Preemergence Herbicide Applications to Six Containerized Woody Ornamental Rootstocks do not Affect Winter Grafting Success[1]

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Abstract

Five common preemergence herbicides [Scotts OH2 (oxyfluorfen and pendimethalin), Snapshot TG (trifluralin and isoxaben), Ronstar (oxadiazon), SureGuard (flumioxazin), or BroadStar (flumioxazin)] were each applied at the highest labeled rates at 6 to 8 week intervals over the growing season to six species of container-grown seedling rootstocks. Dormant scions were bench-grafted to their respective rootstocks the following winter. Research was conducted in 2006–2007 and repeated in 2007–2008. Treatment effects were compared to non-treated control plants. Preemergence herbicide treatments had no effect on grafting success for any of the cultivars. Data indicate that these preemergence herbicides, labeled for use in container-grown nursery crops, can be used in accordance with label recommendations to control weeds in containerized rootstocks without affecting subsequent grafting success.

Index words: bench grafting, asexual or vegetative propagation, scion, understock, plant production, weed control, modified side-veneer graft.

Species used in this study: 'Tamuke Yama' Japanese maple (*Acer palmatum* Thunb. 'Tamuke Yama'); 'Hearts of Gold' eastern redbud (*Cercis canadensis* L.'Hearts of Gold'); 'Autumn Gold' ginkgo (*Ginkgo biloba* L. 'Autumn Gold'); 'Primavera' witch-hazel (*Hamamelis* × *intermedia* Rehd. 'Primavera'); weeping Japanese pagoda tree (*Styphnolobium japonicum* (L.) Schott. 'Pendulum'); 'Lace Parasol' winged elm (*Ulmus alata* Michx. 'Lace Parasol').

Herbicides used in this study: Snapshot 2.5TG (trifluralin) α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine and (isoxaben) *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide and isomers; Ronstar 2G (oxadiazon) 3-[2,4-Dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2(3H)-one; Ornamental Herbicide 2 (OH2) (oxyfluorfen) 2-Chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene and (pendimethalin) N-(1-Ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; SureGuard (flumioxazin) and BroadStar (flumioxazin) 2-[7-fluoro-3,4-dihydro-3-oxo-4-(2-propynyl)-2H-1,4-benzoxazin-6-yl]-4,5,6,7-tetrohydro-1H-isoindole-1,3(2H)-dione.

Significance to the Nursery Industry

Hand weeding is the primary mode of weed suppression in rootstocks designated for winter bench grafting. Herbicides are generally not used for weed control on the rootstocks due to a concern for their potential effects on grafting success. Thus, the safety of common nursery preemergence herbicides applied to container-grown rootstocks on subsequent bench grafting success was evaluated. Snapshot 2.5TG (trifluralin and isoxaben), Ronstar 2G (oxadiazon), Scott's Ornamental Herbicide 2 (OH2) (oxyfluorfen and pendimethalin), Sureguard 51WG (flumioxazin) and BroadStar 0.25G (flumioxazin) were applied during production of containerized rootstocks designated for winter bench grafting. Grafting success of 'Tamuke Yama' Japanese maple, 'Hearts of Gold' eastern redbud, 'Autumn Gold' ginkgo, 'Primavera' witch-hazel, 'Pendula' weeping Japanese pagoda tree, and 'Lace Parasol' winged elm was unaffected by use of the preemergence herbicides when applied to its rootstocks. With caution, we believe that propagators can use these preemergence herbicides during rootstock production and establishment to suppress weed populations without affecting subsequent dormant, winter bench grafting success of these cultivars.

Introduction

Successful bench grafting of deciduous species is aided by growing rootstocks for 8 to 12 months to establish a root system prior to grafting (7). During this time, hand weeding is often the primary method of weed suppression. Although hand weeding can be effective, it is labor intensive, expensive, and inefficient (12, 13). In container production of woody nursery crops, it is common to apply preemergence herbicides several times during the production cycle (9) because these compounds significantly reduce weed growth and the cost of weed control (6). Despite these benefits, preemergence herbicide use in containerized rootstock production is not a common practice. The potential herbicide effects on grafting success are unknown.

