Roundup Pro® Over the Top of Nursery Crops: Rates and Timing[1]

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Abstract

Nine species of container-grown plants were treated over-the-top with Roundup Pro® (41% glyshosate) at four rates: 0.28, 0.56, 1.12, and 2.24 kg ai·ha^{-1} (0.25, 0.5, 1.0 and 2.0 lb ai·A^{-1}) either in June 2007, September 2007, or February 2008. A fourth group was treated on all three dates (June + September + February) (JSF). The experiment was repeated on eight species in 2008–2009. Growth indices (GI) were taken before the spring growth flush in March and after the first growth flush in June. In Exp. 1, dwarf mondo grass (*Ophiopogon japonicus* 'Nana'), mondo grass (*O. japonicus*), liriope (*Liriope muscari* 'Cleopatra'), variegated liriope (*L. muscari* 'Variegata'), and 'Blue Pacific' juniper (*Juniperus rigida* subsp. *conferta* 'Blue Pacific') were not affected by glyphosate rates up to 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) applied singly or JSF, except for temporary injury on 'Blue Pacific' from February applications. The remainder of the species had reduced growth as Roundup Pro® rates increased. 'Blue Rug' juniper (*J. horizontalis* 'Wiltonii') was tolerant in February but injured at ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in June and September (JS). Asiatic jasmine (*Trachelospermum asiaticum*) was tolerant of single applications at rates ≤ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in JS, but showed stunting of new foliage from all February applications. Dwarf yaupon (*Ilex vomitoria* 'Stoke's Dwarf') showed injury at 74 days after treatment (DAT) after June applications, no injury at rates ≤ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in September, and stunting and delay of new foliage from all February applications and rates ≥ 0.56 kg ai·ha^{-1} (0.5 lb ai·A^{-1}) in June. 'Pink Gumpo' azalea (*Rhododendron eriocarpum* 'Gumpo Pink') was injured by rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) applied in June, February, and JSF, however no injury occurred with any September treatment. In Exp. 2, dwarf mondo and mondo tolerated all single application rates up to 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}). Asiatic jasmine was injured by all February treatments and growth was reduced and stunted by ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in February and JSF. Dwarf yaupon GI were reduced by rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in February, 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in June, and by all treatments in JSF. February treatments ≥ 0.28 kg ai·ha^{-1} (0.25 lb ai·A^{-1}) delayed shoot growth of dwarf yaupon for at least 6 weeks. 'Hardy Daisy' gardenia (*Gardenia jasminoides* 'Hardy Daisy') showed slight injury from February rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}), but growth was reduced at 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) for June and JSF. Sky pencil holly (*Ilex crenata* 'Sky Pencil') showed stunting from all February applications, but was tolerant up to 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in June and September; GI were similar for all treatments. Purpleleaf wintercreeper euonymus (*Euonymus fortunei* 'Coloratus') was injured by rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) applied in June and JS, all February treatments, and stunted by two or three applications of 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}), but all other treatments had similar GI. Wintergreen boxwood (*Buxus sempervirens* 'Wintergreen') was injured at 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in June, ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in JS, and all February applications. Growth was reduced by rates of 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in February and ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in JSF.

Index words: glyphosate, over the top, woody ornamentals, container production.

Herbicides used in this study: Roundup Pro® (glyphosate), N-(phosphonomethyl) glycine, in the form of its isopropylamine salt.

Species used in this study: *Exp. 1*: dwarf mondo grass (*Ophiopogon japonicus* 'Nana'), mondo grass (*O. japonicus*), liriope (*Liriope muscari* 'Cleopatra'), variegated liriope (*L. muscari* 'Variegata'), 'Blue Pacific' juniper (*Juniperus rigida* subsp. *conferta* 'Blue Pacific'), 'Blue Rug' juniper (*J. horizontalis* 'Blue Rug'), Asiatic jasmine (*Trachelospermum asiaticum*), dwarf yaupon (*Ilex vomitoria* 'Stoke's Dwarf'), and 'Pink Gumpo' azalea (*Rhododendron eriocarpum* 'Gumpo Pink'). *Exp. 2*: dwarf mondo grass, mondo grass, Asiatic jasmine, dwarf yaupon, 'Hardy Daisy' gardenia (*Gardenia jasminoides* 'Hardy Daisy'), Sky Pencil holly (*Ilex crenata* 'Sky Pencil'), purpleleaf wintercreeper euonymus (*Euonymus fortunei* 'Coloratus'), and wintergreen boxwood (*Buxus sempervirens* 'Wintergreen').

Significance to the Industry

Current economic conditions have caused a significant slump in new home construction and sale of landscape plants. Many growers have lowered their prices to remain competitive. If weed populations exceed growers' ability to control them, they may face the prospect of spending more on hand weeding than what the plant is worth.

Roundup Pro® over the top of woody ornamental nursery crops is showing promise for postemergence weed control. Our work indicates that some woody ornamentals are tolerant to Roundup Pro® applications. Several plants tested in this study were tolerant to glyphosate up to 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) applied in either June or September. The hand-weeding cost for 3-gal pots in early 2005 was 5.63 cents per pot, assuming labor costs of $9.52 per hour (8). If 3-gal pots were jammed in 6-ft beds with 2-ft aisles, it would cost $9225.70·ha^{-1} ($3733.59·A^{-1}) to weed them. With a glyphosate rescue plan, growers can apply 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) of Roundup Pro® for about $31.50·ha^{-1} ($12.50·A^{-1}). Barolli (2) estimated that a backpack application requires 3.46 man hours and a high-clearance boom operated by 2 men requires

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1.35 man hours·A^{-1}. This would cost $32.94 and $12.85·A^{-1}, respectively, at $9.72 per hour.

Introduction

Postemergence weed control in container-grown nursery crops is becoming more critical for economic profitability in the nursery industry. Between 1975 and 1985, Roundup® was evaluated over the top of numerous container-grown crops. Self (13) applied single, double, and triple treatments of Roundup® at 0.56, 0.84, 1.12, and 1.68 kg ai·ha^{-1} (0.5, 0.75, 1.0, and 1.5 lb ai·A^{-1}) over 18 ornamentals. Application dates were April 7 for Treatment A, April 7 and 14 for Treatment B, and April 7, 14, and 21 for Treatment C. Total amounts of glyphosate applied ranged from 0.56 to 5.04 kg ai·ha^{-1} (0.5 to 4.5 lb ai·A^{-1}). Of the 18 species tested, 'Blue Pacific' Juniper (*Juniperus rigida* subsp. *conferta* 'Blue Pacific'), *Magnolia soulangeana*, *Cupressus* sp., *Photinia fraseri*, *Pittosporum tobira*, *Podocarpus* sp., *Ilex cornuta* 'Burfordii Yellow Top', and *Trachycarpus fortunei* were not injured.

