American burnweed), a common weed in US nurseries. Although *Euphobia peplus* and thickhead are not common in US nurseries I have recently observed *Euphorbia peplus* in nursery plants in North Carolina and Dr. Jeffrey Derr of the Virginia Tech. Hampton Roads Experiment Station has observed thickhead in liners obtained from Florida. A bulletin describing common weeds of Australian nurseries and their control was published through the Center for Native Floriculture at the University of Queensland (Neal and Gordon, 2003).

Nursery weed control strategies in Australia are similar to those employed in the US except that only 3 herbicides are labeled for use in Australian nursery crops. In the US we have over 30 herbicides registered. Preemergence herbicides are applied to shortly after potting then re-applied as needed. Preemergence weed control is supplemented with hand weeding. The challenge for Australian nursery crop producers is not “which herbicide to use”, but rather “how to use the available herbicides without crop damage”. The two most commonly used herbicides used in Australian nurseries, Scotts OH2 (oxyfluorfen + pendimethalin) and Ronstar (oxadiazon) will damage the foliage of many crop species. Growers have devised unique application devices to apply the herbicide to the surface of the potting substrate without contacting crop foliage. This is a labor-intensive process and thus would not be practical for many crops in the US. However, for some high-value crop species, it may be a viable option. Also, without many herbicide options, Australian growers rely heavily on sanitation practices to prevent weed introduction, spread and seeding. This emphasis on sanitation reduces weed population by preventing seed-set and spread.

Although Australian nursery crop production practices and weed management practices are similar to those in the US, Australian nursery managers have fewer herbicides available. Consequently, Australian nursery managers rely on innovative application methods to avoid herbicide damage and sanitation to prevent weed population increases and spread. Nurseries in the US could reduce weed spread and infestations by following the example of our Australian counterparts and increasing emphasis on sanitation practices in weed management.

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**Table 1.** Common weeds observed in container nurseries in eastern and southern Australia during the author's study leave in 2003.

| **Cool Season Weeds** | **Warm Season Weeds** |
|---|---|
| *Cardamine* spp.* | *Cardamine* spp.* |
| *Cerastium vulgatum** | *Chamaesyce drummondii* |
| *Conyza Canadensis** | *Chamaesyce hirta** |
| *Epilobium ciliatum** | *Chamaesyce hyssopifolia** |
| *Gnaphalium* spp.* | *Chamaesyce (Euphorbia) peplus* |
| *Marchantia polymorpha** | *Crassocephalum crepidioides* |
| *Oxalis* spp.* | *Oxalis* spp.* |
| *Poa annua** | *Phyllanthus tenellus** |
| *Sagina procumbens** | *Phyllanthus urinaria** |
| *Sonchus* spp.* | *Sonchus* spp.* |
| *Stellaria media** | |
| *Youngia japonica** | |

*These species are also common in US nurseries.

# Early Postemergence Control of Container Weeds with Broadstar, OH2, and Snapshot TG

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**Index Words:** common groundsel, eclipta, hairy bittercress, spotted spurge.

**Significance to Industry**: In container nursery production, it is not always possible to completely remove all emerged weeds prior to preemergence herbicide application or to apply preemergence herbicides before new weeds have germinated. Therefore, we compared early postemergence control of common broadleaf weeds with three preemergence nursery herbicides, Broadstar, OH2, and Snapshot TG. Applied preemergence, each herbicide controlled hairy bittercress, common groundsel, eclipta, and spotted spurge. These herbicides are effective postemergence when applied to small (up to four-leaf) hairy bittercress and spotted spurge. They are less effective postemergence on common groundsel and are not effective postemergence on eclipta. Therefore, if all weeds are not hand removed from containers or if time passes between hand weeding and preemergence applications of Broadstar, OH2, or Snapshot TG, some early postemergence control will occur depending on the weed species present.

**Nature of Work:** The container nursery industry relies upon broad-spectrum preemergence herbicides for weed control. However, preemergence herbicides dissipate rapidly in southeastern US nursery production after which time weeds begin to emerge (3). Weeds in containers must be removed by hand before herbicides are reapplied, an expensive and laborious task (2). In many situations it is not possible to completely remove all emerged weeds or to apply the preemergence herbicides before new weeds have germinated. Altland et al. (1) reported early postemergence control of bittercress with spray applications of Gallery (isoxaben). The granular herbicide, Snapshot TG, also contains isoxaben but has not been tested for early postemergence control. Similarly, spray applications of oxyfluorfen (Goal) control many seedling broadleaf weeds (4). Anecdotal evidence suggests that oxyfluorfen-containing granular herbicides such as OH2, as well as Broadstar (a granular formulation of flumioxazin), a newly registered broad-spectrum preemergence herbicide in nursery production, may provide early postemergence control of common nursery weeds.

A container experiment was conducted in the greenhouse and was repeated outdoors to compare Broadstar 0.17G (flumioxazin) at 0.28 kg ai/ha (0.25 lbs ai/A), Scott's Ornamental Herbicide II 3G (OH 2, oxyfluorfen + pendimethalin) at 3.4 kg ai/ha (3.0 lbs ai/A), and Snapshot TG 2.5G (isoxaben + trifluralin) at 5.6 kg ai/ha (5.0 lbs ai/A). Flumioxazin and oxyfluorfen are both protoporphyrinogen oxidase inhibitors (PPO's) that can burn crop foliage if granules are trapped on the leaf surface (5). Snapshot TG is a non-burning herbicide, and is used in the nursery industry in situations where burning of the crop foliage needs to be avoided. Herbicides were applied using a hand-held shaker jar.

In the greenhouse, the weed species evaluated were hairy bittercress (*Cardamine hirsuta* L.), common groundsel (*Senecio vulgaris* L.), and spotted spurge (*Euphorbia maculata* L.). Outdoors, both hairy bittercress and common groundsel were reevaluated, but eclipta (*Eclipta prostrata* L.) was evaluated instead of spotted spurge. Each herbicide was applied to each weed at each of three different growth stages: preemergence (greenhouse: 9.12.00; outdoors: 5.15.01), cotyledon to one-leaf postemergence (greenhouse: 9.22.00; outdoors: 6.24.01), and two- to four-leaf postemergence (greenhouse: 10.2.00; outdoors: 7.3.01).

In the greenhouse, 15 cm (6 in) diameter round pots were used with Fafard 4P greenhouse substrate. Outdoors, 1-gal (3.8 L) containers were used with pine bark plus sand potting substrate (7:1 v/v) amended with 3.6 kg per $m^3$ (6 lbs per $yd^3$) pulverized dolomitic limestone and 5.9 kg per $m^3$ (10 lbs per $yd^3$) Wilbro 15N-1.8P-7.5K with micros controlled release fertilizer. Each experimental run was a factorial combination of three herbicides, three application timings, and three species arranged in a randomized complete block design. In the greenhouse, there were 12 single-container replications, whereas outdoors, there were 10 single-container replications. In the greenhouse, containers were hand watered daily to container capacity. Outdoors, containers were overhead irrigated receiving two separate cycles of approximately 8.5 mm (1/3 in) each cycle.

Visual estimates of percent weed control were recorded 4 weeks after each application date and compared to non-treated plants. Additionally, shoot fresh weight was determined 4 weeks after final application. Data were pooled across experimental runs where species were the same. Main effects (herbicide, timing, and species) and all two-way and three-way interactions were determined by analysis of variance. Visual evaluations of percent control were highly correlated with shoot fresh weight (Pearson Correlation Coefficients = 0.92). Therefore, for presentation purposes, only visual evaluations of percent control are presented herein.

**Results and Discussion:** For both the greenhouse and outdoor study, all main effects, two-way interactions, and the three way interaction were significant. Thus, the nature of the two-way interaction is significantly different for each species and the effect of herbicide depends on both timing and species.

Broadstar, OH2, and Snapshot TG were all effective preemergence, providing greater than 80% control of all species (Figure 1). Each herbicide controlled hairy bittercress > 96% at the cotyledon to one-leaf growth stage. At the two- to four-leaf growth stage, only Broadstar provided > 80% control (Figure 1A). For common groundsel, Broadstar provided > 90% control at the cotyledon to one-leaf growth stage; whereas, OH2 provided < 80% control and Snapshot TG was ineffective. None of the herbicides were effective on common groundsel at the two- to four-leaf stage (Figure 1B). Eclipta was not controlled by any of the herbicides postemergence (Figure 1C). Each herbicide controlled spotted spurge > 99% at the cotyledon to one-leaf growth stage; whereas, Broadstar, OH2, and Snapshot provided 96, 77, and 84% control, respectively, at the two- to four-leaf stage (Figure 1D).