Limited research has been conducted on use of herbicides in woody plant propagation. Earlier studies reported rooting percentage and root system quality were not affected when stem cuttings were collected from stock plants receiving either repeated applications within a year or repeated annual applications of a wide variety of preemergence herbicides (1, 2, 4, 18). More recently, this finding has been supported when, over 3 years, semiannual applications of Ronstar 2G (oxadiazon), Surflan 4G (oryzalin), Treflan 5G (trifluralin), and OH2 2 + 1G (oxyfluorfen and pendimethalin) to field-grown stock plants of 'Nellie R. Stevens' holly (*Ilex* × 'Nellie R. Stevens'), shore juniper (*Juniperus conferta*), 'Pfitzer'

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juniper (*Juniperus chinensis*), and glossy privet (*Ligustrum lucidum*) did not affect the rooting percentage or root system quality of hardwood cuttings collected from the stock plants (5). Therefore, as an inference, collecting dormant scion wood for grafting from stock plants treated with preemergence herbicides may not affect grafting success.

Herbicide treatments applied to rooting substrates prior to or after setting softwood cuttings in propagation beds or flats have yielded results that depended on the herbicide and crop species. In two separate studies utilizing stem cuttings of 'Trouper' azalea (*Rhododendron* × 'Trouper'), Rout (oxyfluorofen and oryzalin) and OH2 did not affect rooting percentage but decreased root length and root quality (8, 17), whereas Ronstar affected all three variables in one study (17), but not the other (8). For other herbicides, Rout 3G was the most likely to reduce rooting, root length, or number of roots compared to Ronstar 2G, OH2 3G, and Prowl 60 DF (pendimethalin) and 2.45G (pendimethalin) when rooting stem cuttings of 'Rosy Glow' barberry (*Berberis thunbergia* 'Rosy Glow'), Foster holly (*Ilex* × *attenuata*), Japanese euonymus (*Euonymus japonica*), and gardenia (*Gardenia jasminoides*) (17). If the herbicides were applied after stem cuttings were set into the media, then Rout 3G had less of an affect on rooting and root system quality (10). Surflan reduced rooting percentage and root system quality of Kurume azalea (*Rhododendron* × *obtusum*) and rockspray cotoneaster (*Cotoneaster horizontalis*) (10). During grafting, it is unclear how preemergence herbicides might affect success because no root primordia are formed during cambium contact or subsequent healing of graft unions.

Budding is the closest form of vegetative propagation to dormant bench grafting because both rely on cambial contact and a successful union between scion and rootstock. During field-budding of roses (*Rosa* sp.), Bentley (3) found no effect on budding success after applications of liquid or granular oryzalin, pendimethalin, or isoxaben to rootstocks. Similarly, Weller and Carpenter (20) reported no effect of oryzalin, diphenamid, 3, 4-Dichloropropionanilide (DCPA), and napropamide on field-budding success of 'Indian Magic' crabapple (*Malus* 'Indian Magic').

Most herbicides labeled for use in container nursery crops contain a dinitroanaline herbicide such as pendimethalin, oryzalin, trifluralin, or prodiamine. The mode of action of this class of herbicides is inhibition of cell division with symptoms most commonly expressed as inhibition of root growth (14). Rooting stem cuttings and grafting are both forms of vegetative propagation and the relationship between root inhibition and vegetative propagation may be why grafters are reluctant to use preemergence herbicides. Moreover, grafting is an art form passed from propagator to propagator, with careful consideration to every environmental and physiological variable that affects success. Applying preemergence herbicides may not have been in the time-honored protocol, nor is their use mentioned in Garner (7) or Macdonald (12). Therefore, the objective of this research was to investigate the effect of selected preemergence herbicides applied to containerized rootstocks on the subsequent grafting success of six commonly grown cultivars.