Perry and Knowles (12) applied Roundup® at 0.28, 0.84, and 1.12 kg ai·ha^{-1} (0.25, 0.75, and 1.0 lb ai·A^{-1}) over the top of 10 species, once on August 3 and again on August 17, 1978. Following two applications, no phytotoxicity was observed on *Berberis* × *mentorensis*, *Camellia japonica*, *Forsythia* × *intermedia* and *Ligustrum* 'Vicaryi' at all rates. Temporary slight yellowing was observed later in the fall on *B. julianae*, *Euonymus japonicus* and *Ilex cornuta* 'Dwarf Burford' (syn 'Burfordi Nana') regardless of rate.

Neal and Skroch (10) investigated rates and timing of Roundup® applications on 13 species of ornamentals from March 12 to November 11, 1982. They applied Roundup® at 0.65, 1.3, and 2.6 kg ai·ha^{-1} (0.73, 1.33, and 2.67 lb ai·A^{-1}) at six different times throughout the season. They divided plants and their responses to Roundup® into 4 groups. Group 1 species: ajuga (*Ajuga reptans*), azalea [*Rhododendron* × 'Kirin' (syn. 'Coral Bells')], and variegated liriope (*Liriope muscari* 'Variegata') were injured by all application times and rates. Group 2, 3, and 4 species showed tolerance to fall applications. Group 2 [dwarf yaupon, English ivy (*Hedera helix*), 'Helleri' holly (*I. crenata* 'Helleri) and ligustrum (*L. japonicum*)] sustained the most injury from spring applications. Group 3 [Andorra Juniper (*Juniperus horizontalis* 'Plumosa'), compacta holly (*I. crenata* 'Compacta'), Fraser's photinia (*Photinia* × *fraseri*), and green liriope (*Liriope spicata*)] were most injured by summer applications. Group 4 ['Blue Pacific' juniper and 'Blue Rug' juniper (*Juniperus horizontalis* 'Wiltonii')] tolerated all but the highest rates with acceptable damage, which was considered to be ≤ 15%. Ratings were taken every 3.5 weeks after treatment, and the study was terminated 15 months after treatment, in June 1983.

Neal et al. (10) reported that the susceptibility of ligustrum to glyphosate decreased linearly between March and November, while 'Blue Pacific' juniper sustained only temporary tip chlorosis from summer applications at high rates. Both species recovered by the end of the growing season. In a study with foliar droplet applications, it was reported that except for ligustrum treated on young expanding leaves, the time required for absorption of detectable levels of ^{14}C-glyphosate into ligustrum and juniper was slow when compared to absorption rates for herbaceous weeds, but the time was similar for absorption rates for other woody species such as Norway spruce (*Picea abies*), white birch (*Betula verrucosa*), and European ash (*Fraxinus excelsior*) (11). Research by Ferreira and Reddy (7) on *Erythroxylum coca* and *E. novogranatense* demonstrated the role of the leaf cuticle in the slow uptake of glyphosate by woody plants. This indicates that there is likely a degree of selectivity with glyphosate applied over woody ornamentals and weeds due to leaf adsorption rates.

Altland et al. (1) showed that Roundup Pro® at 1.8 kg ai·ha^{-1} (1.6 lb ai·A^{-1}) could be safely used as a cleanup treatment for control of spurge in *L. muscari* 'Big Blue' and 'Variegata'. Walsworth et al. (15) reported that Roundup applied on September 6, 2005, in a 1% solution (8.8 kg ai·378.5 liter^{-1}, 4 lb ai·100 gal^{-1}) caused no injury to liriope and Asiatic jasmine.

Recent work by Czarnota (6) showed that 'Blue Pacific' juniper, 'Blue Star' juniper (*J. squamata* 'Blue Star'), and 'Parsoni' juniper (*J. davurica* 'Parsoni') were tolerant of Roundup Pro® applications at rates up to 2.8 kg ai·ha^{-1} (2.5 lb ai·A^{-1}) in May. Final dry weights for 'Blue Pacific' and 'Blue Star' juniper at 12 weeks after treatment were similar to untreated plants with rates up to 11.2 kg ai·ha^{-1} (10.0 lb ai·A^{-1}). Injury did not exceed 27% for rates up to 5.6 kg ai·ha^{-1} (5.0 lb ai·A^{-1}) on 'Blue Pacific.'

Monsanto (9) recommends the use of 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) of Roundup Pro® if weeds are less than 6 inches in height or runner length.

Recent economic downturns have had severe effects on nursery crop production. Cost cutting by growers has resulted in less available labor. Reduced sales have caused carry-over of plants ready for market into another growing season. As a result, growers are increasingly interested in potential use of Roundup Pro® or generic glyphosate over the top of nursery crops to reduce labor costs. For preemergence herbicides to work effectively, containers must be weed free at the time of application. Our application dates were selected based on general timing of preemergence herbicdes, where glyphosate could be used as a clean up spray prior to application of preemergence herbicides. The objective of this research was to further evaluate the tolerances of individual container-grown species to various rates and application times of Roundup Pro® applied over the top.

Materials and Methods

In Exp. 1, dwarf mondo grass (*Ophiopogon japonicus* 'Nana'), mondo grass (*O. japonicus*), liriope (*Liriope muscari* 'Cleopatra'), variegated liriope (*L. muscari* 'Variegata'), 'Blue Pacific' juniper (*Juniperus rigida* subsp. *conferta* 'Blue Pacific'), 'Blue Rug' juniper (*J. horizontalis* 'Blue Rug'), Asiatic jasmine (*Trachelospermum asiaticum*), dwarf yaupon (*Ilex vomitoria* 'Stoke's Dwarf'), and 'Pink Gumpo' azalea (*Rhododendron eriocarpum* 'Gumpo Pink') liners were potted in pinebark:peat moss (3:1 by vol) amended with 8.5 kg·m^{-3} (14.0 lb·yd^{-3}) Osmocote 19-6-12 (N-P-K), 3.6 kg·m^{-3} (6 lb·yd^{-3}) dolomitic limestone, 1.2 kg·m^{-3} (2.0 lb·yd^{-3}) gypsum, and 0.9 kg·m^{-3} (1.5 lb·yd^{-3}) Micromax·yd^{-3} in 1-gal containers on April 30, 2007. Roundup Pro® was applied at four rates: 0.28, 0.56, 1.12, and 2.24 kg ai·ha^{-1} (0.25, 0.50, 1.0, and 2.0 lb ai·A^{-1}) in 30 GPA with a CO_2 backpack sprayer at 25 psi with an 8004 flat fan nozzle and allowed to dry at least 4 hours before irrigation. Single treatments were applied on June 10, 2007, September 1, 2007, and February 20, 2008, to separate groups of plants not previously treated. One group of plants was treated on all dates [June + September + February (JSF)]. There was one non-treated control (NTC)