The preemergence nursery herbicides Broadstar, OH2, and Snapshot TG can be effective postemergence when weeds are very small, especially hairy bittercress and spotted spurge. The herbicides are less effective postemergence on common groundsel and are not effective postemergence on eclipta. Therefore, if all weeds do not get removed by hand from the containers or if time passes between hand weeding and preemergence applications of Broadstar, OH2, or Snapshot, some early postemergence control will occur depending on the weed species present.

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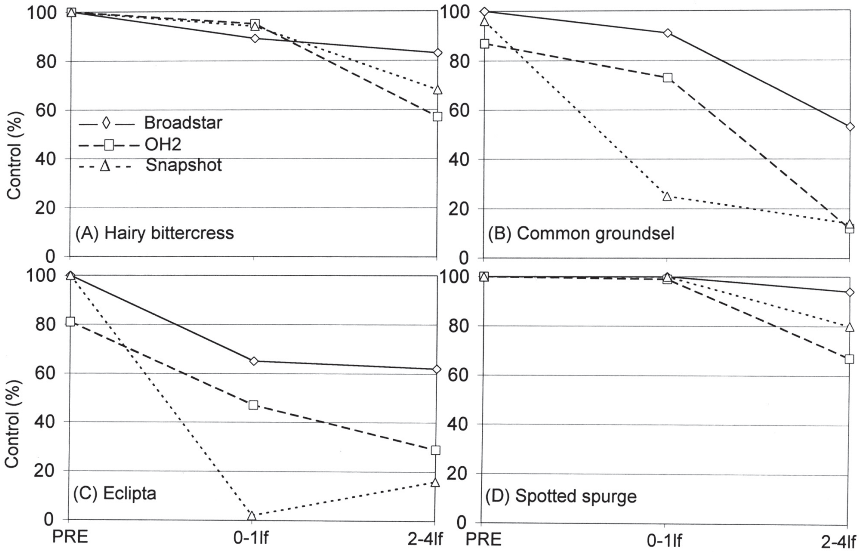
**Figure 1.** Percent control of (A) hairy bittercress, (B) common groundsel, (C) eclipta, or (D) spotted spurge with Broadstar, OH2, and Snapshot TG applied preemergence, or postemergence at the cotyledon to one-leaf or two- to four-leaf growth stage.



# Biology and Control of a Perennial *Viola* Species - A Potential Nursery Weed -

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**Index Words:** Container plant nurseries, Gallery, Preemergent herbicides, Seed germination, Snapshot TG, Violet

**Significance to the Industry:** These studies indicate that Gallery and Snapshot TG applied at recommended rates provide excellent preemergence control of this *Viola* species. Gallery applied at 1/2X label rates also provided over 90% control at six weeks after treatment. Snapshot TG may be effective in reducing plant regrowth. An investigation of seed characteristics on *Viola* germination suggests that dark coated seeds are more viable than light coated seeds.

**Nature of Work:** A perennial *Viola* species (tentatively identified as *Viola labradorica*) is a possible weed threat to horticultural operations in the SE United States. Unfortunately, little research on control or biology of this or similar species has been conducted. Initial observations indicated that this *Viola* produces two seed types with a brown or white pericarp; it also produces chasmogamous and cleistogamous flowers at non-overlapping sequential time periods. Similar flowering phenology has been observed in other *Viola* species (2, 3). The nature of these seed types has not been previously documented. Although no herbicide work has been conducted specifically concerning this *Viola*, other *Viola* species exhibited differing responses to preemergent herbicide applications (1). Identifying preemergence herbicides effective on *Viola* will give horticultural operations control options. Investigating the viability of the two seed types in relation to germination will increase awareness of the plant's biology and enhance control.

All studies were conducted in a climate controlled greenhouse at Montana State University, Bozeman, Montana. In the control study, preemergence herbicides were evaluated for emergence control of *Viola* from seed as well as suppressed re-growth from the perennial crown. Mature *Viola* plants, grown in a perlite: peat media in 8 inch azalea pots and allowed to self seed, were pruned to soil level prior to treatment. Herbicides were applied on 12 Sept. 2003 (Table 1). There were six replications of all treatments including the untreated control, arranged in a complete randomized block design. Snapshot TG (isoxaben + trifluralin) was applied using a handheld shaker can, while all other herbicides were applied in a spray chamber calibrated to deliver 17 GPA. Two visual evaluations were conducted on a weekly basis: suppressed regrowth from the pruned perennial crown and reduced emergence of *Viola* from seed (0 = no control; 100 = complete control). At 12 weeks after treatment (WAT), plants were harvested and above-ground fresh weights recorded. Plants were then dried at 40C for three days and dry weights were recorded. The study was repeated beginning in Jan. 2005.

In a subsequent study, reduced rates of Snapshot TG and Gallery were evaluated for successful preemergence control of *Viola* from seed One hundred *Viola* seeds were planted on 05 Mar. 2004 in a perlite:peat media in 6 inch azalea pots. Gallery was applied 08 Mar. 2004 while Snapshot TG was applied 05 Mar. 2004. Both herbicides were applied at rates of 1x, 1/2x, 1/4x, and 1/8x recommended rates using the application methods described above. There were six replications of each treatment and the untreated control. Treatments were visually evaluated weekly for preemergent control using the rating scale described above. At 11 WAT, above-ground biomass was recorded. Plants were dried at 40C for three days and dry mass was calculated. This study is currently being repeated.

To quantify effects of seed coat coloration on germination percentage and time to germination, greenhouse studies were conducted. Plastic cell packs (36 to a tray) were filled with a perlite:peat substrate on 13 February 2004. Ten *Viola* seeds were planted in each individual cell with 6 replications of each seed type. The number of germinated seeds was recorded weekly. Twelve weeks after planting, the study was terminated and above ground biomass recorded. Plants were dried for three days at 40C and dry weights were measured.

**Results and Discussion:** Snapshot TG provided excellent preemergent control of *Viola* (>95%) and suppressed top re-growth (>99%) at 11 WAT (Table 1). Similar effective control of germination was provided by Gallery (>96%) but re-growth was not suppressed. Other herbicides evaluated provided only marginal (40-60%) control. In the Snapshot TG dose study, reduced rates did not provide substantial control of germination when compared to the recommended rate of 4.03 kg ai/ha (3.75 lb ai/A) (Table 2). However, Gallery applied at 1/2x and 1/4x rates resulted in an 86 and 82% reduction, respectively (Table 3).

The germination study revealed that the dark coated *Viola* seed germinated at a statistically greater percentage than the light coated seeds. Eleven weeks after planting, more than 50% of dark coated seeds had germinated while only 13% of light coated seeds had germinated (Table 4). This suggests that the light seeds may be less viable than the dark seeds. A second study is currently underway in order to better understand and elucidate the effect of seed coat on seed germination characteristics. TZ (tetrazolium violet) tests for seed viability are also being conducted.

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**Table 1.** Preemergent herbicide control of *Viola* re-growth and emergence at 11 weeks after application. Dry weight was recorded 12 weeks after treatment.

| Treatment | Active ingredient | Rate | | Re-growth control[z] | Germination control | Dry weight |
|---|---|---|---|---|---|---|
| | | kg ai/ha | lb ai/A | % - - - | - - - | g |
| Dimension | dithiopyr | 0.55 | 0.50 | 14 bcd | 70 a-d | 3.13 ab |
| Gallery | isoxaben | 0.83 | 0.75 | 27 bc | 97 ab | 2.51 ab |
| Goal | oxyfluorfen | 0.41 | 0.37 | 12 bcd | 72 a-d | 2.18 b |
| Kerb | pronamide | 0.75 | 0.50 | 3 cd | 53 bcd | 3.70 a |
| Prowl | pendimethalin | 3.30 | 3.00 | 2 d | 58 a-d | 3.01 ab |
| Snapshot TG | isoxaben + trifluralin | 4.13 | 3.75 | 99 a | 100 a | 0.18 c |
| Surflan | oryzalin | 3.30 | 3.00 | 12 bcd | 45 cde | 2.98 ab |
| Untreated | | | | 0 d | 0 d | 2.62 ab |

[z]Means within a column followed by the same letter are not statistically different at $P = 0.05$

**Table 2.** Preemergent herbicide control of *Viola* germination at 6, 9, & 11 WAT in the Snapshot TG rate study. Plant dry weights were measured 11 WAT.

| Snapshot TG Application Rate Treatments | | 6 WAT[z] | 9 WAT | 11 WAT | Dry weight |
|---|---|---|---|---|---|
| kg ai/ha | lb ai/A | | % control | | g |
| 4.03 | 3.75 | 96 a | 97 a | 97 a | 0.12 c |
| 2.06 | 1.88 | 53 b | 48 b | 36 b | 2.95 b |
| 1.03 | 0.94 | 32 bc | 22 c | 20 bc | 4.65 a |
| 0.52 | 0.47 | 12 cd | 8 cd | 11 c | 5.15 a |
| Untreated | | 0 d | 0 d | 0 d | 5.80 a |

