

The Effects of Repeated Applications of Roundup Over the Top of Three Container-Grown Crops®

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Liriope muscari, *Gardenia jasminoides* 'Radicans' and *Camellia sasanqua* 'Shishigashira' in 1-gal containers were treated with single applications of Roundup Pro at 1 lb active ingredient per acre in July, August, September, or October 2008. Other plants were treated in July and August; July, August, and September; July, August, September, and October; or July and September. Injury ratings were taken at multiple times after treatments. Growth indices were taken in January and June 2009. Plant vigor ratings were taken in May 2009 and marketability ratings in June. *Camellia* exhibited no injury from any Roundup application. *Liriope* showed minor injury from multiple applications. *Gardenia* showed stunting and chlorosis from multiple applications. Growth rates of *camellia*, *liriope*, and *gardenia* the following spring were similar to the controls except those treated four times the previous fall. Final growth indices, plant vigor, and marketability were similar to controls except for plants receiving four applications.

INTRODUCTION

Previous research through the years has shown that numerous nursery crops have some degree of tolerance to over-the-top applications of Roundup. Between 1975 and 1980, Roundup was evaluated over the top of numerous container-grown crops. Self (1978) applied Roundup once, twice, or three times at 0.5, 0.75, 1.0, and 1.5 lb active ingredient per acre (ai/A) on 7, 14, and 21 April 1978 to eighteen ornamental species. Total amounts of glyphosate applied ranged from 0.5 to 4.5 lbs ai/A. Of the 18 species tested, eight were not injured, including *Magnolia soulangeana*, *Juniperus rigida* subsp. *conferta*, *Cupressus* sp., *Ilex cornuta* 'Burfordii', *I. cornuta* 'Yellow Top', *Photinia fraseri*, *Podocarpus*, and *Trachycarpus fortunei*. *Gardenia jasminoides* 'Radicans' was injured at 3 and 4.5 total lbs ai/A. Of the remaining species, 'Hinodegiri' and 'Fashion' azaleas were the most sensitive, with injury occurring from as little as two applications of the 0.5 lb rate. Perry and Knowles (1979) applied glyphosate at 0.25, 0.75, and 1.0 lb ai/A over the top of 10 species, once on 3 Aug. and again on 17 Aug. 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 on *B. julianae*, *Euonymus japonicus*, and *Ilex cornuta* 'Dwarf Burford' regardless of rate. Damage was more severe on the remaining species at ≥ 0.75 lb ai/A. All spe-

cies overwintered well, but evaluation of root systems in late February indicated slightly less root density on plants treated with 1.0 lb ai/A.

Neal et al. (1985) reported that ligustrum showed a linear decrease in susceptibility from March to November. Blue Pacific juniper sustained tip necrosis on young elongating tips from early summer applications, when growth is acropetal, but applications at other growth stages resulted in no significant absorption of glyphosate.

Altland et al. (2002) reported that Roundup at 0.4 lb ai/A could be used as a cleanup treatment for effective control of spurge (96%) in *L. muscari* 'Big Blue' with no short-term or long-term injury to 'Big Blue'. In separate experiments, Roundup at 1.6 lbs ai/A, the maximum rate tested, was applied to recently divided liners of 'Variegata' and 'Big Blue' infested with mature and flowering spurge. Effective control of spurge (92.8% and 100%, respectively) with no short-term or long-term injury to 'Variegata' was reported. 'Big Blue' showed slight initial injury which was outgrown by 60 days after treatment (DAT).

Walsworth et al. (2006) reported that Roundup applied on 6 Sept. 2005 in a 1% solution (4 lbs ai in 100 gal) caused no injury on liriopie or Asiatic jasmine. Van Hoogmoed et al., (2009) reported no differences in growth indices or marketability of mondo, dwarf mondo, liriopie 'Cleopatra,' variegated liriopie, and Blue Pacific juniper between nontreated controls and plants treated with 1 lb ai/A Roundup Pro applied in June, late August, and mid-February.

As growers have increased the use of over-the-top Roundup applications, they are asking how often can they apply Roundup over the top. The objective of the experiment was to determine crop tolerance of container-grown nursery crops to repeated glyphosate applications at 1 lb ai/A, a rate found to be adequate for control of most weeds found in container production (Van Hoogmoed et al., 2009).