group for a total of 17 treatments. Plants were grouped by species in a completely randomized block design with eight single-pot replications. Snapshot was applied at 168.41 kg ai·ha^{-1} (150 lb·A^{-1}) to all species except mondo and dwarf mondo on May 8, 2007. Plants were observed at 15, 30, 60, and 90 days after treatment (DAT); injury and new growth were rated and recorded when differences from NTC were noted. Growth indices were taken on March 3, 2008, before the start of spring growth, and June 13, 2008, after the first growth flush. Dwarf mondo, mondo, liriope 'Cleopatra' and liriope 'Variegata' were trimmed to one inch tall in May to simulate nursery production practices. Marketability was rated on October 11, 2008.

In Exp. 2, dwarf mondo grass (*Ophiopogon japonicus* 'Nana'), mondo grass (*O. japonicus*), Asiatic jasmine (*Trachelospermum asiaticum*), dwarf yaupon (*Ilex vomitoria* 'Stoke's Dwarf'), gardenia (*Gardenia jasminoides* 'Hardy Daisy'), 'Sky Pencil' holly (*Ilex crenata* 'Sky Pencil'), euonymus (*Euonymus fortunei* 'Coloratus'), and 'Wintergreen' boxwood (*Buxus sempervirens* 'Wintergreen') liners were potted as in Exp. 1 on May 12, 2008. Roundup Pro® was applied similarly to Exp. 1. Single treatments were applied on June 24 and September 16, 2008, and February 20, 2009. One group of plants was treated on JSF. There was one NTC group; 17 treatments in all. Plants were grouped by species in a completely randomized block design with seven single-pot replications. Snapshot was applied to *Buxus* at 150 lb·A^{-1} due to significant weed pressure in the pots. Plants were observed for injury at 15, 30, 60, and 90 DAT. Bud break and new growth were rated the following spring and recorded when differences from NTC were noted. Growth indices were taken on February 23, 2009, before the start of spring growth, and July 6, 2009, after the first growth flush. Marketability was rated on October 23, 2009. Dwarf mondo, mondo, Asiatic jasmine, and euonymus were trimmed on May 11, 2009, to simulate nursery practices.

Both experiments were conducted at the Ornamental Horticultural Research Center in Mobile, AL. Data collected were analyzed in a statistical software package (SAS Institute, Cary, NC) using Least Significant Difference tests ($P \leq 0.05$). Data were analyzed separately for each sampling date.

Results and Discussion

Dwarf mondo grass. In Exp. 1, March injury ratings showed that slight injury (8%) occurred with 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) applied in JSF (Table 1). All growth indices taken in March (Table 2) (prior to spring flush) and June 2008 (Table 3) (at end of first flush), and marketability ratings in October 2008 (Table 4) were similar to NTC plants. In Exp. 2, injury ratings taken in April 2009 showed no injury from rates ≤ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) applied in February and JSF (Table 5). February growth indices were similar for all plants treated in June, September, and JS (Table 6), while JSF treatments at 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) caused growth suppression (Table 7). All plants were rated marketable in October 2009 (Table 8).

Mondo grass. In Exp. 1, injury ratings taken in March were similar to NTC (Table 1). Growth indices taken in March (Table 2) and June 2008 (Table 3) were similar to NTC, except for plants treated with 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in February, JS, and in JSF. All treatments < 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) were marketable except plants treated in JSF at 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) rates, with February and June treatments smaller but marketable (Table 4). In Exp. 2, injury ratings in April 2009 showed all treatments were similar to NTC except at rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) applied in February or JSF (Table 5). Growth indices taken in February for all June, September, and JS treatments were similar to NTC (Table 6). Growth indices in July for all single treatments up to 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) were similar to NTC, while JSF treatments ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) showed growth reductions (Table 7). All plants were marketable in October, with February treatments of 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) yielding significantly smaller but marketable plants (Table 8). Our data concurs with Self and Pounders (14) who reported *O. japonicus* was tolerant of glyphosate rates up to 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) when applied in June, and Walsworth et al. (2006), who reported no injury with a 1% solution (8.8 kg ai·378.5 liters^{-1}, 4.0 lb ai in 100 gal) applied in September.

Liriope 'Cleopatra'. No injury was noted throughout the study (Table 1). Growth indices in March (Table 2) and June 2008 (Table 3) and marketability ratings in October 2008 (Table 4) were similar to NTC. Altland et al. (1) observed slight injury to 'Big Blue' liriope when glyphosate was applied on June 1, June 28, or Aug 24 at 1.8 kg ai·ha^{-1} (1.6 lb ai·A^{-1}); however, plants outgrew injury by 60 DAT. Walsworth et al. (2006) reported no injury to liriope treated with a 1% solution (8.8 kg ai·378.5 liters^{-1}, 4.0 lb ai in 100 gal) in September.

Liriope 'Variegated'. No injury was noted throughout the study. Growth indices in March 2008 were similar to NTC (Table 2). Growth indices in June 2008 showed that 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) treatments applied in February and in JSF were smaller than the rest of the treatments and the NTC (Table 3); however, all plants had similar marketability in October 2008 (Table 4). Altland et al. (1) reported tolerance at 1.8 kg ai·ha^{-1} (1.6 lb ai·A^{-1}) applied June 1, June 28, or August 24. Self (13) reported no injury at 1.0 lb ai·A^{-1} in Aug.

