Production of Six Woody Landscape Plants in Copper-coated and Styrene-lined Containers[1]

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Abstract

Growth of *Rhododendron* L. 'Hershey's Red' (azalea), *Magnolia grandiflora* L. (magnolia), *Ilex* x *meserveae* S.Y. Hu. 'Blue Princess' (holly), *Pittosporum tobira* (Thunb.) Ait. (pittosporum), *Gardenia jasminoides* Ellis 'August Beauty' (gardenia), and *Nerium oleander* L. (oleander) were evaluated for 8 months in 3.8 liter (#1) containers treated with (+) or without (–) copper hydroxide (Cu) and with (+) or without (–) a styrene lining. Plants were then repotted into 10.3 liter (#3) untreated containers to determine treatment effects on root regeneration and shoot growth. In addition, azalea, gardenia, and holly were planted in the ground to evaluate root regeneration and shoot growth during landscape establishment. All species tested had less root growth at the substrate-container interface at the end of the first growing season when grown in Cu-treated containers. Other growth parameters measured (height, trunk diameter, growth index) varied among species in response to Cu treatment. One growing season (11 months) after repotting into 10.3 liter (#3) containers, all species had less surface root coverage when the original 3.8 liter (#1) container was Cu-treated. Dry weights of newly generated roots outside the original rootball of repotted or transplanted plants were not affected by Cu or styrene treatment, except for a lower root dry weight of holly when previously grown in +Cu containers. After repotting into larger containers, shoot growth in response to Cu was species-dependent. Transplanted azaleas had a lower growth index after transplanting from +Cu containers than from –Cu containers. Growth index of gardenia was increased after repotting into 10.3 liter (#3) containers from 3.8 liter (#1), styrene-lined containers; surface root coverage 5 months after repotting also was increased when plants were previously grown in styrene-lined containers. Oleander, holly, and magnolia previously grown for 8 months in 3.8 liter (#1), styrene-lined containers without Cu all had more surface root coverage after being grown for 11 months in 10.3 liter (#3) containers compared to plants grown in unlined containers.

Index words: copper hydroxide, root pruning, root growth, root regeneration.

Species used in this study: azalea (*Rhododendron* L. 'Hershey's Red), magnolia (*Magnolia grandiflora* L.), holly (*Ilex* x *meserveae* S.Y. Hu. 'Blue Princess'), pittosporum (*Pittosporum tobira* (Thunb.) Ait.), gardenia (*Gardenia jasminoides* Ellis 'August Beauty'), oleander (*Nerium oleander* L.).

Significance to the Nursery Industry

Coating interior surfaces of containers with copper hydroxide is an effective method of controlling circling roots of many species of woody landscape plants. However, root and shoot growth a growing season after repotting or transplanting into the ground are not always enhanced and, in the case of 'Blue Princess' holly, root growth was less. Lining containers with styrene has little effect on surface root development during the first year of production, but enhances root development in some species in the year following repotting. With a few exceptions, significant benefits in plant shoot growth and root regeneration from copper coating or styrene lining of containers were not realized in this study.

Introduction

Summer temperatures above 38C (100F) for 6 hours per day have been recorded at the substrate-container interface (9); temperatures in excess of 50C (122F) have also been recorded in containers (7). Because container temperatures above 35C (95F) may lead to a reduction in root and shoot growth, and death of root tips occurs when temperatures are above 45C (113F) (16), many approaches to minimize high temperature root stress have been examined (8, 10, 11). A recent method, similar to using insulated pallets (1), uses manufactured compressed styrene sheeting inserted into containers to insulate the substrate. Reductions in maximum substrate temperatures of up to 8C (14.4F) have been previously reported (5) in styrene-lined containers compared to conventional, unlined containers. Styrene lining has also been reported by a commercial nurseryman to increase shoot and root growth (2), and a grower in south Alabama currently uses a similar styrene lining in large containers. To our knowledge, effects of styrene lined containers on shoot and root growth of several woody landscape species have not been evaluated in a scientific study.

An additional problem in container production is circling and matting of roots at the perimeter of the growth medium, which has a negative impact on plant growth and root regeneration (3). This condition is common with species characterized by vigorous growth (13) or plants held too long in containers (15). Root pruning by scarring the outer edge of the rootball is a common practice for correcting rootball-bound plants; however, significant root loss and, more importantly, the loss of root tips, is inevitable (14). Research has shown that coating the interior of containers with various copper-containing compounds inhibits root circling and results in a more fibrous root system (3, 4). Yet, benefits of copper coating on plant growth and transplant establishment have been inconsistent (13). Therefore, the objective of this study was to determine the influence of styrene-lined and copper-coated containers on production and landscape establishment of six woody landscape species.