[z]Means within a column followed by the same letter are not statistically different at *P*= 0.05

**Table 3.** Preemergent herbicide control of *Viola* germination 6, 9, & 11 WAT in the Gallery rate study. Plant dry plant weights were measured 11 WAT.

| Gallery Application Rate Treatments | | 6 WAT[z] | 9 WAT | 11 WAT | Dry weight |
|---|---|---|---|---|---|
| kg ai/ha | lb ai/A | | % control | | g |
| 0.84 | 0.75 | 96 a | 93 a | 95 a | 0.05 b |
| 0.42 | 0.38 | 92 ab | 88 ab | 86 ab | 0.37 b |
| 0.21 | 0.19 | 85 b | 79 b | 82 b | 0.54 b |
| 0.10 | 0.09 | 8 c | 3 c | 5 c | 4.83 a |
| Untreated | | 0 d | 0 d | 0 d | 4.80 a |

[z]Means within a column followed by the same letter are not statistically different at *P*= 0.05

**Table 4.** Percent germination of the two *Viola* seed types at 3, 7, & 11 weeks after planting. Fresh and dry weights were taken 12 weeks after planting. Means with similar labels are not statistically different at P= 0.05.

| | **Weeks after planting**[z] | | | **Fresh weight** | **Dry weight** |
|---|---|---|---|---|---|
| **Seed coat type** | 3 | 7 | 11 | g | |
| Light | 6 b | 10 b | 14 b | 0.77 b | 0.09 b |
| Dark | 24 a | 48 a | 58 a | 3.45 a | 0.44 a |

[z]Means within a column followed by the same letter are not statistically different at *P*= 0.05

# Preemergent Herbicides for Establishment of Native Plant Species

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**Index Words:** Blanket flower, common yarrow, slender white prairie clover, upright prairie coneflower, seed production, Prowl, Kerb.

**Significance to Industry:** Increased interest in native plant species for landscape use and reclamation projects has escalated the demand for seed production. Four native Montanan forbs - slender white prairie clover *(Dalea candida)*, upright prairie coneflower *(Ratibida columnifera)*, common yarrow *(Achillea millefolium)*, and blanket flower *(Gaillardia aristata)* were evaluated for establishment tolerance to preemergence herbicides. Results indicate that Prowl may be used at a rate of 3 lb ai/A (3.3 kg ai/ha) as a preemergence herbicide on the four species tested and that Kerb can be used at a rate of 0.5 lb ai/A (0.55 kg ai/ha) on common yarrow, upright prairie coneflower and blanket flower. Herbicides that prevented growth of the four native species were Dimension, Gallery, Goal, SnapshotTG and Surflan. Excellent control of prevalent MT weed species was achieved by Prowl.

**Nature of Work:** Increased interest in native species for use in the landscape and for reclamation projects has increased demand for seed production. Germination protocols have been developed for many native species, but limited work has been conducted on establishment procedures such as preemergence weed control.

Four native Montanan forbs, scheduled for release by the USDA Plant Materials Center, Bridger, MT, were evaluated for tolerance to preemergence herbicides. Species in this study were slender white prairie clover *(Dalea candida)*, upright prairie coneflower *(Ratibida columnifera)*, common yarrow *(Achillea millefolium)*, and blanket flower *(Gaillardia aristata)*. Other researchers have reported that metolachlor did not reduce flowering or stand of purple coneflower or blanket flower seedlings but plants were transplanted and not evaluated for germination tolerance in the study (2). A combination of trifluralin + EPTC did not injure prairie coneflower, annual blanket flower or red yarrow when treated before establishment (3). Plateau, Manage and Image did not inhibit seedling emergence of blanket flower or purple coneflower but did adversely affect upright prairie coneflower (1). Clearly, additional research is needed to provide preemergence herbicide information for establishment of native plants.

Experiments were conducted during 2003-04, in a climate-controlled greenhouse at Montana State University to evaluate the safety of preemergence herbicides on native flowers. Native species were seeded in 4-6 in containers in a native field soil (pH $\approx$ 7.5). Sprayable herbicides were applied in a spray chamber fitted with 8004 nozzles delivering 20 gpa, and granular herbicides were applied with a shaker can. In the initial screening study, initiated in May 2003, herbicides (see Table 1 for treatments and rates) were applied immediately after native species were planted. Common weed species including *Kochia scoparia*, Russian thistle *(Salsola iberica)* redroot pigweed *(Amaranthus retroflexus)* and lambsquarters *(Chenopodium album)* were seeded two weeks after application (WAA). Six replications of each herbicide treatment and the untreated control were arranged in a randomized complete block design within a species. On a weekly basis, injury to the native species, manifesting as lack of emergence and growth inhibition as compared to the untreated, was rated on a 0-100 scale with 0 = no injury or control, 100 = complete control. At the end of the study, 9 WAA, growth index was determined for the surviving native plants and calculated as the average of the height + (width at widest point + width perpendicular to widest point)/2. Weed control was also evaluated in this study both visually and through top growth harvest and fresh and dry weights at 9 WAA.

The experiment was repeated in September 2003 and February 2004 as described above, with the following exceptions. In the September 2003 test, Blanket flower was omitted from the study, weed species were not planted, and treatments were applied one week after natives were planted. The February 2004 test was similar to the initial study except weeds were omitted and fresh and dry weights of native species replaced GI measurements.

**Results and Discussion:** In the initial screening study, Prowl and Surflan did not injure slender white prairie clover. Kerb, Prowl and Surflan did not injure upright prairie coneflower, Kerb did not injure common yarrow, and Dimension, Kerb and Prowl did not injure blanket flower (Table 1). Gallery, Goal and SnapshotTG severely injured or killed all of the native species tested. Growth index of native species was generally greater for the non-injurious herbicide treatments than the untreated controls due to lack of interference from weedy species. Most effective control of planted weed species was achieved by Surflan and Prowl (data not shown).

Results of the second study reinforced the data from the first study. Prowl was minimally injurious (manifesting as growth reduction) to slender white prairie clover and upright prairie coneflower, and Kerb did not injure upright prairie coneflower and only slightly reduced growth of common yarrow (Table 2). In the third study, Prowl was not injurious to any of the four native species, and Kerb was also found to be safe for use on common yarrow, upright prairie coneflower and blanket flower (Table 3). Fresh weight data supports these observations. as weights of treated plants were similar to weights of untreated plants (Table 3). Dimension slightly injured slender white prairie clover, common yarrow and upright prairie coneflower. Dimension was similarly effective in the first study on blanket flower, but prevented emergence of all species in the second study perhaps due to the delayed treatment date after planting.

These studies indicate that Prowl may be used at labeled rates as a preemergence herbicide on the four species tested and that Kerb can be used on common yarrow, upright prairie coneflower and blanket flower. As data supporting use of Dimension is contradictory, it cannot be recommended for use on any of these species at this time.

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**Table 1.** Preemergence herbicide effects on native flower growth; initial study evaluated 9 weeks after treatment.

| | Rate | | *Dalea* | | *Ratibida* | | *Achillea* | | *Gaillardia* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lb ai/A | kg ai/Ha | Injury* (%) | GI** (mm) | Injury (%) | GI (mm) | Injury (%) | GI (mm) | Injury (%) | GI (mm) |
| Dimension | 0.5 | 0.55 | 100 | 7 | 100 | 12 | 85 | 18 | 17 | 29 |
| Gallery | 0.75 | 0.83 | 72 | 29 | 100 | 0 | 100 | 3 | 94 | 0 |
| Goal | 0.37 | 0.41 | 87 | 9 | 100 | 17 | 92 | 13 | 82 | 5 |
| Kerb | 0.5 | 0.55 | 100 | 0 | 7 | 102 | 0 | 133 | 3 | 74 |
| Prowl | 3 | 3.3 | 22 | 46 | 0 | 107 | 58 | 61 | 0 | 63 |
| SnapshotTG | 3.75 | 4.13 | 93 | 0 | 96 | 24 | 100 | 37 | 58 | 30 |
| Surflan | 3 | 3.3 | 17 | 44 | 10 | 96 | 62 | 50 | 70 | 30 |
| Untreated | -- | -- | 0 | 32 | 0 | 57 | 0 | 84 | 0 | 33 |
| LSD *P*=0.05 | | | 28 | 30 | 15 | 48 | 28 | 55 | 33 | 41 |

*Visual estimates of growth reduction where 100 = complete kill and 0 = no growth reduction compared to the untreated.