METHODS AND MATERIALS

Liriopie, gardenia, and camellia 'Shishigashira' in 1-gal containers in pine bark and sand substrate (6 : 1, v/v) were obtained and treated with single applications of Roundup Pro® at 1 lb ai/A in July, August, September, or October 2008 with a CO₂-powered backpack sprayer at 25 psi and 30 GPA. Multiple applications were applied in July and August; July, August, and September; July, August, September, and October; and July and September. There was one nontreated control group; nine treatments in all. Plant injury ratings (1 = no injury, 10 = dead) were taken throughout the study and final growth indices were taken on 9 June 2009. Plants were grouped by species in a completely randomized block design with 8 single-pot replications. Injury ratings were collected at 11- to 19-day intervals after test initiation until the end of the growing season. Growth indices were collected 21 Jan. and 9 June 2009. Plant vigor (1 = healthy, 5 = chlorotic) and marketability (1 = marketable, 3 = not marketable) were rated on 14 May 2009. Data was analyzed in a statistical software package (SAS Institute, Cary, North Carolina) using Waller-Duncan k ratio t tests ($P \leq 0.05$). Data was analyzed separately for each sampling date.

RESULTS

Liriopie. Injury ratings for liriopie were similar to controls through the end of September (Table 1). However, at the end of October slight injury was observed, characterized by 1–4 yellow leaf blades per plant. All treatments with an August application had the highest percentage of plants with a few yellow leaves. Plants were

rated for vigor on 14 May 2009 and no differences were observed. Growth indices taken on 21 Jan. 2009 showed that single treatments in September and October and successive treatments in July and August were similar to nontreated controls. Single treatments in July and August and successive treatments in July and August, and July and September were slightly smaller than nontreated control plants. Liriope receiving multiple treatments tended to be the smallest. Growth indices on 9 June 2009 followed about the same trend as the 21 Jan. ratings. Comparison of the differences in growth indices between 21 Jan. and 9 June showed no significant difference in spring growth from the nontreated controls for any single or multiple treatments except for the July and August treatment and the four successive applications. Although some treatments received up to 4 lbs ai/A total, regrowth was similar to the controls. All plants were similar to the controls in plant vigor ratings on 14 May 2009. Plants were rated for marketability on 6 June 2009. All treatments except the group treated four times from July to October were similar to the controls; however, all plants were marketable.

Camellia. No injury was noted in any treatment (Table 1). Growth indices were similar in camellia for all treatments and controls on 21 Jan. and 9 June 2009. There was no difference in plant vigor or color on 14 May 2009. Differences in growth between January and June were similar as well except for the July, August, and September multiple treatment. Plant vigor for all treatments was similar to the control. All camellias were marketable.

Gardenia. Injury on gardenia from various single treatments appeared as chlorotic leaves about 7 days after treatment (Table 2). However, within 3 weeks, treated plants were similar to the controls. As multiple treatments were applied, chlorosis and stunting became more evident. Treatments applied on 28 July were significantly different from the controls on 8 Aug. Five treatments received a July single application but rated differently; three of five treatments were significantly different from each other. These data demonstrate the slight but variable initial results from over-the-top Roundup treatments. Within 1 month, all plants had recovered from the July treatment and were visually similar to the controls. On 12 Sept., the July treatment was similar to the control. Three July and August treatments (September and October not applied yet) were similar to each other and had significantly greater injury than all other treatments. On 29 Sept., the day of the September treatment, all gardenia treated in July and August had the most injury while plants treated in July only were similar to non-treated plants. Plants treated only in August exhibited slight injury. In October the trend was similar to September ratings with all plants receiving July and August applications exhibiting the most injury. Injury among all other treatments was minimal with the August-only treatment having slightly greater injury than the nontreated plants.

Growth indices for gardenia on 21 Jan. 2009 were similar for nontreated control plants and plants treated only in August, September, and October (single applications). All gardenia treated in July were smaller than nontreated controls. Gardenia receiving two Roundup applications were smaller than all other plants. Growth indices taken after the spring flush on 9 June 2009 indicated that the nontreated control and single applications in August, September, and October were similar. All gardenia receiving multiple applications were smaller than nontreated control plants. As previously noted, gardenia treated any time in July were smaller in size.

Table 1. Liriope and camellia injury, plant vigor, growth indices, and marketability ratings.