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Materials and Methods

In April 1993, 64 uniform liners each of azalea, magnolia, holly, pittosporum, gardenia and oleander were selected for a 2 × 2 factorial experiment in Mobile, AL, that included all combinations of +/–styrene lining and +/–copper coating (+Cu or –Cu). Styrene, 2.6 mm (0.1 in) thick, was cut to cover the interior sidewall but not the bottom of 3.8 liter (#1) black containers. A spray of 100g $Cu(OH)_2$/liter (3.34 oz/qt) in a latex base (SpinOut, Griffin Corp., Valdosta, GA) was applied to the interior surface of the unlined containers or directly to the styrene with an electric paint sprayer (Wagner Spray Tech Corp., Minneapolis, MN). After the Cu product had dried on the styrene, the lining was inserted into the container (painted side facing substrate). Copper also was applied to the bottom interior of all containers receiving Cu treatment. Liners were potted in a pinebark:peat (3:1 by vol) medium amended per m^3 (per yd^3) with 8.3 kg (14 lb) 17N–3P–10K Osmocote (17–7–12, Scott Co., Marysville, OH), 0.9 kg (1.5 lb) Micromax (Scotts Co.), 3.6 kg (6 lb) dolomitic limestone, and 1.2 kg (2 lb) gypsum. Plants were spaced 0.6 m (2 ft) within rows and 0.9 m (3 ft) between rows in full sun on a white shell container bed with overhead irrigation [1-hr interval delivering 1.3 cm (0.5 in)] applied from 4 pm–5 pm daily from May through September and every other day before and after this period during the growing season. Containers were completely randomized within species with 16 single-plant replications. Percent surface root coverage along the rootball perimeter was visually estimated independently by two investigators and averaged in November 1993; this parameter was used as a non-destructive indicator of root growth. Magnolia height and trunk diameter, and the growth index [(height + width at the widest point + width 90° to first width) / 3] for the other species were recorded in July and November 1993.

Six replications per treatment of each species were repotted in December 1993 into 10.3 liter (3 gal) non-treated containers of the substrate previously described. Plant roots were left intact to determine treatment effects on root regeneration outside the original rootball. Plants were placed at the same location and spacing, and treatments were completely randomized within species. Height and trunk diameter of magnolia, and growth index for remaining species were recorded in May 1994. Percent surface root coverage (n = 6) was estimated by two investigators at that time, and three replications per treatment were harvested to determine dry weight of roots regenerated outside the original rootball. In November 1994, shoot growth measurements, percent surface root coverage determined by two people, and regenerated root dry weight were determined for the other three replications of each species.

In January 1994, six replications of azalea, gardenia, and holly were planted in a Marvyn loamy sand soil in Auburn, AL, to determine treatment effects on landscape establishment. Pittosporum and oleander were not planted due to cold hardiness concerns, while adequate space was a concern with magnolia. Prior to planting, fertilizer was broadcast applied at 448 kg 15N–0P–12.5K (15–0–15)/ha (400 lb/A) based on soil test recommendations. Plants were spaced 0.9 m (3 ft) within and between rows with a randomized complete block experimental design. In May 1994, 202 kg 34N–0P–0K (34–0–0)/ha (180 lb/acre) was broadcast over the test plot. Plants were irrigated with overhead impact nozzles [(1-hr duration delivering 1.3 cm (0.5 in)] at the first signs of wilting. Growth index was measured in November 1994, and plants were dug to determine dry weight of newly generated roots outside the original 3.8 liter (#1) rootball. All data were subjected to an analysis of variance, and treatment interactions were separated by orthogonal contrasts (12).

Table 1. Percent surface root coverage at the growth medium-container interface for 6 species grown in containers with or without copper treatment, November 1993 (n = 32).

Species	Copper[z] (%)	
	+	–
Azalea	2[y]	65
Gardenia	2	68
Oleander	2	64
Pittosporum	2	40
Holly	2	24
Magnolia	2	24

[z]Interior surfaces of containers were either coated with copper hydroxide (+) or not (–).

[y]All paired means significantly different at P ≤ 0.05. Cu × styrene interaction was not significant for any species; hence data were averaged over styrene treatment.