** Growth index was the calculated as the average of the height + (width at widest point + width perpendicular to widest point)/2

**Table 2.** Preemergence herbicide effects on native flower growth; second study, evaluated 12 weeks after treatment.

| | Rate | | *Dalea* | *Ratibida* | *Achillea* |
|---|---|---|---|---|---|
| | lb ai/A | kg ai/ Ha | Injury (%) | | |
| Dimension | 0.5 | 0.55 | 96 | 93 | 100 |
| Gallery | 0.75 | 0.83 | 65 | 100 | 100 |
| Goal | 0.37 | 0.41 | 100 | 100 | 100 |
| Kerb | 0.5 | 0.55 | 96 | 10 | 40 |
| Prowl | 3 | 3.3 | 33 | 34 | 85 |
| SnapshotTG | 3.75 | 4.13 | 99 | 98 | 100 |
| Surflan | 3 | 3.3 | 66 | 75 | 88 |
| Untreated | -- | -- | 0 | 0 | 0 |
| LSD *P*=0.05 | | | 30 | 16 | 24 |

*Visual estimates of growth reduction where 100 = complete kill and 0 = no growth reduction compared to the untreated.

**Growth index was the calculated as the average of the height + (width at widest point + width perpendicular to widest point)/2.

**Table 3.** Preemergence herbicide effects on native flower growth; third study, evaluated 11 weeks after treatment.

| | Rate | | *Dalea* | | *Ratibida* | | *Achillea* | | *Gaillardia* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lb ai/A | kg ai/Ha | Injury (%) | FWt (g) | Injury (%) | FWt (g) | Injury (%) | FWt (g) | Injury (%) | FWt (g) |
| Dimension | 0.5 | 0.55 | 31 | 1.49 | 30 | 5.14 | 30 | 4.40 | 64 | 3.11 |
| Gallery | 0.75 | 0.83 | 63 | 1.48 | 100 | 0 | 100 | 0 | 100 | 0 |
| Goal | 0.37 | 0.41 | 94 | 0.28 | 100 | 0 | 100 | 0 | 90 | 0.75 |
| Kerb | 0.5 | 0.55 | 43 | 1.10 | 18 | 6.65 | 0 | 4.78 | 21 | 6.20 |
| Prowl | 3 | 3.3 | 15 | 1.32 | 18 | 5.25 | 37 | 2.16 | 10 | 7.42 |
| SnapshotTG | 3.75 | 4.13 | 55 | 1.45 | 51 | 3.47 | 90 | 0.61 | 73 | 2.53 |
| Surflan | 3 | 3.3 | 53 | 1.51 | 75 | 2.15 | 98 | 0.02 | 89 | 2.24 |
| Untreated | -- | -- | 0 | 1.37 | 0 | 6.53 | 0 | 3.28 | 0 | 7.76 |
| LSD *P*=0.05 | | | 28 | 1.23 | 30 | 2.25 | 30 | 2.12 | 50 | 2.80 |

*Visual estimates of growth reduction where 100 = complete kill and 0 = no growth reduction compared to the untreated.

**Growth index was the calculated as the average of the height + (width at widest point + width perpendicular to widest point)/2.

# Mugwort Regeneration from Rhizome Sections in Sand, Pine Bark, and Soil Substrates

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**Index Words:** *Artemisia vulgaris*, ARTVU, False Chrysanthemum

**Significance to Industry:** Mugwort is one of the 10 most problematic weeds in eastern U.S. nurseries. Mugwort spreads by rhizome pieces on cultivation equipment and in root balls of nursery crops. Cutting rhizomes into small sections (e.g. cultivation and rototilling) reduces the proportion of pieces that survive. Still, sufficient plants regenerate from surviving sections that mugwort populations and subsequent stand density are expected to increase. In this study, regardless of substrate type, high proportions of rhizome sections as small as 0.5 cm (0.2 in), including those without leaf scales, were able to produce shoots and roots within 45 days when irrigated. The greatest numbers of rhizomes produced plants when sections were grown in pine bark. Fewer plants were established on rhizome sections grown in soil, though these plants had the highest root and shoot biomasses. Results demonstrate the need to maintain clean field-grown liner stock. Mugwort has great potential to establish in the landscape if infested nursery crops are transplanted. Growers and landscape managers should scout proactively for mugwort and initiate aggressive management action when populations are found.

**Nature of Work:** Mugwort or false chrysanthemum (*Artemisia vulgaris* L.) is a non-native perennial aster that has naturalized in parts of Canada and much of the eastern U.S. (2, 8, 12). Mugwort foliage appears similar to common ragweed (*Ambrosia artemisiifolia* L.) and ornamental chrysanthemums (*Chrysanthemum* spp.). Unlike cultivated chrysanthemums and common ragweed, the lower surfaces of mugwort leaves are covered with a dense, silver-white pubescence (2, 12). Mature *A. vulgaris* stems, which can grow 2 m (6 ft) tall, yield rankly aromatic flower heads in panicles of composite flowers, each consisting of 15 to 30 greenish-yellow disk-shaped florets, in late summer (5). Seed set is variable: an attribute of climatic factors. At optimum, individual plants may generate 200,000 seeds in a season (5, 8, 9). In the eastern U.S., few seeds are viable (2, 8, 12). Weed dispersal in nurseries and landscape plantings occurs primarily by rhizomes transported on contaminated cultivation equipment and ornamental nursery crop plants (3, 4, 8, 11, 12).

Once established, mugwort rhizomes gradually expand outward from the source, excluding other plants and forming a dense, monotypic stand (7, 8, 10, 11). Mugwort is extremely adaptable to soil and climatic variation extending across 56 countries (2). It has named one of the 10 most problematic weeds in nurseries of the eastern U.S. (7, 8). Although mugwort is listed as a noxious weed in Manitoba province (1), it is not listed in U.S. lists as a federal or state noxious weed. In the U.S., it has been offered for retail sale (2).

In nursery fields, mugwort rhizomes are generally abundant in the upper 10 cm (4 in) of soil (10). Guncan (6) reported that 75% of rhizome fragments 2 to 5 cm (0.75 – 2 in) long produced shoots, but no roots in the warm, humid climate along the Black Sea coast. Longer rhizome sections produced ample roots and shoots during seasonal growth. The regenerative potential of mugwort from rhizomes is problematic for commercial growers, home gardeners and landscape maintenance professionals. Repeated rototilling and soil cultivation is expected to subject rhizome fragments to mortality from desiccation, but may stimulate population growth where cultivation is infrequent (2). The objective of this study was to quantify regeneration potential of mugwort rhizome sections in growing substrates chosen to represent those encountered in landscapes, nursery fields, container nurseries, and propagation beds.

In 2001, mugwort was collected from the border of a commercial tree nursery and transplanted into 4:1 (v/v) sieved (5.7 mm) pine bark: medium-coarse (mined, washed) quartz sand, grown under 40% shade in an outdoor shade house and irrigated as needed. In June, rhizomes (2.0 ± 0.5 mm (0.08 in) in diameter) were washed free of substrate and all lateral and fine roots were removed. Rhizomes appeared to darken with age, thus were separated into white (newer) or brown (older) groups. Rhizomes were cut into 0.5 cm, 1.0 cm and 2.0 cm-long (0.2 in, 0.4 in, 0.8 in) sections. Half of the 0.5 and 1.0 cm sections were cut to include a leaf scale. The other half had no leaf scale present. All 2.0 cm long sections included at least two leaf scales. Ten sectioned rhizomes per treatment were transplanted into 235 $cm^3$ (14.3 $in^3$) pots filled with pre-moistened pine bark, quartz sand or sieved (4 mm) field soil (Sequatchie, fine-loamy Hapludults, pH 6.5). Factorial combinations of 5 rhizome lengths, 3 substrates, and 2 rhizome colors were arranged in a RCB design with six replicates. The study lasted 45 days and was repeated in July.

Both repetitions of the experiment were conducted in a greenhouse with daytime temperatures of 25 ± 3C (77 ± 5F) and 21 ± 3C (70 ± 5F) at night with approximately 80% relative humidity. Plants were exposed to ambient (about 12 h) photoperiod. Plants were irrigated by automated mist that delivered 6 seconds of mist every 8 minutes from 1000 to 1600 hr. Every seventh day, plants were provided 40 ml 150 mg L N as Peters 20.0N-8.6P-16.6K (Peters 20-20-20) water-soluble fertilizer (Peters General Purpose 20-20-20, Scotts–Sierra Horticultural Products, Marysville, OH).

After 45 days, substrates were washed from the roots and rhizomes to yield shoot and root length and fresh weight data. Intact but inactive sections, described as firm rhizome tissues with no evident putrefaction, were recorded. Recovered root or shoot portions were combined within treatment, dried for 48 hr at 60C (140F), and weighed. Data were analyzed using PROC GLM in SAS (SAS Institute, Cary, NC). Linear contrasts described significant differences in rhizome growth in the presence or absence of a single leaf scale. Means were separated using a LSD procedure ($P \leq 0.05$).

**Results and Discussion:** Rhizome color, a hypothetical attribute of age, did not account for differences in growth among treatments. Root and shoot growth on individual rhizome sections did not differ between June- and July-initiated trials.