'Blue Pacific' juniper. Injury ratings in March 2008 indicated that rates ≥ 0.56 kg ai·ha^{-1} (0.5 lb ai·A^{-1}) applied in February had higher injury than all other treatments, including JSF treatments (Table 1). By 31 DAT, affected needles had recovered and all plants were similar to NTC. Growth indices in March 2008 (Table 2) and June (Table 3) were similar to NTC. All plants were similar and marketable in October 2008 (Table 4). Our data concurs with Neal and Skroch (1985), who reported the highest injury at 25 DAT from applications in mid-March, with tolerance increasing through the rest of the season after April 30 with injury not greater than 17% at 1.5 kg ai·ha^{-1} (1.33 lb ai·A^{-1}). Final injury ratings one year later reported injury ≤ 21% with this rate for all treatment dates. Similarly, Czarnota (5) reported tolerance up to 2.8 kg ai·ha^{-1} (2.5 lb ai·A^{-1}) with mid- to late-May applications with injury not exceeding 23%. Our results showed no long-term injury from applications made in February, June, or September or JSF for rates up to 2.24 kg ai·A^{-1} (2.0 lb ai·A^{-1}).

'Blue Rug' juniper. No injury from June applications was observed in November, but plants treated in September were injured by rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}). JS applications

Table 1. Injury ratings following applications of Roundup Pro® over the top of nine species, Exp 1.

Treatment			Ornamental species									
Roundup rate		Application timing	Dwarf mondo	Mondo grass	Blue Pacific juniper	Blue Rug juniper		Asiatic jasmine	Dwarf yaupon		Pink Gumpo azalea	
lb ai·A^{-1}	kg ai·ha^{-1}		Date recorded									
			3/7/08	3/7/08	3/7/08	11/15/07	6/23/08	6/23/08	8/20/07	6/23/08	8/23/07	6/23/08
Non-treated control			0.1[z,y]	1.6	0.5	0	0	0	0	0	0	0
0.25	0.28		0	1.1	0.7	0.1	0	0	0.7	0	0	1.1
0.50	0.56	Once	0	2.1	1.4	0.3	0	0	5.5	0	0	1.1
1.00	1.12	6/10/07	0	0.5	1.1	0	0	0	6	0	4.1	0
2.00	2.24		0.1	0	0	0	0	0	6	0	5.2	0
0.25	0.28		0	1.5	0.5	0	0	0	—	0	—	0
0.50	0.56	Once	0	1.5	1.9	0.1	0	0	—	0	—	0
1.00	1.12	9/1/07	0	3.1	1.6	1.1	0	0	—	0	—	0
2.00	2.24		0	2	1.9	7.3	9.5	0.5	—	0	—	0.5
0.25	0.28		0	0.5	1.4	—	0	1	—	4	—	0
0.50	0.56	Once	0.5	0.5	3.2	—	0	3.7	—	4	—	0
1.00	1.12	2/20/08	0.5	0.5	3	—	0	5.8	—	5.5	—	2.3
2.00	2.24		0.5	1	0.5	—	0	5.9	—	7	—	6.6
0.25	0.28	Three times	0.3	0	0	0[x]	0	3	0[w]	4	0[w]	0
0.50	0.56	(repeated	0.1	1.4	2	0	0	4.7	0	4.4	0	1
1.00	1.12	on all	0.3	1.5	0.5	0.4	0	5.4	5.4	5.5	5.4	6.4
2.00	2.24	three dates)	0.8	2	0	3.4	5.4	6	6	8.7	6	10
		$LSD_{(0.05)}$	0.5	1.7	1.6	0.6	1.8	0.9	1.1	0.5	0.6	1.5

[z]Injury ratings (0 = no injury, 5 = 50% injury, 10 = dead plant).

[y]Means separation was according to Fisher's least significant difference (LSD) test ($P \leq 0.05$).

[x]Only June + September treatments at this time.

[w]Only June treatments at this time.

Liriope 'Cleopatra' and 'Variegata' exhibited no injury for all dates and treatments.

Table 2. Growth indices of nine species treated with Roundup Pro®, Exp 1, recorded on 3/3/08.

Treatment			Ornamental species								
Roundup rate		Application timing	Dwarf mondo grass	Mondo grass	Liriope 'Cleopatra'	Liriope 'Variegata'	Blue Pacific juniper	Blue Rug juniper	Asiatic jasmine	Dwarf yaupon	Pink Gumpo azalea
lb ai·A^{-1}	kg ai·ha^{-1}										
Non-treated control			19.0[z,y]	31.3	30.6	31.5	25.5	38.4	78.6	23.0	20.7
0.25	0.28		18.4	32.5	35.4	34.4	31.6	41.5	77.0	22.2	21.7
0.50	0.56	Once	18.2	33.1	27.9	33.5	41.6	41.9	72.0	18.3	19.4
1.00	1.12	6/10/07	18.9	32.3	32.5	33.8	35.0	34.2	81.7	15.3	18.3
2.00	2.24		19.3	32.8	31.8	33.8	31.3	26.1	78.8	13.8	17.7
0.25	0.28		19.0	31.9	32.3	34.5	37.0	42.1	71.0	23.0	21.6
0.50	0.56	Once	20.0	32.4	31.8	34.6	29.2	39.5	77.5	20.5	20.2
1.00	1.12	9/1/07	20.3	31.8	29.0	35.8	39.5	32.1	73.0	22.3	20.7
2.00	2.24		19.7	32.6	30.5	32.8	37.5	31.6	68.4	19.2	18.5
0.25	0.28		19.0	31.2	33.2	32.1	20.1	38.7	72.7	23.3	20.4
0.50	0.56	Twice (both	19.2	32.8	28.6	33.8	28.1	38.8	71.8	19.1	19.9
1.00	1.12	dates above)	18.4	32.6	30.9	34.1	22.0	25.6	69.0	14.2	15.7
2.00	2.24		18.2	25.7	26.3	31.5	20.7	17.9	53.4	9.4	12.7
		$LSD_{(0.05)}$	1.2	2.1	7.0	3.4	9.8	5.1	8.9	2.7	1.9

[z]Growth indices (cm) = [(height + width1 + width2) / 3].

[y]Means separation was according to Fisher's least significant difference (LSD) test ($P \leq 0.05$).

Table 3. Growth indices of nine species treated with Roundup Pro®, Exp 1, recorded on 6/13/08.