Methods and Materials

The experiment was replicated twice (2006–2007 and 2007–2008). Seedlings of eastern redbud (*Cercis canadensis*) (Shadow Nursery, Winchester, TN, 2006 and Carlton Plants, Inc., 2007), Japanese maple (*Acer palmatum*), ginkgo (*Ginkgo biloba*), witch-hazel (*Hamamelis virginiana*), Japanese pagoda tree [*Styphnolobium japonicum* (formerly *Sophora japonica*)] (Heritage Seedlings, Inc., Salem, OR), and winged elm (*Ulmus alata*) (Superior Trees, Inc., Lee, FL) with root collar diameters approximately 0.48 cm (3/16 in) were obtained in February to March 2006 and 2007, and heeled in composted sawdust and river sand. In March of each year, plants were potted in either 7.1 × 7.1 × 14.0 cm (2 7/8 × 2 7/8 × 5 1/2 in) (*A. palmatum*, *G. biloba*, *H. virginiana*, *S. japonicum*, and *U. alata*), or 9.2 × 9.2 × 15.2 cm (3 5/8 in × 3 5/8 × 6 in) (*C. canadensis*, 2006) plastic containers (Anderson Die and Manufacturing Co., Portland, OR) or #1 containers (2.8-liter) (*C. canadensis*, 2007). The potting substrate was composted pine bark amended with 0.69 kg·m^{-3} (2 lbs·yd^{-3}) dolomitic limestone and 3.45 kg·m^{-3} (10 lbs·yd^{-3}) alfalfa meal. After potting, plants were side-dressed with 8 g (0.28 oz) (or 15 g for #1 containers) of a commercial controlled-release fertilizer (18N:6P_2O_5:8K_2O; Nutricote, 5–6-month, Sun-Gro Hort., Canada) and placed in a cold frame covered with white polyethylene until the experiments began.

Snapshot 2.5TG (isoxaben + trifluralin) (Dow Agro Sciences LLC, Indianapolis, IN) at 5.6 kg ai·ha^{-1} (5.0 lbs ai·A^{-1}), Scott's OH2 3G (pendimethalin + oxyfluorfen) (Scotts-Sierra Crop Protection Co. Marysville, OH) at 3.4 kg ai·ha^{-1} (3.0 lbs ai·A^{-1}), Ronstar 2G (oxadiazon) (Bayer Environ. Sci., Res. Triangle Park, NC) at 4.5 kg ai·ha^{-1} (4.0 lbs ai·A^{-1}), or SureGuard 51 DG (flumioxazin) (Valent U.S.A. Corp., Walnut Creek, CA) at 0.43 kg ai·ha^{-1} (0.38 lbs ai·A^{-1}) in 2006 [BroadStar 0.25G (flumioxazin) at 0.43 kg ai·ha^{-1} (0.38 lbs ai·A^{-1}) (Valent U.S.A. Corp.) in 2007] was surface applied using either a shaker jar or a diaphragm pump backpack sprayer delivering 112 liters·ha^{-1} (12 gal·A^{-1}) through a wide-angle, single, fan-spray nozzle at 14 psi (SureGuard only).

Herbicides were applied to containerized rootstocks on April 21, June 9, August 11, and September 29, 2006. In 2007, herbicides were applied on July 5, August 31, and October 26. After treatment, herbicides were watered with 0.5 in (1.3 cm) of water delivered by an overhead impact sprinkler. Rootstocks treated with herbicides were compared to non-treated plants.

The experimental design was a randomized complete block with seven blocks. Species were considered separate experiments and were grown and analyzed separately. Treatments in each replicate contained three plants (subsamples). During the growing season, plants were under 40% shade cloth and grown following general nursery practices (19). In November of each year, plants were placed in an overwintering structure covered with white polyethylene. In December of each year, plants were brought into an unshaded greenhouse structure covered with two layers of clear polyethylene. Temperatures were maintained between 3.3 and 18.3C (38 and 65F). Plants were not irrigated prior to grafting. During the next 30–60 days, plants were removed periodically from containers to observe root growth. When white root tips were observed, indicating active root growth, plants were considered ready for grafting.

Scion wood, collected from non-treated plants, of 'Primavera' witch-hazel (*Hamamelis* × *intermedia* 'Primavera'), 'Autumn Gold' ginkgo (*Ginkgo biloba* 'Autumn Gold'), 'Tamuke Yama' Japanese maple (*Acer palmatum* 'Tamuke Yama'), 'Lace Parasol' winged elm (*Ulmus alata* 'Lace Parasol'), 'Pendula' weeping Japanese pagoda tree (*Styphnolo-*

Table 1. Grafting success of six unrelated woody ornamental cultivars from 2006 to 2007. Seedling rootstocks were treated during establishment prior to grafting with no herbicide (non-treated control) or four preemergence herbicides.