Data for non-significant factors were pooled for analyses. Contrary to previous research, 85, 78, and 69% of 2 cm-long rhizome sections produced both roots and shoots when grown in pine bark, sand, and soil substrates, respectively, during 45-day trials. Slightly less than 31% of rhizome fragments 0.5 cm long without a leaf scale produced both roots and shoots in soil. Though fewer rhizomes survived in soil, root and shoot fresh weights were greater than in pine bark and sand. When rhizome sections included a leaf scale, survival, fresh weights of roots and shoots, shoot height, leaf number and root lengths were greater, regardless of substrate type (Table 1).

Shoot emergence preceded root emergence from rhizome sections. This adaptation enhances the likelihood that mugwort will establish when transplanted by contaminated equipment. Photosynthesis in early emerging shoot tissues would provide energy for subsequent rhizome and root development. Fewer inactive rhizome sections (that maintained tissue turgor and showed no evidence of putrefaction) were recovered when similarly sized sections included a leaf scale, regardless of substrate type. In all substrates, more inactive sections were recovered later in the season (data from individual trials not shown). These sections were not tested further, but inactive rhizome pieces will function like a seed bank if root primordia develop once conditions become favorable. Because mugwort has great potential to spread once established in the nursery and landscape, growers and landscape managers should learn to identify mugwort, scout regularly, and initiate aggressive management action when populations are found.

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**Table 1.** Regeneration of mugwort plants from individual rhizome sections grown in a greenhouse for 45 days.

| Substrate | Rhizome Length (cm) -/+ Leaf Scale | Regenerated Plants (%) (n=240) | Inactive Rhizome Sections (2-trial mean) | Shoot Fresh Weight (g) | | Root Fresh Weight (g) | |
|---|---|---|---|---|---|---|---|
| Pine Bark | 0.5 - | 73 | 4.9 | 0.02 | | 0.03 | |
| | 0.5 + | 84 | 0.9 | 0.04 | | 0.06 | |
| | 1.0 - | 78 | 4.4 | 0.02 | - b | 0.05 | - b |
| | 1.0 + | 88 | 0.7 | 0.06 | | 0.09 | |
| | 2.0 ++ | 85 | 0.2 | 0.11 | | 0.18 | |
| Sand | 0.5 - | 85 | 4.8 | 0.01 | | 0.03 | |
| | 0.5 + | 65 | 1.2 | 0.04 | | 0.06 | |
| | 1.0 - | 68 | 3.5 | 0.03 | - b | 0.06 | - b |
| | 1.0 + | 70 | 0.6 | 0.05 | | 0.09 | |
| | 2.0 ++ | 78 | 0.2 | 0.10 | | 0.16 | |
| Soil | 0.5 - | 32 | 2.8 | 0.06 | | 0.08 | |
| | 0.5 + | 40 | 1.6 | 0.22 | | 0.31 | |
| | 1.0 - | 48 | 3.7 | 0.13 | - a | 0.22 | - a |
| | 1.0 + | 54 | 0.8 | 0.35 | | 0.47 | |
| | 2.0 ++ | 69 | 0.5 | 0.33 | | 0.43 | |
| Significance | | | | | | | |
| | Substrate [z] | | | *** | | *** | |
| | Rhizome Length | | | *** | | *** | |
| | Substrate x Rhizome Length | | | *** | | *** | |
| | - vs + [y] | | | *** | | *** | |

[z]Within columns, substrate means followed by the same letter are not significantly different by Fisher's LSD ($P > 0.05$).

[y]Linear contrast in absence (-) or presence (+) of leaf scales on 0.5 and 1.0 cm rhizome sections significantly different at $P < 0.001$ (***).

# Postemergence Control of Liverwort in Container Production

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**Index words:** *Marchantia polymorpha*, quinoclamine, hydrogen peroxide

**Significance to Industry:** Liverwort is growing rapidly as a weed problem within the southern United States. Hand removal is currently the only option for removal of present infestations. Postemergence control of liverwort with minimal injury to ornamental crops would be a key defense to this weed. This study demonstrates good postemergence control of liverwort with two products.

**Nature of Work:** Liverwort (*Marchantia polymorpha*) is one of the most difficult to control weeds within many areas of the United States. It has spread throughout the nursery industry and into the Southeast. Liverwort is a physiological primitive plant within the phylum *Hepatophyta* that has no vascular system. *Marchantia polymorpha* can be identified by prostrate leaf-like structures called thalli that create a mat over media surfaces. They propagate sexually by spores and asexually by gemmae. The thalli can cover the entire media surface of a container and restrict water and nutrient movement into the root zone, as well as reduce the marketability of a crop (Svenson, 1998). Liverwort thrives in low UV light, high fertility, high moisture, and high humidity environments. Propagation houses, shade houses, and other covered structures provide ideal conditions for liverwort (Svenson, 1997). Conditions conducive to propagation are especially favorable to liverwort.

There are no postemergence herbicides labeled for liverwort control in container or greenhouse crops, and hand removal of liverwort is costly and inefficient. Two chemicals have recently been shown to provide postemergence control of liverwort in Oregon (Altland, 2003). Quinoclamine is an algaecide that has been used in Japanese rice production. Crompton Uniroyal Company is seeking a label for its use in nursery and greenhouse crops in enclosed structures in the United States. Preliminary research indicates that quinoclamine is safe for over-the-top application to a broad range of ornamental crops (Altland, 2003). TerraCyte is a granular formulation of sodium carbonate peroxyhydrate that breaks down into sodium carbonate and hydrogen peroxide upon contact with water. Recent studies have indicated that this product also provides postemergence liverwort control (Altland, 2003).

The objective of this study was to evaluate quinoclamine and TerraCyte for postemergence control of liverwort.

Experiment 1 was conducted at the Oregon State University North Willamette Research and Extension Center (NWREC) in Aurora, OR. Trade-gallon containers were filled with Douglas fir bark amended with 16 lbs Osmocote 18-6-12 and

1.5 lbs Micromax per cubic yard. Containers were inoculated with liverwort in the summer of 2003 by pouring an inoculum slurry onto the substrate surface (Svenson, 1998). Liverwort was grown inside a retractable roof greenhouse under a daily overhead irrigation rate of 1⁄2 inch split into two cycles per day. Treatments were applied on 22 July 2003 when liverwort were mature. Quinoclamine was applied at 1 oz/gal (0.25 oz ai/gal), 2 oz/gal (0.5 oz ai/gal), and 4 oz/gal (1.0 oz ai/gal). Quinoclamine was applied with a $CO_2$ backpack sprayer with an 8008 flat fan nozzle at a pressure of 35 psi and calibrated to deliver 100 gal/A. TerraCyte was applied at 653 lb/A (222 lb ai/A), and Broadstar 0.25G was applied at the labeled rate of 150 lb/A (0.375 lb ai/A). A non-treated control group was also included. Treatments were arranged in a completely randomized design with 10 single pot replications. Percent control was recorded at 2 and 14 DAT on a 0 to 100 percent scale where 0 percent equals no control of liverwort and 100 percent equals death of entire liverwort. Similar treatments were also applied over the top to 8 single-pot replications of *Salvia nemorosa*, *Scabiosa columbaria*, *Rhododendron* ‘PJM’, and *Rudbeckia fulgida* ‘Goldstrum.’ Injury ratings were recorded on these species at 2 and 14 DAT on a 0 to 10 scale where 0 equals no injury and 10 equals death of the plant. Species were randomized separately in a completely randomized design. Data were subjected to analysis of variance and means were separated with Duncan’s Multiple Range Test ($\alpha$=0.05).

Experiment 2 was conducted at Auburn University in the spring of 2004. Full-gallon containers were filled with a 6:1 pine bark to sand substrate amended with 14 lb of Polyon 18-6-12, 5 lb of dolomitic lime, and 1.5 lb of Micromax per cubic yard. On 26 February 2004, containers were inoculated with liverwort as described in Experiment 1. Liverwort was grown inside a temperature controlled greenhouse under a cyclic mist irrigation system. Treatments were applied on 16 April 2004 when liverwort was well established and covered at least half of the substrate surface. Eight treatments of quinoclamine were applied. Rates of 1 oz/gal (0.25 oz ai/gal) and 2 oz/gal (0.5 oz ai/gal) were applied with and without surfactant (Silwet L-77 organosilicone surfactant) at 1 qt./100 $ft^2$ (109 gal/A) and 2 qt./100 $ft^2$ (218 gal/A). Treatments were applied with a $CO_2$ backpack sprayer with an 8005 flat fan nozzle at 30 PSI. Two rates of TerraCyte were applied at 435 lb/A (148 lb ai/A) and 653 lb/A (222 lb ai/A). Two rates of an experimental TerraCyte (ETC) with twice the amount of active ingredient were also applied at 292 lb/A (192 lb ai/A) and 435 lb/A (296 lb ai/A). Broadstar 0.25G was applied at the labeled rate of 150 lb/A (0.375 lb ai/A). TerraCyte, ETC, and Broadstar treatments were applied with a handheld shaker. A non-treated control group was maintained. Treatments were arranged in a completely randomized design with 6 single pot replications. Percent control was recorded at 1, 3, 7, 14, and 21 DAT on a 0 to 100 percent scale where 0 percent equals no control of liverwort and 100 percent equals death of entire liverwort. As a measure of liverwort re-growth, percent of the substrate surface covered with living liverwort was recorded at 35 DAT. Means were separated with Duncan’s Multiple Range Test ($\alpha$=0.05).