Treatment			Ornamental species								
Roundup rate		Application timing	Dwarf mondo grass	Mondo grass	Liriope 'Cleopatra'	Liriope 'Variegata'	Blue Pacific juniper	Blue Rug juniper	Asiatic jasmine	Dwarf yaupon	Pink Gumpo azalea
lb ai·A^{-1}	kg ai·ha^{-1}										
Non-treated control		18.0[z,y]	35.4	29.4	36.9	34.4	44.2	46.6	27.4	27.2	
0.25	0.28		17.6	35.3	35.2	34.1	38.3	44.4	47.4	27.0	27.9
0.50	0.56	Once	17.8	36.5	27.5	37.5	46.2	45.7	51.6	21.8	26.3
1.00	1.12	6/10/07	18.6	34.9	29.0	35.5	42.2	39.6	46.1	20.6	24.5
2.00	2.24		17.8	34.7	33.0	37.6	38.4	35.4	44.2	18.9	23.4
0.25	0.28		19.0	35.0	30.6	36.4	42.5	48.8	42.0	27.2	28.0
0.50	0.56	Once	19.5	36.0	20.7	35.3	38.2	44.5	45.0	24.9	27.8
1.00	1.12	9/1/07	19.5	35.6	32.7	34.1	42.7	36.2	52.4	26.3	26.9
2.00	2.24		19.1	37.1	34.0	36.1	42.2	12.6	46.5	22.7	24.9
0.25	0.28		17.7	35.9	33.7	37.6	44.1	39.8	44.3	25.5	28.6
0.50	0.56	Once	17.2	38.0	33.5	38.4	47.1	46.3	36.2	24.5	26.0
1.00	1.12	2/20/08	15.0	36.7	29.8	38.0	45.2	47.2	25.9	22.0	23.8
2.00	2.24		18.5	32.7	26.8	33.2	46.6	45.4	26.0	17.1	22.0
0.25	0.28	Three times	18.3	34.0	31.0	35.4	30.5	46.0	45.1	27.4	27.6
0.50	0.56	(repeated on	18.7	36.6	26.4	35.3	36.0	44.0	35.6	22.2	25.1
1.00	1.12	all three	18.0	34.9	29.3	34.5	32.3	31.0	28.7	16.1	17.2
2.00	2.24	dates)	17.0	16.6	23.0	21.6	28.4	22.4	25.2	7.2	0.0
		$LSD_{(0.05)}$	1.9	2.6	4.2	2.9	8.3	5.6	4.7	2.7	2.1

[z]Growth indices (cm) = [(height + width1 + width2) / 3].

[y]Means separation was according to Fisher's least significant difference (LSD) test ($P \leq 0.05$).

did not injure 'Blue Rug' juniper at rates ≤ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) (Table 1). Injury ratings in June 2008 showed no injury from September and JSF applications ≤ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) (Table 1). Growth indices recorded in March were reduced at rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) applied in September and JS, and at 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in June (Table 2). June growth indices were reduced at rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) when applied in June, September, or JSF (Table 3). There were no growth reductions from any February treatments. All plants were marketable in October 2008 except for 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) treatments applied in September and JSF, with 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) applied in June yielding smaller but marketable plants (Table 4). Neal and Skroch (10) reported injury levels at 25 DAT of 11% or less when applied up to 3.0 kg ai·ha^{-1} (2.67 lb ai·A^{-1}) during the growing season, except for an increase in injury noted in late June and early August treatments. Final data taken one year later reported injury ≤ 15% for rates up to 3.0 kg ai·ha^{-1} (2.67 lb ai·A^{-1}). Our data showed a similar trend in initial injury, but our final injury ratings indicated long-term effects from 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) applied in early September and mid-June.

Asiatic jasmine. Exp. 1: Injury ratings in June 2008 indicated that all plants treated in June or September 2007 were similar to NTC (Table 1). Slight to severe leaf stunting was observed on plants treated with ≥ 0.28 kg ai·ha^{-1} (0.25 lb ai·A^{-1}) in February and JSF. Growth indices in March 2008 (Table 2) were similar to NTC for all June treatments and up to 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in September. The 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) rate applied in September and rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) applied in JSF resulted in growth reductions. Plants were trimmed in June to simulate common nursery practices. Growth indices in June 2008 were similar to NTC for all June and September treatments, while plants treated in February and JSF at rates ≥ 0.56 kg ai·ha^{-1} (0.5 lb ai·A^{-1}) showed 22–46% reductions in growth (Table 3). Marketability ratings in October were lower for plants treated with rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) applied in February and JSF, while 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in June or September caused reductions in marketability (Table 4).

In Exp. 2, April injury ratings from February and JSF applications indicated delayed flush from all rates, with suppression increasing with increased rates (Table 5). February growth indices were similar to NTC for all rates except JS rates of 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) (Table 6). July growth indices showed all treatments similar to NTC except for JSF applications ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) (Table 7). Plant marketability was similar to NTC for all treatments except rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) applied in February and 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) applied in JSF (Table 8). Walsworth et al (15) reported similar tolerance to September treatments with a 1% solution (8.8 kg ai·378.5 liters^{-1}, 4.0 lb ai in 100 gal).

Dwarf yaupon. In Exp. 1, significant injury was recorded at 71 DAT from single June 2007 applications ≥ 0.56 kg ai·ha^{-1} (0.5 lb ai·A^{-1}) (Table 1). Injury ratings in June 2008 showed that all June or September applications were similar to NTC, while February applications caused slight to severe leaf distortion with increasing rates, with slight necrosis at the 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) rates. Growth indices in early March before the spring flush showed growth reductions for rates ≥ 0.56 kg ai·ha^{-1} (0.5 lb ai·A^{-1}) in June and JS, and 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in September (Table 2). Growth indices taken in June 2008 showed growth reductions at rates ≥ 0.56 kg

Table 4. Marketability of nine species treated with Roundup Pro®, Exp 1, recorded on 10/11/08.

Treatment			Ornamental species								
Roundup rate		Application timing	Dwarf mondo grass	Mondo grass	Liriope 'Cleopatra'	Liriope 'Variegata'	Blue Pacific juniper	Blue Rug juniper	Asiatic jasmine	Dwarf yaupon	Pink Gumpo azalea
lb ai·A^{-1}	kg ai·ha^{-1}										
Non-treated control			1[z,y]	1	1	1	1	1	1	1	1
0.25	0.28		1	1	1	1	1	1	1	1	1
0.50	0.56	Once	1	1	1	1	1	1	1	1	1
1.00	1.12	6/10/07	1	1	1	1	1	1	1	2	1
2.00	2.24		1	1	1	1	1	2	2	3	1
0.25	0.28		1	1	1	1	1	1	1	1	1
0.50	0.56	Once	1	1	1	1	1	1	1	1	1
1.00	1.12	9/1/07	1	1	1	1	1	1	1	1	1
2.00	2.24		1	1	1	1	1	3	3	2	1
0.25	0.28		1	1	1	1	1	1	1	1	1
0.50	0.56	Once	1	1	1	1	1	1	1	2	1
1.00	1.12	2/20/08	1	1	1	1	1	1	2	3	1
2.00	2.24		1	2	1	1	1	1	2	3	3
0.25	0.28	Three times	1	1	1	1	1	1	1	1	1
0.50	0.56	(repeated on	1	1	1	1	1	1	1	1	1
1.00	1.12	all three	1	1	1	1	1	1	2	2	3
2.00	2.24	dates)	1	3	1	1	1	3	2	3	3
		$LSD_{(0.05)}$	0.0	0.0	0.0	0.0	1.6	1.8	0.3	0.0	0.3

[z]Marketability rating (1 = marketable, 2 = small but marketable, 3 = unmarketable).