Preemergence herbicide treatments	Cultivars					
	'Tamuke Yama' Japanese maple	'Heart's of Gold' eastern redbud	'Autumn Gold' ginkgo	'Primavera' witch-hazel	'Pendula' weeping Japanese scholar tree	'Lace Parasol' winged elm
	Grafting success[z] (% ± SE)					
Non-treated control	95.2 ± (2.8)	100.0 ± (0.0)	100.0 ± (0.0)	90.5 ± (6.6)	100.0 ± (0.0)	90.0 ± (6.9)
Snapshot 2.5TG (isoxaben + trifluralin)	90.5 ± (6.6)	90.5 ± (6.6)	94.7 ± (5.3)	90.5 ± (6.6)	100.0 ± (0.0)	95.2 ± (4.8)
OH2 3G (pendimethalin + oxyfluorfen)	95.2 ± (4.8)	90.0 ± (6.9)	100.0 ± (0.0)	95.2 ± (4.8)	100.0 ± (0.0)	100.0 ± (0.0)
Ronstar (oxadiazon)	90.5 ± (6.6)	85.0 ± (8.2)	100.0 ± (0.0)	94.7 ± (5.3)	94.7 ± (5.3)	100.0 ± (0.0)
SureGuard[y] (flumioxazin)	NG[x]	85.7 ± (7.8)	95.2 ± (4.8)	94.4 ± (5.6)	NG	NG
Mean	92.9 ± (2.8)	90.2 ± (3.0)	97.8 ± (1.5)	93.0 ± (2.6)	98.6 ± (1.4)	96.3 ± (2.1)

[z]There was no significant difference between the preemergence herbicide treatments.

[y]SureGuard was included only in the 2006–2007 experiment. BroadStar was included only in the 2007–2008 experiment.

[x]NG = not grafted after an initial application of SureGuard injured rootstocks prior to grafting.

bium japonicum 'Pendula'), and 'Hearts of Gold' eastern redbud (*Cercis canadensis* 'Hearts of Gold') approximately 10.2–15.2 cm (4–6 in) long and consisting of three to five nodes was grafted to its respective genus of seedling rootstock on January 30 or February 5, 2007, or on January 26, February 26, or March 5, 2008 (*Ginkgo* 'Autumn Gold' was not included in 2007–2008), using a modified side-veneer graft (19). Graft unions were wrapped with 0.48 cm (3/16 in) wide budding rubbers and painted with Tree Kote (both from A.M Leonard, Inc., Piqua, OH). Plants were maintained under the same temperature regime until the graft unions healed and the buds of the scions began to swell. Plants were then irrigated two to three times daily for three to four days to re-wet substrates, and temperatures were maintained between 7.2 and 21.1C (45 and 70F).

Data recording and analysis. The number of successful grafts was recorded April 10, 20, or 25, 2007, for the 2006–2007 experiment, and April 21, or June 15, 2008, for the 2007–2008 experiment, depending on cultivar. Grafts were considered successful if leaves of new growth were fully expanded and were judged marketable by the cooperating grower. Data were converted to percent graft success. Due to the high occurrence of 100% success in both years of the experiment, data were not normally distributed nor had equal variances. Raw data for percent success were transformed using the arcsine square root transformation, however, neither distribution nor variance were improved by the transformations. Nevertheless, the transformed data were subjected to analysis of variance (ANOVA) including the raw data using SAS v 9.1.3 (16). There were no differences between analyses, therefore, results and means presented are based on nontransformed data.

Results and Discussion

Grafting success in both years was not affected significantly by application of the five preemergence herbicides to containerized rootstock when compared to the non-treated control ($P < 0.05$; ANOVA not presented) (Tables 1 and 2). Grafting success was affected significantly by year for 'Hearts of Gold' eastern redbud and 'Lace Parasol' winged elm. Mean success was 90% in 2006–2007 (Table 1) and 62% in 2007–2008 (Table 2) for 'Hearts of Gold' eastern redbud. For 'Lace Parasol' winged elm, grafting success was 96% in 2006–2007 (Table 1) and 82% in 2007–2008 (Table 2). For both cultivars, there was no significant treatment by experiment interaction, indicating overall grafting success was lower in 2007–2008 for these cultivars. Therefore, mean

Table 2. Grafting success of five[z] woody ornamental cultivars from 2007 to 2008. Seedling rootstocks were treated during establishment prior to grafting with no herbicide (non-treated control) or four preemergence herbicides.