**Results and Discussion:** In both experiments, quinoclamine provided excellent postemergence control. Control with TerraCyte differed with dose and formulation, and Broadstar provided little postemergence control. In Experiment

1 quinoclamine at 1 oz/gal provided 98.5% control at 2 DAT, while rates of 2 oz/gal and 4 oz/gal provided 100% control (Table 1). Control with TerraCyte at 653 lb/A was significantly less with only 67%. Broadstar provided only 20% control at 2 DAT. At 14 DAT, control with all quinoclamine rates was very high. Quinoclamine at 1 oz/gal provided 97.8% control, while rates of 2 oz/gal and 4 oz/gal still provided 100% control. Control with TerraCyte increased to 79% by 14 DAT, while control with Broadstar increased to 39%. No species treated displayed injury from any treatment.

In Experiment 2, all quinoclamine rates provided excellent control throughout the study with no differences between chemical rates, surfactant use, or spray volume (Table 2). At 3 DAT, all quinoclamine treatments provided at least 97.8% control. By 14 DAT, quinoclamine treatments ranged from 92.5% control to 100% control with no significant differences between chemical rates, surfactant use, or application rates. At 3 DAT, TerraCyte control was significantly lower than quinoclamine treatments with 75.8% control, while TerraCyte at 15 lbs/1,000 $ft^2$, ETC at 6.7 lbs/1,000 $ft^2$ and 10 lbs/1,000 $ft^2$ provided similar control to quinoclamine with 88.2%, 88%, and 94.8%, respectively. By 14 DAT both TerraCyte treatments provided significantly less control than quinoclamine treatments; however control with both ETC rates were similar to quinoclamine control. Broadstar control was significantly less than all other treatments and similar to the control group throughout the trial.

At 35 DAT, liverwort coverage in quinoclamine treatments ranged from 0% to 13.3% within the container with no significant differences between chemical rates, surfactant use, or spray volume. Liverwort coverage within containers treated with TerraCyte at 435 lb/A and 653 lb/A was 45% and 25.8%, respectively. Liverwort coverage within containers treated with ETC at 292 lb/A and 435 lb/A was 19.2%; ETC treatments were statistically similar to most quinoclamine treatments. Liverwort coverage in containers treated with Broadstar was significantly greater than all other treatments at 62.5%. Liverwort covered an average of 89.2% of the containers in the non-treated control group by 35 DAT.

These data have demonstrated two effective products for selective postemergence control of liverwort. With these tools growers can combat existing infestations of liverwort with little or no injury to ornamental crops.

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**Table 1.** Experiment 1, Herbicide influence on postemergence control of liverwort.

| | quinoclamine | | | TerraCyte (34%) | Broadstar | |
|---|---|---|---|---|---|---|
| | 1 oz/gal | 2 oz/gal | 4 oz/gal | 653 lb/A | 150 lbs/A | Control |
| 2 DAT[Z] | 98.5[Y] a[X] | 100 a | 100 a | 67.0 b | 20.0 c | 2.0 d |
| 14 DAT | 97.8 a | 100 a | 100 a | 79.0 b | 39.0 c | 3.0 d |

[Z]Days after treatment

[Y]Percent control of liverwort where 0%=no control and 100%=death of entire liverwort

[X]Duncan's Multiple Range Test ($\alpha$=0.05). Means within row with same letter are not signifcantly different.

**Table 2.** Experiment 2, Herbicide influence on postemergence control of liverwort.

| | quinoclamine 1 oz/gal | | | | quinoclamine 2 oz/gal | | | |
|---|---|---|---|---|---|---|---|---|
| | w/o surfactant[Z] | | w/surfactant | | w/o surfactant | | w/surfactant | |
| | 1 qt/100 ft$^2$ | 2 qt/100 ft$^2$ | 1 qt/100 ft$^2$ | 2 qt/100 ft$^2$ | 1 qt/100 ft$^2$ | 2 qt/100 ft$^2$ | 1 qt/100 ft$^2$ | 2 qt/100 ft$^2$ |
| 3 DAT | 99.0[Y] a[X] | 99.7 a | 97.8 a | 100 a | 99.8 a | 99.8 a | 100 a | 100 a |
| 14 DAT | 92.5 a | 100 a | 92.5 a | 99.5 a | 98.8 a | 100 a | 98.8 a | 100 a |
| % coverage at 35 DAT | 13.3[W] def | 1 f | 12.5 def | 2.8 ef | 1.3 ef | 0 f | 2.0 ef | 0 ef |
| | TerraCyte (34%) | | Experimental TerraCyte (68%) | | Broadstar | | | |
| | 435 lb/A | 653 lb/A | 292 lb/A | 435 lb/A | 150 lbs/A | Control | | |
| 3 DAT | 75.8 b | 88.2 a | 88.0 a | 94.8 a | 4.5 c | 0 c | | |
| 14 DAT | 74.0 b | 76.7 b | 86.7 ab | 87.0 ab | 20.8 c | 8.3 c | | |
| % coverage at 35 DAT | 45 c | 25.8 d | 19.2 de | 19.2 de | 62.5 b | 89.2 a | | |

[Z]Silwet L-77 organosilicone surfactant

[Y]Percent control of liverwort where 0%=no control and 100%-death of entire liverwort

[X]Duncan's Multiple Range Test ($\alpha$=0.05). Means within same DAT with same letter are not signifcantly different.

[W]Percent coverage of liverwort within the container

## *Oxalis corniculata* L. Response to Substrate pH

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**Index words:** creeping woodsorrel, lime, weed control

**Significance to the Nursery Industry:** The following data demonstrate that creeping woodsorrel germinates poorly with virtually no growth and flowering in alkaline substrates (pH > 7). Leda and Wright (2) demonstrated that surface applications of pulverized lime do not greatly affect substrate pH. Surface applications of lime might raise pH levels on the container substrate surface high enough to inhibit growth of small seeded weeds, such as creeping woodsorrel, without adversely affecting pH levels in the bulk container substrate. Current research is evaluating how surface applications of dolomitic limestone affect substrate pH levels throughout the container.

**Nature of Work:** Weed control is important for producing quality container crops. Weeds in container systems are commonly controlled with preemergence herbicides; however, herbicides are not practical in every situation. Some crops such as hydrangea and azalea are sensitive to preemergence herbicides (3), and no preemergence herbicide is labeled for use inside enclosed structures. Understanding weed biology and environmental factors that influence weed growth may provide alternatives to preemergence herbicides. Substrate pH is a major factor that affects plant growth. Changes in pH can increase or decrease chemical nutrients to toxic or deficient levels (4), and only a few species grow equally well in both alkaline and acidic soils. Substrate pH affects the growth of many container crops (6). Soil pH has also been shown to influence the severity of weed infestations. Research in field soils has demonstrated that broadleaf weed densities decrease as pH rises above pH 5.5 (5). Also in a field soil, *Oxalis martiana* leaf number, plant height and dry weight decreased with increasing soil pH (1). A similar species, creeping woodsorrel (*Oxalis corniculata* L.), is one of the most common and problematic weeds in container crops throughout the U.S.

The objective of our research is to determine the influence of substrate pH on creeping woodsorrel establishment, growth, and reproduction. Once an optimal (or detrimental) pH range is established, cultural practices that modify pH at the container surface might be developed to inhibit creeping woodsorrel growth and reproduction.

An experiment was conducted in a heated hoophouse at the North Willamette Research and Extension Center in Aurora, OR. Containers 14 cm (5.5 inches) tall and wide were filled with 100% Douglas fir (*Pseudotsuga menziesii*) bark amended with 0.9 kg/m$^3$ (1.5 lbs/ yd$^3$) Micromax micronutrients and 7.1 kg/m$^3$ (12 lbs/yd$^3$) Osmocote 14-14-14. Pulverized dolomitic limestone was incorporated at 0, 5.9, 11.8, 23.7, or 47 kg/m3 (0, 10, 20, 40, or 80 lbs/yd$^3$).