[y]Means separation was according to Fisher's least significant difference (LSD) test ($P \leq 0.05$).

ai·ha^{-1} (0.5 lb ai·A^{-1}) from June, February, and JSF treatments, and from 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) rates in September (Table 2). Plants were marketable at treatment rates up to 0.56 kg ai·ha^{-1} (0.5 lb ai·A^{-1}) with February applications, 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) with June and JSF applications and all rates for September applications (Table 2).

In Exp. 2, injury ratings in September 2008 (15 DAT from September applications) indicated plant injury from Roundup Pro® treatments in June from 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) applications, while all other rates were similar to NTC (Table 5). Injury ratings in April 2009 were similar to NTC for all June or September treatments, while rates ≥ 0.28 kg ai·ha^{-1} (0.25 lb ai·A^{-1}) applied in February showed increasing spring growth suppression with increasing rates from February and JSF treatments (data not shown). Bud break was similar to NTC for June and September treatments, but all February and JSF treatments saw virtually no bud break, with February treatments resulting in 26, 10, 3 and 0% new growth compared to the NTC for 0.28, 0.56, 1.12, and 2.24 kg ai·ha^{-1} (0.25, 0.5, 1.0 and 2.0 lb ai·A^{-1}) respectively (data not shown). Similarly, JSF applications had 33, 19, 0, and 0% new growth respectively with increasing rates of Roundup Pro®. Growth indices in February 2009 showed that June, September, and JS treatments were all similar to NTC except for 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in JS (Table 6). Growth indices in July 2009 were smaller than NTC when treated in February at rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}), 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in June, and ≥ 0.28 kg ai·ha^{-1} (0.25 lb ai·A^{-1}) for JSF applications (Table 7). All September treatments were similar to NTC. Plants treated with ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in February and 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in JSF were small but marketable, while JSF applications at 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) were unmarketable due to excessive stunting (Table 8). All other treatments were similar to NTC. Neal and Skroch (10) reported that 25-DAT evaluations indicated great sensitivity to all mid-March treatments, and significant injury from April, June, and August treatments. However, applications at the end of September and the middle of November did not show injury above 16% for treatments up to 3.0 kg ai·ha^{-1} (2.67 lb ai·A^{-1}). Final evaluations one year later reported injury ≤ 18% for treatments on or after April 30 at 1.5 kg ai·ha^{-1} (1.33 lb ai·A^{-1}). Our data likewise indicated significant effects early in the growing season on injury, growth indices and marketability with June and February treatments ≥ 0.56 kg ai·ha^{-1} (0.5 lb ai·A^{-1}) and tolerance to all treatments in September. Similarly, Whitcomb et al. (1976) reported no injury from glyphosate up to 3 lb ai·A^{-1} in August.

Azalea 'Pink Gumpo'. Injury ratings at 74 DAT from June 2007 treatments showed significant injury at rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) (Table 1). June 2008 injury ratings showed all treatments similar to NTC except for plants treated with rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) applied in February and JSF. Growth indices in March 2008 showed growth reductions with June and JS treatments at rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) and with 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) applied in September (Table 2). Growth indices in June 2008 showed growth reductions for rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) from February, June, and JSF applications, and growth reductions when 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) was applied in September (Table 3). All azaleas were marketable and similar to NTC in Oct 2008 except those treated with 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in February and rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) for JSF applications (Table 4). Similarly, Cobb and Self (4) reported severe apical chlorosis and some necrosis

Table 5. Injury and growth ratings from Roundup Pro® applications over the top of eight species, Exp 2.

Treatment			Ornamental species									
			Injury ratings							Growth reduction		
Roundup rate		Application timing	Dwarf mondo grass	Mondo grass	Dwarf yaupon	Gardenia 'Hardy Daisy'	Euonymus 'Colorata'	Boxwood		Asiatic jasmine	'Sky Pencil' holly	Euonymus 'Colorata'
lb ai·A^{-1}	kg ai·ha^{-1}		Date recorded									
			4/8/09	4/8/09	9/25/08	7/8/08	3/10/09	9/25/08	10/2/08	4/8/09	4/8/09	4/8/09
Non-treated control			0.9[z,x]	1.0[z]	0.0[z]	0.0[z]	0.3[z]	0.0[z]	0.0[z]	1.0[z]	3.7[y]	5.0[y]	4.9[y]
0.25	0.28		1.0	0.4	0.0	0.0	0.6	0.0	0.0	1.3	3.6	5.0	4.7
0.50	0.56	Once	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	3.6	5.0	4.9
1.00	1.12	6/24/08	1.0	1.0	0.0	0.6	0.1	3.4	0.7	1.0	3.4	5.0	4.9
2.00	2.24		0.7	1.0	2.7	2.3	0.1	6.7	3.9	1.7	3.7	5.0	4.3
0.25	0.28		0.7	1.0	0.0	—	0.3	0.0	0.0	1.1	3.9	5.0	4.6
0.50	0.56	Once	1.0	1.0	0.0	—	0.1	0.0	0.0	1.4	3.7	5.0	4.7
1.00	1.12	9/16/08	0.7	1.0	0.0	—	0.0	0.0	0.0	1.4	3.9	5.0	4.7
2.00	2.24		1.0	1.0	0.0	—	0.1	0.0	0.0	1.4	3.9	4.9	4.3
0.25	0.28		1.1	0.7	—	—	0.7	—	—	5.5	3.1	4.4	3.9
0.50	0.56	Once	0.9	1.6	—	—	0.4	—	—	3.6	2.3	3.4	2.9
1.00	1.12	2/20/09	1.0	2.1	—	—	1.0	—	—	6.9	1.6	1.9	2.1
2.00	2.24		1.4	3.3	—	—	1.0	—	—	7.3	1.0	1.4	2.3
0.25	0.28	Three times	1.1	1.3	0.0	0.0[w]	0.9	0.0[v]	0.0[v]	2.7	2.9	4.6	4.0
0.50	0.56	(repeated on	1.3	1.6	0.0	0.0	0.3	0.0	0.3	5.9	1.9	3.1	3.0
1.00	1.12	all three	1.3	3.4	0.0	0.0	1.0	1.9	1.4	8.0	1.4	2.4	2.1
2.00	2.24	dates)	4.1	2.3	2.2	2.1	0.7	7.3	2.7	8.4	1.0	1.3	2.0
		$LSD_{(0.05)}$	0.6	0.8	1.7	0.2	0.6	1.2	1.3	1.0	0.5	0.4	0.5