Roundup Pro 1 lb ai/A	Liriope				Camellia ¹						
	10/16/08 IR ^z	5/14/09 Plant vigor ^y	1/21 Growth indices ^x	6/9 Growth indices	Diff growth indices	6/9 Mkt ^w	5/14 Plant vigor	1/21 Growth indices	6/9 Growth indices	Diff growth indices	6/9 Mkt
Control	1.1 cd ^v	1.0 a	32.0 a	44.4 a	12.4 ab	1.1 b	1.0 a	23.6 a	30.8 a	7.2 ab	1.0 a
28-Jul	1.5 bc	1.0 a	28.5 cd	40.2 c	11.7 abc	1.1 b	1.0 a	22.7 a	28.7 a	6.0 ab	1.0 a
Jul, Aug	1.9 ab	1.0 a	30.7 abc	44.9 a	14.2 a	1.0 b	1.7 a	20.2 a	24.9 a	4.6 bc	2.3 a
Jul, Aug, Sep	1.9 ab	1.0 a	26.7 d	38.1 cd	11.4 abc	1.2 b	1.4 a	23.0 a	26.0 a	3.0 c	2.0 a
Jul, Aug, Sep, Oct	2.0 a	1.0 a	27.0 d	35.9 d	8.8 c	1.7 a	1.0 a	24.5 a	29.1 a	4.6 bc	1.0 a
Jul, Sep	1.3 bc	1.0 a	29.7 bc	40.0 c	10.3 bc	1.2 b	1.0 a	22.9 a	31.5 a	8.6 a	1.0a
28-Aug	1.9 ab	1.0 a	30.2 bc	40.8 bc	10.7 bc	1.4 a	1.3 a	21.1 a	27.4 a	6.2 abc	1.7 a
29-Sep	1.0 d	1.0 a	33.2 a	43.6 ab	10.3 bc	1.2 b	1.4 a	24.7 a	30.3 a	5.7 abc	1.9 a
29-Oct	.	1.0 a	32.2 ab	44.9 a	12.6 ab	1.0 b	1.0 a	22.9 a	32.0 a	9.1 a	1.0 a

^zInjury ratings 1 = no injury, 10 = dead plant

^yPlant vigor 1 = healthy, 5 = chlorotic

^xGrowth indices = [(height × width1 × width 2)/3] in cm

^wMarketability 1 = marketable, 2 = small but marketable, 3 = unmarketable

^vDuncan's Multiple Range test $\alpha = 0.05$

¹No injury was recorded for camellia

Table 2. Gardenia injury, plant vigor, growth indices, and marketability ratings.

Roundup Pro 1 lb ai/A	8/8/08	8/27	9/12	9/29	10/16	5/14/09	1/21	6/9	6/9	
	IR ^z	IR	IR	IR	IR	Plant vigor ^y	Growth indices ^x	Growth indices	Diff growth indices	Mkt ^w
Control	1.0 d ^v	1.0 a	1.0 c	1.0 c	1.0 d	1.0 d	40.5 a	45.7 a	5.2 ab	1.0 c
28-Jul	2.5 ab	1.0 a	1.5 c	1.6 b	2.0 bc	1.2 d	35.6 bc	38.9 c	3.4 bc	1.0 c
Jul, Aug	2.9 a	1.0 a	5.0 a	4.5 a	4.1 a	2.0 c	30.2 d	33.0 d	2.8 bc	1.7 ab
Jul, Aug, Sep	2.7 ab	1.0 a	4.7 a	4.9 a	4.7 a	2.4 b	29.7 d	33.1 d	3.4 bc	2.0 ab
Jul, Aug, Sep, Oct	2.4 b	1.0 a	4.7 a	4.9 a	4.7 a	2.9 a	28.5 d	31.7 d	3.2 bc	2.1 a
Jul, Sep	1.9 c	1.0 a	1.2 c	1.1 c	1.5 bcd	1.0 d	32.7 cd	39.8 bc	7.2 a	1.6 b
28-Aug	.	.	2.0 b	2.0 b	2.4 b	1.0 d	38.7 ab	43.5 abc	4.8 ab	1.0 c
29-Sep	.	.	.	1.0 c	1.1 d	1.0 d	41.2 a	44.1 ab	2.8 bc	1.1 c
29-Oct	.	.	.	.	.	1.0 d	42.1 a	42.8 abc	0.7 c	1.1 c

^zInjury ratings (IR) 1 = no injury, 10 = dead plant

^yPlant vigor 1 = healthy, 5 = chlorotic

^xGrowth indices = [(height × width 1 × width 2)/3] in cm

^wMarketability 1 = marketable, 2 = small but marketable, 3 = unmarketable

^vDuncan's Multiple Range test $\alpha = 0.05$

Ratings for plant vigor on 14 May showed that all single applications were similar to the nontreated control, while gardenia receiving multiple treatments were rated lower due to slight leaf stunting. Marketability ratings showed that all single treatments were similar to the nontreated controls, while plants receiving multiple treatments had slightly higher ratings due to smaller leaf size. All plants were marketable.

DISCUSSION

This research demonstrates that Roundup is much safer around some ornamentals than previously thought. Our research shows that many ornamentals are very tolerant, especially when treatments are applied from July through the end of the growing season. After application to some species, growth was slightly reduced and slight visual differences could be detected as compared to the controls. However, regrowth was similar for all treatments except those treated four times in successive months. Individual species should be tested for tolerance before large groups of plants are treated. Our research is intended to provide data for emergency measures for weed control in nurseries and landscapes when labor is unavailable or when hand weeding would exceed budget limitations. It should not replace a solid program of weed management consisting of monitoring, some hand weeding, and application of preemergence herbicides.

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