Twenty seeds of creeping woodsorrel were applied to each pot December 19, 2003. Containers were overhead irrigated 0.6 cm (0.25 inch) per day. Data collected included substrate pH, flower number and shoot fresh weight (SFW) 80 days after potting (DAP). The experimental design was completely randomized with 10 single pot replications. Data in all experiments were subjected to regression analysis.

The experiment was repeated, with the following exceptions, in a greenhouse at Oregon State University in Corvallis, Oregon. Containers were filled with Douglas fir bark and peat moss (9:1 v:v) amended with the same nutrients described above. Fourteen seeds of creeping woodsorrel were applied to each pot February 1, 2004. Data collected included substrate pH and percent creeping woodsorrel germination 35 days after potting (DAP), and seed pod number and SFW 75 DAP.

**Results and Discussion:** In the hoophouse experiment, substrate pH increased with increasing lime throughout the experiment (only 80 DAP shown, Table 1). At 80 DAP, creeping woodsorrel growth and flowering decreased quadratically with increasing lime rate. In substrates receiving 40 or 80 lbs/yd$^3$ limestone, plants were severely stunted and foliage was chlorotic. Foliage on these plants was bleached and displayed symptoms of iron deficiency.

Similarly, in the greenhouse experiment substrate pH increased with increasing lime rate (Table 2). Substrate pH remained consistent within treatments throughout the experiment (only 35 DAP shown). At 35 DAP, germination of creeping woodsorrel was high under conditions of low pH (4.5) and decreased linearly with increasing lime rate (and pH), although differences in germination were not great over the pH range of 6.1 to 7.5. By 75 DAP, creeping woodsorrel growth and seed pod number decreased linearly with increasing lime rate, with plants were severely stunted in substrates receiving the highest lime rate. Despite 49% germination rate in containers receiving 80 lbs/yd$^3$, plants were small and had no flowers (data not shown) or seed pods. Similar to the hoophouse experiment, creeping woodsorrel in these containers were stunted and chlorotic.

Creeping woodsorrel germination and growth is affected by substrate pH. Manipulating substrate pH could lead to alternatives to preemergence herbicides in some facets of container production.

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**Table 1.** Influence of lime rate on substrate pH, creeping woodsorrel growth, and flower number.

| Lime rate (lbs/yd$^3$) | Substrate pH 80 DAP[z] | Flower number 80 DAP | Shoot fresh weight (g) 80 DAP |
|---|---|---|---|
| 0 | 5.3 | 16.2 | 20.8 |
| 10 | 6.2 | 20.9 | 25.3 |
| 20 | 6.6 | 12.4 | 16.7 |
| 40 | 7.5 | 1.3 | 4.8 |
| 80 | 8.2 | 0.0 | 0.4 |
| Significance | L***Q*** | L***Q** | L***Q** |

[z]Days after planting.

L, Q represent linear and quadratic rate response.

*, **, *** represent significant effects where P < 0.05, 0.01, and 0.001, respectively.

**Table 2.** influence of lime rate on substrate pH, and subsequent creeping woodsorrel germination, growth, and seed production (Experiment 2).

| Lime rate (lbs/yd$^3$) | Substrate pH 35 DAP[z] | Germination (%) 35 DAP | Seed pod number 75 DAP | Fresh weight (g) 75 DAP |
|---|---|---|---|---|
| 0 | 4.5 | 82 | 8.7 | 10.6 |
| 10 | 6.1 | 55 | 2.2 | 9.5 |
| 20 | 6.3 | 54 | 5.7 | 7.8 |
| 40 | 6.7 | 62 | 0.2 | 3.6 |
| 80 | 7.5 | 49 | 0.0 | 0.5 |
| Significance | L***Q*** | L*** | L** | L*** |

[z]Days after planting.

L, Q represent linear and quadratic rate response.

*, **, *** represent significant effects where P < 0.05, 0.01, and 0.001, respectively.

# Effect of Nitrogen Form on Weed Vigor in Containers

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**Index words:** creeping woodsorrel, bittercress, nitrate, ammonium, urea

**Significance to the Nursery Industry:** Nitrogen form affects weed vigor. This and other cultural practices that reduce weed vigor should result in improved herbicide efficacy. Ultimately, this should allow for integration of container management and weed control practices.

**Nature of the work:** Nitrogen (N) is most often applied to container crops as nitrate, ammonium, urea, or a combination thereof. Some ornamental and weed species germinate more readily and grow more vigorously in the presence of one N form. Walden and Epelman (4) demonstrated that boxwood prefer nitrate-N over ammonium-N. Teyker et al. (3) reported that redroot pigweed (*Amaranthus retroflexus*) shoot weight was reduced 75% when fertilized with ammonium-N and a nitrification inhibitor compared to nitrate-N. Seeds of many weeds and crops germinate more readily in the presence of nitrate (2). Plants that have a preference for N form still germinate and grow, although somewhat less vigorously when non-preferred forms are supplied.

While N form may not be enough to suppress weed growth altogether, reduced weed vigor may result in greater weed susceptibility to herbicides. Ultimately, reduced weed vigor from N form selection could improve efficacy and longevity of herbicidal weed control. Fertilizer products are available in any combination of the three major nitrogen forms (nitrate, ammonium, and urea). The objective of this experiment was to determine if N form affects establishment and growth of common container weed species.

*Experiment 1.* Trade gallon containers were filled with Douglas fir bark amended with 1.5 lbs/yd$^3$ Micromax micronutrients on February 26, 2003. Containers were seeded with 20 seeds each of bittercress (*Cardamine hirsuta*) and creeping woodsorrel (*Oxalis corniculata*) on March 3, 2003. N was applied at 150 ppm in nitrate:ammonium ratios of 100:0 (from magnesium nitrate and calcium nitrate), 0:100 (from ammonium sulfate), 50:50 (from ammonium nitrate), or as urea. At the same time as N fertilizer applications, containers were fertilized with 62 ppm phosphorus and 150 ppm potassium using dibasic potassium phosphate. Plants were grown in an unheated glass house and fertigated with nutrient solutions described above twice weekly, and watered additionally when needed. Data collected included weed number for bittercress, percent coverage of the container surface for creeping woodsorrel, and number of plants with flowers and shoot dry weight (SDW) of bittercress and creeping woodsorrel. All data were collected 60 days after sowing. Each N treatment was replicated 10 times in a completely randomized design with weed species randomized separately. Data were subjected to analysis of variance and means separation by Duncan's multiple range test (∀ = 0.05).

*Experiment 2.* Experiment 2 was conducted similarly to experiment 1 with the following exceptions. Only prostrate spurge (*Chamaesyce maculata*) was used in this study. Containers were filled and 20 seeds were sown in each container June 27, 2003. Plants were grown in a retractable roof greenhouse. Data collected included weed numbers and shoot fresh weight (SFW) 60 days after sowing.

**Results and Discussion:** *Experiment 1.* The influence of N form on bittercress number was subtle though significant (Table 1). Bittercress numbers in containers fertilized with ammonium and nitrate was greater than those fertilized with just ammonium or urea, however, differences in weed number were small. Despite small differences in the number of plants, containers fertilized with urea had fewer plants with flowers than those fertilized with other N forms. Bittercress is most problematic in container production because of its short life cycle and prolific seed production. It can produce up to 5000 seed in just 5 week (1). Although urea had little effect on bittercress germination, reduction in flower and subsequent seed production could have great impact on bittercress control. Bittercress fertilized with only ammonium had the greatest SFW, while those fertilized with other N forms were similar in weight.

Creeping woodsorrel surface coverage was less in containers fertilized with urea compared to those fertilized with only nitrate or ammonium. Similar to bittercress, creeping woodsorrel fertilized with only ammonium had greater SFW than those fertilized with other N forms. Number of plants with flowers followed a similar trend to surface coverage. Unlike bittercress, reduced flower numbers in containers fertilized with urea is likely a result of reduced plant size.

*Experiment 2.* Spurge numbers were greater in containers fertilized with only nitrate compared to those fertilized with urea. In natural systems, tillage stimulates decomposition of organic matter and the sudden release of nitrate from nitrification. This is a germination cue for many weed species, indicating the soil has been recently disturbed and that there is likely little competing vegetation (2). This type of germination cue would be particularly important for prostrate growing plants such as spurge, and may in part explain improved germination with nitrate-N. Despite greater weed numbers, spurge fertilized with only nitrate had less SDW than those fertilized with ammonium or a combination of nitrate and ammonium.

These data indicate that N form affects the growth and development of bittercress, creeping woodsorrel, and spurge. Nursery growers might improve weed control by switching to fertilizers that reduce the vigor of their most problematic weeds. Additional experiments are currently underway using a more accurate method of fertigation to verify these results.