[z]Injury ratings (0 = no injury, 5 = 50% injury, 10 = dead plant).

[y]Spring growth rating scale (1 = no new flush, 2 = buds but no leaves, 3 = new leaves beginning to unfurl, 4 = 50% leaves unfurled, 5 = full of new growth).

[x]Means separation was according to Fisher's least significant difference (LSD) test ($P \leq 0.05$).

[w]Only June treatments at this time.

[v]Only June + September treatments at this time.

Table 6. Growth indices of eight species treated with Roundup Pro®, Exp 2, recorded on 2/23/09.

Treatment			Ornamental species							
Roundup rate		Application timing	Dwarf mondo grass	Mondo grass	Asiatic jasmine	Dwarf yaupon	Gardenia 'Hardy Daisy'	'Sky Pencil' holly	Euonymus 'Colorata'	Boxwood
lb ai·A^{-1}	kg ai·ha^{-1}									
Non-treated control			17.8[z,y]	26.2	121.7	26.0	54.0	27.6	49.8	27.8
0.25	0.28		18.1	26.8	132.6	27.6	55.6	30.7	54.8	30.8
0.50	0.56	Once	18.3	28.0	109.1	27.2	54.4	30.5	54.4	29.5
1.00	1.12	6/24/08	19.2	25.5	140.4	27.5	55.9	29.2	46.8	28.8
2.00	2.24		17.7	25.1	119.6	20.7	49.6	26.2	45.6	29.4
0.25	0.28		16.4	26.3	118.3	26.6	56.9	31.2	59.2	30.4
0.50	0.56	Once	17.9	27.5	123.0	28.7	53.8	31.2	54.0	29.7
1.00	1.12	9/16/08	17.3	26.9	116.6	27.6	55.6	30.8	53.0	28.5
2.00	2.24		16.9	25.9	104.0	27.6	55.6	29.1	49.2	30.2
0.25	0.28		18.3	26.1	105.8	26.2	57.2	32.2	48.5	29.5
0.50	0.56	Twice (both	18.4	26.6	127.3	26.7	54.0	31.2	58.8	30.0
1.00	1.12	dates above)	18.7	23.8	105.0	25.3	53.9	31.5	49.2	28.4
2.00	2.24		18.1	27.2	90.3	21.4	51.3	28.6	29.9	26.1
		$LSD_{(0.05)}$	1.6	3.1	20.1	3.0	3.1	4.2	9.2	2.7

[z]Growth indices (cm) = [(height + width1 + width2) / 3].

[y]Means separation was according to Fisher's least significant difference (LSD) test ($P \leq 0.05$).

Table 7. Growth indices of eight species treated with Roundup Pro®, Exp 2, recorded on 7/6/09.

Treatment			Ornamental species							
Roundup rate		Application timing	Dwarf mondo grass	Mondo grass	Asiatic jasmine	Dwarf yaupon	Gardenia 'Hardy Daisy'	'Sky Pencil' holly	Euonymus 'Colorata'	Boxwood
lb ai·A^{-1}	kg ai·ha^{-1}									
Non-treated control			15.6[z,y]	20.8	32.5	33.3	60.7	79.1	28.0	32.8
0.25	0.28		15.7	21.1	34.5	34.8	62.1	92.3	30.3	35.3
0.50	0.56	Once	16.1	21.2	33.3	34.0	62.5	87.4	32.7	36.1
1.00	1.12	6/24/08	15.6	20.5	32.5	35.0	62.6	88.3	26.1	34.8
2.00	2.24		15.4	20.7	28.1	29.3	56.8	83.1	30.6	35.2
0.25	0.28		15.6	19.0	34.2	33.0	62.4	95.1	30.9	37.8
0.50	0.56	Once	14.9	20.0	33.9	35.1	61.3	90.1	28.4	36.4
1.00	1.12	9/16/08	15.2	20.8	33.0	34.1	62.2	87.0	30.9	35.2
2.00	2.24		15.0	20.0	34.7	33.5	63.3	87.7	26.1	35.9
0.25	0.28		15.0	20.5	34.8	31.7	61.4	84.9	28.9	33.3
0.50	0.56	Once	15.1	20.7	32.0	30.8	63.5	85.3	31.5	32.3
1.00	1.12	2/20/09	15.0	27.6	28.6	29.8	61.3	83.3	27.6	32.0
2.00	2.24		15.4	25.1	28.5	26.9	60.9	75.4	25.1	30.1
0.25	0.28	Three times	15.6	20.6	33.2	30.1	64.7	91.9	33.5	33.2
0.50	0.56	(repeated	16.4	21.5	32.4	29.6	59.0	90.4	30.4	32.3
1.00	1.12	on all three	16.1	17.0	25.6	26.8	61.7	81.0	24.1	28.7
2.00	2.24	dates)	12.8	17.9	22.8	24.2	56.8	76.1	17.0	26.3
		$LSD_{(0.05)}$	1.0	2.1	5.6	3.0	3.2	12.9	6.4	2.7

[z]Growth indices (cm) = [(height + width1 + width2) / 3].

[y]Means separation was according to Fisher's least significant difference (LSD) test ($P \leq 0.05$).

on 'Hinodegiri' from applications of 0.375 and 0.75 lb ai in mid-June, while Perry and Knowles (12) reported August injury at rates above 0.75 lb ai on 'Hino' as well.