Preemergence herbicide treatments	Cultivars				
	'Tamuke Yama' Japanese maple	'Heart's of Gold' eastern redbud	'Primavera' witch-hazel	'Pendula' weeping Japanese scholar tree	'Lace Parasol' winged elm
	Grafting success[z] (% ± SE)				
Non-treated control	90.5 ± (6.6)	61.1 ± (11.8)	100.0 ± (0.0)	89.5 ± (7.2)	85.0 ± (8.2)
Snapshot 2.5TG (isoxaben + trifluralin)	95.2 ± (4.8)	75.0 ± (9.9)	100.0 ± (0.0)	84.2 ± (8.6)	75.0 ± (9.9)
OH2 3G (pendimethalin + oxyfluorfen)	89.5 ± (7.2)	68.4 ± (11.0)	100.0 ± (0.0)	85.0 ± (8.2)	90.0 ± (6.9)
Ronstar (oxadiazon)	90.0 ± (6.9)	52.9 ± (12.8)	95.0 ± (5.0)	95.2 ± (4.8)	85.7 ± (7.8)
BroadStar[x] (flumioxazin)	76.5 ± (10.6)	52.6 ± (11.8)	100.0 ± (0.0)	80.0 ± (9.2)	76.2 ± (9.5)
Mean	88.8 ± (3.2)	62.4 ± (5.1)	98.9 ± (1.1)	86.9 ± (3.4)	82.4 ± (3.8)

[z]*Ginkgo biloba* 'Autumn Gold' was included only in the 2006–2007 experiment.

[y]There was no significant difference between the preemergence herbicide treatments.

[x]BroadStar was included only in the 2007–2008 experiment. SureGuard was included only in the 2006–2007 experiment.

grafting success over both years was 77% for 'Hearts of Gold' eastern redbud and 89% for 'Lace Parasol' winged elm, regardless of which preemergence herbicide was applied to containerized rootstocks prior to grafting. Mean grafting success over both years was 91, 96, and 92% for 'Tamuke Yama' Japanese maple, 'Primavera' witchazel, and 'Pendula' Japanese scholar tree, respectively ('Autumn Gold' ginkgo was not included in 2007–2008).

After the first application of SureGuard to rootstocks on April 21, 2006, mortality, lesions and stem necrosis was noted for Japanese maple, Japanese pagoda tree, and winged elm. Therefore, treatment was discontinued on those species and subsequent cultivars were not grafted to those SureGuard-treated rootstocks in 2006–2007. Minor specks of leaf necrosis occurred on rootstocks of ginkgo, however the SureGuard treatment was continued because plants recovered before the next application on June 9, 2006, and the cultivar was grafted subsequently in winter. Rootstocks of witch-hazel and eastern redbud were unaffected by SureGuard applications. The SureGuard label mentions that flumioxazin should not be sprayed on green stemmed species. As a result, BroadStar, the granular formulation of flumioxazin, was used in 2007–2008 and no injury was observed on any species of rootstock.

It is not known if the herbicides tested would affect grafting success if applied closer to the time of grafting. In the present study, 90 to 120 days elapsed between grafting and the last preemergence herbicide applications. This was because preemergence herbicides cannot be used in greenhouses or similarly covered structures. Degradation rates of the chemicals combined with frequent irrigation events and high temperatures decrease the amount of the chemical remaining in the soilless substrate after 6–8 weeks (11, 15). Therefore, the chemical may not have been present in the substrates of containerized rootstocks at the time of grafting. However, the methods used in this study were consistent with label recommendations and current operational methods of winter bench grafting. In practice, both weed suppression and graft success should occur.

Results herein indicate preemergence herbicides can be used for containerized rootstocks to control weed populations prior to grafting. The six taxa tested represent a wide diversity of ornamental species bench-grafted by the nursery industry. Similarly, the active ingredients tested represent the most common preemergence herbicides used on containerized nursery stock. By following the methods described and the label recommendations for the herbicides tested, growers can use preemergence herbicides on rootstocks of the taxa investigated. When implementing preemergence herbicides into any production system, growers are cautioned to test the herbicides on a small scale first prior to widespread use.

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