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**Table 1.** Influence of nitrogen form on growth of bittercress and oxalis 60 days after sowing.

| | Bittercress | | | Oxalis | | |
|---|---|---|---|---|---|---|
| **NH4:NO3** | **Weed number** | **Plants with flowers** | **Shoot dry weight (g)** | **Surface coverage (%)** | **Plants with flowers** | **Shoot dry weight (g)** |
| 0:100 | 13.7 ab[z] | 7.0 a | 0.7 b | 74 a | 4.8 a | 0.9 bc |
| 100:0 | 11.2 b | 9.4 a | 2.2 a | 84 a | 6.8 a | 1.7 a |
| 50:50 | 15.3 a | 7.2 a | 0.8 b | 66 ab | 3.7 ab | 1.0 b |
| urea | 11.3 b | 1.9 b | 0.3 b | 44 b | 1.3 b | 0.6 c |

[z]Means with the same letter are not significantly different by Duncan's multiple range test ($\alpha$=0.05).

**Table 2.** Influence of nitrogen form on growth of prostrate spurge 60 days after sowing.

| **NH4:NO3** | **Surge number** | **Shoot fresh weight (g)** |
|---|---|---|
| 0:100 | 4.0 a | 17.0 c |
| 100:0 | 2.5 ab | 25.7 b |
| 50:50 | 2.7 ab | 34.3 a |
| urea | 2.1 b | 22.0 bc |

[z]Means with the same letter are not significantly different by Duncan's multiple range test ($\alpha$=0.05).

# The Effect of Preemergent Herbicides on Bigleaf Hydrangeas (*Hydrangea macrophylla* 'Nikko Blue')

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**Index Words:** Hydrangea, *Hydrangea macrophylla*, Barricade, Dimension, Gallery, Pennant Magnum, Surflan, Ronstar, RegalKade, Prodiamine, Dithiopyr, Isoxaben, Metolachlor, Oryzalin, Oxadiazon, Preemergence Herbicides.

**Significance to Industry:** Results of this study showed that preemergent herbicides labeled for weed control in hydrangeas can cause plant growth reduction and/or visual injury symptoms. Obviously, minimal growth reduction of Nikko Blue hydrangea is not serious concern for most containerized nursery, and often times welcomed. However, care should be taken when using preemergent herbicides after hydrangeas have broken bud. More research needs to be performed in order to determine injury/growth reduction that occurs to hydrangeas when preemergent herbicides are applied before and after foliage emergence.

**Nature of Work:** Many species of hydrangeas are very popular in the nursery industry. Bigleaf hydrangeas *(Hydrangea macrophylla)* are one of the most sought after hydrangeas, and a myriad of cultivars are available. Unfortunately, bigleaf hydrangeas are often injured with preemergence herbicides, particularly when these herbicides are applied after hydrangea leaves emerge. With this sensitivity to herbicides, bigleaf hydrangeas are seldom included on ornamental herbicide labels. Moreover, no published information could be found that evaluated the safety of preemergence herbicides on bigleaf hydrangeas. A study was designed to help identify registered and non-registered preemergence herbicides that might significantly damage bigleaf hydrangeas *(Hydrangea macrophylla)* when applied after bud break. The goal of the project was to determine the amount of phytotoxicity or growth reduction caused by preemergent herbicides applied over the top of actively growing hydrangeas.

On July 27, 2003 at the Center for Applied Nursery Research, 72 three gallon pots of bigleaf hydrangea (*Hydrangea macrophylla* 'Nikko Blue') were assembled. Nine, three gallon pots of each species were placed in a 6ft. x 6 ft. area. Herbicide treatments were then applied, and pots were moved to assigned test area where they were arranged in a randomized complete block (RCB) design. Each treatment contained 3 replications, and each replication contained 3 subsamples. The process was continued for each herbicide treatment. Sprayable herbicides were applied with a $CO_2$ backpack sprayer calibrated to deliver 20 gallons per acre (GPA). Granular herbicides were applied at the appropriate rate with a cheese shaker jar. Watering occurred on an as needed basis, and this represented approximately 1/2 to 1 inch of water per day. The treatment list is presented in Table 1.

Injury ratings were taken at 4, 8, and 12 weeks after treatment (WAT). At the termination of the study, 12 WAT, plant heights and shoot biomass was collected from each treatment. Average plant height was recorded in centimeters among the 3 subsamples. Shoots from each subsample were collected, dried, and weighted. Plant injury was taken on a (0-100 scale) and numbers represented the following:

| Value | Plant Symptoms |
|---|---|
| 0 | No visual injury present |
| 10-30 | Minimal injury to desirable plant. Less than 10% of the plant leaf service area showing chlorosis and necrosis. |
| 40-70 | More noticeable plant injury or stunting. Greater than 50% of the leaf area showing symptoms of chlorosis and/or necrosis |
| 80-90 | Plants severally injured. Most of the leaves and leaf surface showing signs of chlorosis and necrosis. |
| 100 | Plant appears dead. No signs of regrowth. |

**Results and Discussion:** All treatments produced either growth reduction or visual injury symptoms, some symptoms. At 4 weeks after treatment (4 WAT), plants were significantly injured with all herbicides except Pennant Magnum, RegalKade, and Ronstar (Table 2). By 8 WAT, Barricade, Dimension, and Gallery were the only treatments still exhibiting causing significant injury (Table 2). At 12 WAT, most plants had recovered from prior injury and no significant treatment differences were evident. The average height of the control was 540 centimeters (cm), and Barricade, Dimension, Gallery, Pennant Magnum, and Surflan treatments all caused significant height reductions (Table 3). All treatments except Pennant Magnum and Ronstar caused reduced shoot dry weight (Table 3).

**Table 1.** Preemergence herbicide treatments and application rates.

| Treatment# | Treatment | Rate |
|---|---|---|
| 1 | Barricade 65 WG | 1.5 (lb ai/A) |
| 2 | Dimension 1 SL | 0.5 (lb ai/A) |
| 3 | Gallery 75 WP | 1.0 (lb ai/A) |
| 4 | Pennant Magnum 7.62 SL | 2.5 (lb ai/A) |
| 5 | Surflan 4 SL | 4.0 (lb ai/A) |
| 6 | RegalKade 0.37 GR | 406 (lb product/A) |
| 7 | Ronstar 2 GR | 200 (lb product/A) |
| 8 | Untreated | |

**Table 2.** Injury to Bigleaf Hydrangea (Hydrangea macrophylla 'Nikko Blue').

| Treatment# | Treatment | Rate | Hydrangea Injury Rating (0-100)* | | |
|---|---|---|---|---|---|
| | | | 4 WAT | 8 WAT | 12 WAT |
| 1 | Barricade 65 WG | 1.5 (lb ai/A) | 26.7a | 30.0ab | 13.3a |
| 2 | Dimension 1 SL | 0.5 (lb ai/A) | 26.7a | 46.7a | 20.0a |
| 3 | Gallery 75 WP | 1.0 (lb ai/A) | 30.0a | 40.0a | 20.0a |
| 4 | Pennant Magnum 7.62 SL | 2.5 (lb ai/A) | 6.7bc | 10.0c | 6.7a |
| 6 | Surflan 4 SL | 4.0 (lb ai/A) | 23.3ab | 13.3bc | 10.0a |
| 7 | RegalKade 0.37 GR | 406 (lb product/A) | 16.7abc | 13.3bc | 13.3a |
| 8 | Ronstar 2 gR | 200 (lb product/A) | 16.7abc | 3.3c | 3.3a |
| 9 | Untreated | | 0.0c | 0.0c | 0.0a |
| LSD | | | 16.82 | 17.57 | 14.86 |

*Means followed by same letter do not significantly differ (P=0.05, LSD)

**Table 3.** Shoot Height and Shoot Dry Weight of Bigleaf Hydrangea (Hydrangea macrophylla 'Nikko Blue')

| Treatment# | Treatment | Rate | Hydrangea Height in centimeters 12 WAT* | Hydrangea Shoot Weight in grams 12 WAT* |
|---|---|---|---|---|
| | | | | |
| 1 | Barricade 65 WG | 1.5 (lb ai/A) | 383.3 c | 48.7 cd |
| 2 | Dimension 1 SL | 0.5 (lb ai/A) | 386.7 c | 40.7 d |
| 3 | Gallery 75 WP | 1.0 (lb ai/A) | 366.7 c | 47.2 cd |
| 4 | Pennant Magnum 7.62 SL | 2.5 (lb ai/A) | 396.7 c | 63.5 ab |
| 6 | Surflan 4 SL | 4.0 (lb ai/A) | 436.7 bc | 56.2 bc |
| 7 | RegalKade 0.37 GR | 406 (lb product/A) | 516.7 ab | 60.8 ab |
| 8 | Ronstar 2 GR | 200 (lb product/A) | 516.7 ab | 53.0 bc |
| 9 | Check | | 540.0 a | 69.4 a |
| LSD | | | 92.71 | 11.67 |

*Means followed by same letter do not significantly differ (P=0.05, LSD)