Results and Discussions

Plants grown in 3.8 liter (1 gal) containers in 1993. Cu × styrene interactions occurred only in azalea, and all other data are the means of main effects, i.e., data averaged over styrene or copper treatments. Surface root growth of all species measured at the end of the first growing season was effectively controlled by Cu-treated containers (Table 1), while styrene lining had no effect on surface root coverage (data not shown). Similar results in surface root control with Cu were reported by Arnold and Struve (3) and Beeson and Newton (4). Magnolia grown in +Cu containers were shorter than those grown in –Cu containers in July [44.0 cm (17 in), +Cu vs. 60.7 cm (24 in), –Cu] and November 1993 [77.8 cm (31 in), +Cu vs. 97.4 cm (38 in), –Cu] (P ≤ 0.05). Magnolia had less trunk diameter growth between July and November 1993 when grown in +Cu containers [0.6 cm (0.2 in)] than in –Cu containers [1.1 cm (0.4 in)] (P ≤ 0.05). Beeson and Newton (4) reported less trunk diameter growth of sweet gum and weeping willow, but more with loblolly pine and bald cypress when grown in +Cu containers versus –Cu contain-

Table 2. Change in growth index[z] of azalea in 3.8 liter (1 gal) containers coated with or without copper and lined with or without styrene, from July to November 1993 (n = 16).

Copper	Styrene lining (cm)	
	+	–
+	5.6aB[y]	11.6aA
–	7.5aA	7.1bA

[z]Growth index = (height + width at widest point + width 90° to first width) / 3.

[y]Mean separation within columns (lower case) and rows (upper case) by orthogonal contrasts, P ≤ 0.05.

Table 3. **Percent surface root coverage at the substrate-container interface for plants grown in containers coated (+) or not coated (–) with copper compound and repotted into 10.3 liter (3 gal) containers, November 1994[z] (n = 6).**

Species	1993 copper treatment[y] (% root coverage)	
	+	–
Azalea	5.0b	98.1a[x]
Gardenia	48.8b	53.7a
Pittosporum	3.8b	82.5a

[z]In December 1993, six replicate 3.8 liter (1 gal) container plants per treatment for each species were repotted into non-treated 10.3 liter (3 gal) containers. Three replications were sampled in November 1994, and data were averaged over plants grown in styrene-lined containers in 1993.

[y]Interior surface of 3.8 liter (1 gal) containers was either coated with copper hydroxide (+) or not (–).

[x]Mean separation within rows by ANOVA, P ≤ 0.05.

Table 4. **Percent surface root coverage at the substrate-container interface of 3 species previously grown in containers receiving copper or styrene treatments and repotted into 10.3 liter (3 gal) containers, November 1994[z].**

Species	1993 copper treatment	1993 styrene treatment (%)	
		+	–
Holly	+	8.8bA[y]	5.5bA
	–	85.0aA	67.5aB
Magnolia	+	22.0bA	10.3bA
	–	90.4aA	77.0aB
Oleander	+	7.5bA	12.5bA
	–	98.8aA	89.8aB

[z]Plants were grown during 1993 in containers treated with (+) or without $Cu(OH_2$ (–) and/or with (+) or without styrene lining (–). In December 1993, six replicate 3.8 liter (1 gal) container plants per treatment for all species were repotted into 10.3 liter (3 gal) containers; three replications were sampled in November 1994.

[y]Mean separation by species within column (lower case) and rows (upper case) by orthogonal contrasts, P ≤ 0.05.

ers. Copper had no effect on first year growth index of any species (data not shown). Styrene lining had no effect on plant height of magnolia or growth index of the remaining species during the first growing season (data not shown). Between July and November 1993, the change in growth index for azalea was affected by a Cu × styrene interaction (Table 2). The change in growth index for azaleas grown in the presence of Cu was smaller in styrene-lined containers compared to that in unlined containers; however, the change in growth index was similar in the absence of Cu, regardless of styrene treatment. When azaleas were grown in unlined containers, the change in growth index was greater in +Cu containers than in –Cu containers.