Gardenia 'Hardy Daisy'. Injury was observed from ratings 14 DAT after June 2008 treatments at rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) (Table 5). No injury was noted later from plants receiving September treatments. Injury ratings 18 DAT after the February 2009 treatments indicated damage for rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) with February and JSF treatments. However, injury was slight (10%) and temporary. Growth indices in February 2009 indicated all treatments were similar to NTC except plants treated with 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in June (Table 6). Growth indices in July 2009 showed all plants similar to NTC except 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) applied in June and JSF applications (Table 7). All plants were rated marketable and similar to NTC in October 2009 (Table 8).

Ilex 'Sky Pencil'. Spring growth was rated in April 2009, with all treatments similar to NTC with June and September treatments (Table 5). However, all rates applied in February and JSF caused delayed spring growth and stunting increased with increasing rates of Roundup Pro®. Due to the growth habit of Sky Pencil holly, this injury was not particularly noticeable. All growth indices in February (Table 6) and July 2009 (Table 7) were similar to NTC. All plants were similar and marketable in October 2009 (Table 8).

Euonymus 'Coloratus'. September injury ratings 24 DAT after the September 2008 treatments indicated no plant injury. Injury occurred at rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) with June and JS applications (Table 5). Spring growth ratings in April 2009 revealed no growth suppression at rates up to 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) from single applications in June or September, while both 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) rates delayed spring growth. Growth from all February and JSF treatments were significantly delayed compared to NTC (Table 5). All growth indices in February 2009 were similar to NTC except for JS treatments at 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) (Table 6). Growth indices in July were all similar to NTC except for JSF applications of 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) (Table 7). In October, all plants were marketable and similar to NTC except for smaller but marketable ratings on plants treated with 0.56 and 1.12 kg ai·ha^{-1} (0.5 and 1.0 lb ai·A^{-1}) in February and 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) in JSF. Plants were not marketable when treated with 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in February and with JSF applications (Table 8). Bing (3) reported tolerance over liners potted on May 9–11, 1973 and treated with 1.12, 2.24, and 3.36 kg ai·ha^{-1} (1.0, 2.0, and 3.0 lb ai·A^{-1}) on July 24, 1973. Vigorous growth at all rates was observed in September and October.

'*Wintergreen*' *boxwood*. No injury was observed until Octobr 2008, when all treatments were similar to NTC except for 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) applied in June and JS treatments ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) (Table 5). Injury ratings in April 2009 showed all June and September treatments similar to NTC, while all February and JSF applications caused injury (Table 5). All growth indices from June, September, and JS applications were similar to NTC in February 2009 (Table 6). All growth indices were similar to NTC in July except for rates ≥ 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) with JSF treatments and the 2.24 kg ai·ha^{-1} (2.0 lb ai·A^{-1}) in

Table 8. Marketability of eight species treated with Roundup Pro®, Exp 2, recorded on 10/23/09.

Treatment			Ornamental species							
Roundup rate		Application timing	Dwarf mondo grass	Mondo grass	Asiatic jasmine	Dwarf yaupon	Gardenia 'Hardy Daisy'	'Sky Pencil' holly	Euonymus 'Colorata'	Boxwood
lb ai·A^{-1}	kg ai·ha^{-1}									
Non-treated control			1[z,y]	1	1	1	1	1	1	1
0.25	0.28		1	1	1	1	1	1	1	1
0.50	0.56	Once	1	1	1	1	1	1	1	1
1.00	1.12	6/24/08	1	1	1	1	1	1	1	1
2.00	2.24		1	1	1	1	1	1	1	1
0.25	0.28		1.3	1	1	1	1	1	1	1
0.50	0.56	Once	1	1	1	1	1	1	1	1
1.00	1.12	9/16/08	1	1	1	1	1	1	1	1
2.00	2.24		1	1	1	1	1	1	1	1
0.25	0.28		1.3	1.3	1.3	1.3	1	1	1	2
0.50	0.56	Once	1.3	1	1	1	1	1	1	3
1.00	1.12	2/20/09	1	1.7	2	2	1	1	2	3
2.00	2.24		1	2	3	2	1	1	3	3
0.25	0.28	Three times	1	1	1	1	1	1	1	2
0.50	0.56	(repeated on	1	1	1	1	1	1	1	2
1.00	1.12	all three	1	1.3	1	2	1	1	2	3
2.00	2.24	dates)	1.3	1.3	2	3	1	1	3	3
		$LSD_{(0.05)}$	0.5	0.8	0.8	0.5	0.0	0.0	0.3	0.8

[z]Marketability rating (1 = marketable, 2 = small but marketable, 3 = unmarketable).

[y]Means separation was according to Fisher's least significant difference (LSD) test ($P \leq 0.05$).

February (Table 7). All plants treated in June and September were marketable and similar to NTC in October, while February and JSF treatments were unmarketable at all rates due to leaf distortion (Table 8). Cobb and Self (5) reported similar summer tolerance with no injury and normal rooting of boxwood cuttings treated with 0.75 lb ai·A^{-1} three times applied one week apart in June 1978.

Our research indicates windows of opportunity exist for Roundup use over the top of selected container-grown nursery crops with little to no injury or loss of growth, with some species showing tolerance for accumulations of 6.72 kg ai·ha^{-1} (6.0 lb ai·A^{-1}) over the course of a growing season. Most plants were tolerant to single applications in June after the spring growth flush through September. Three applications generally caused stunting and·or leaf deformities on the majority of the species evaluated. However, 7 species exhibited no detrimental effects from 3 applications of Roundup provided the rate did not exceed 1.12 kg ai·ha^{-1} (1.0 lb ai·A^{-1}) per application. These species were dwarf mondo grass, mondo grass, liriope 'Cleopatra,' variegated liriope, 'Blue Pacific' juniper, gardenia "Hardy Daisy,' and Sky Pencil holly, which experienced acceptable levels of stunting from February applications. Therefore, these species offer the greatest potential for clean up of weedy plants prior to application of preemergence herbicides.

Our research indicates varied responses of individual species to applications of Roundup Pro®. Therefore, individual species should be tested for tolerance before large groups of plants are treated. Over time, tolerant plants outgrow symptoms of Roundup Pro® applications. Spring was the most susceptible time for plant injury; most species tested were tolerant from the middle of June through the rest of the year. Symptoms observed in May were mostly gone by mid to late June. 'Blue Rug' juniper was the exception, with no injury in February but significant injury and growth reductions from June or September applications. Our research is intended to provide data for emergency measures for weed control when labor is unavailable or when it would cost more to weed the crop than it is worth. It should not replace a solid program of weed management consisting of scouting, hand weeding, and a good preemergence herbicide program.

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