Plants grown in 10.3 liter (3 gal) containers during 1994. Percent surface root coverage (averaged over styrene) of gardenia in May 1994 was higher (P ≤ 0.05) for plants previously grown in –Cu containers (47%) than for plants previously grown in +Cu containers (25%). Gardenia also had more (P ≤ 0.05) surface root coverage (averaged over Cu treatment) in May 1994 when previously grown in styrene-lined containers (46%) than in unlined containers (26%); however, by November 1994 surface root coverage was nearly 100% and was similar for plants regardless of styrene treatment (data not shown). Copper or styrene had no effect on percent surface root coverage for any other species in May 1994 (data not shown), probably because of the lack of surface root development in all treatments. At the end of the growing season (November 1994), azalea, gardenia, and pittosporum had higher percent surface root coverages when previously grown in –Cu compared to +Cu containers (Table 3). Azalea and pittosporum previously grown in +Cu containers had few roots present along rootball surfaces. Percent surface root coverage of holly, oleander, and magnolia was affected by a Cu × styrene interaction in November 1994 (Table 4). Plants had less surface root coverage when previously grown in +Cu containers compared to –Cu containers, regardless of styrene treatment. In the absence of Cu, plants previously grown in styrene-lined containers had more surface root coverage than those previously grown in unlined containers; however, in the presence of Cu surface root coverage was not affected by styrene treatment. Similar results have been reported for red maple (6). Dry weights of newly generated roots outside the original rootball recorded in May and November 1994 were not affected by treatment except for holly in May. Holly previously grown in +Cu containers had a lower (P ≤ 0.05) root dry weight [1.4 g (0.05 oz)] than plants previously grown in –Cu containers [2.2 g (0.08 oz)]. A similar reduction in root dry weight from Cu application has been reported for other species (4).

Copper or styrene had no effect on trunk diameter or height of magnolia, or growth index of other species in May 1994 (data not shown). However, by November 1994, growth index of gardenia was less (P ≤ 0.05) for plants previously grown in +Cu containers [85.1 cm (33.5 in)] than for those previously grown in –Cu containers [97.0 cm (38.2 in)]. Furthermore, growth index of gardenia previously grown in styrene-lined containers was higher (P ≤ 0.05) [94.3 cm (37 in)] than that of plants previously grown in unlined containers [88.3 cm (35 in)]. Growth index of holly was affected by a Cu × styrene interaction (Table 5). Plants previously grown in containers treated with both Cu and styrene had a lower growth index than plants previously grown in the absence of Cu or styrene. Growth index for other treatment compari-

Table 5. **Growth index[z] of 'Blue Princess' holly grown in containers coated (+) or not coated (–) with copper compound and repotted into 10.3 liter (3 gal) containers, November 1994[y].**

1993 copper treatment	1993 styrene treatment (cm)	
	+	–
+	41.5bB[x]	49.5aA
–	53.0aA	50.0aA

[z]Growth index = (height + width at widest point + width 90° to first width) / 3.

[y]Plants were grown during 1993 in containers treated with (+) or without $Cu(OH_2)$ (–) and/or with (+) or without styrene lining (–). In December 1993, six replicate 3.8 liter (1 gal) container plants for all species were repotted into 10.3 liter (3 gal) containers; three replications were sampled in November 1994.

[x]Mean separation within columns (lower case) and rows (upper case) by orthogonal contrasts, P ≤ 0.05.

sons were similar (data not shown). When applied to a porous material such as styrene, $Cu(OH)_2$ formulated as SpinOut is wetted from both faces, causing more rapid breakdown of Cu and possibly Cu toxicity (Mark Crawford, Griffin Corp., personal communication).

Landscape establishment during 1994. Dry weight of newly regenerated roots outside the original rootball was not affected by treatment for either azalea or gardenia (data not shown). Root dry weight of holly was higher ($P \leq 0.05$) for plants previously grown in –Cu containers [6.5 g (0.2 oz)] than in +Cu containers [1.6 g (0.06 oz)], a response similar to that of holly repotted into 10.3 liter (3 gal) containers. These results differ from those of Arnold and Struve (3) who reported that Cu-coating of containers promoted more root regeneration of green ash and red oak after transplanting than did root pruning.

Azalea growth index, averaged over styrene treatment, was higher ($P \leq 0.05$) for plants previously grown in –Cu containers than for plants grown in +Cu containers [43.4 cm (17 in), –Cu vs. 38.5 cm (15 in), +Cu]. Growth index for gardenia or holly was not affected by treatment (data not shown).

Data from this study indicated that copper hydroxide provides an effective means of controlling circling roots. Plants grown in +Cu 3.8 liter (#1) containers and repotted into larger containers generally had less surface root coverage following repotting, and those transplanted into the ground had similar dry weights of roots generated outside the original rootball compared to –Cu containers. However, root dry weights of hollies were less 5 months after repotting or 11 months after planting in the ground when plants were previously grown in +Cu containers compared to –Cu containers. Also, no clear benefits in shoot growth were derived from the use of copper because of inconsistencies in growth index during production and after transplanting from the original container. In addition, shoot growth of magnolia was adversely affected by the use of copper hydroxide. Benefits in plant shoot growth and root generation from styrene lining of containers were not realized, with the exception of more surface root coverage of gardenia, oleander, holly, and magnolia, and a higher growth index of gardenia after repotting into 10.3 liter (3 gal) containers.

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