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Shoot and Root Responses of Eighteen Southeastern Woody Landscape Species Grown in Cupric Hydroxide-treated Containers[1]

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Abstract

Eighteen species of woody landscape trees commonly produced in the southeastern United States were grown in 3.8 l (#1) plastic containers painted on the inside with cupric hydroxide (7% w/w) and untreated control containers. Plants were evaluated for copper toxicity symptoms, root circling and growth. No copper toxicity symptoms were observed. Root circling and deflection were completely controlled except for bald cypress and laurel oak. Yet for these two species, root circling was less in the copper-treated than control containers. Root circling was not controlled in the bottom of square containers designed to prevent root circling for a subset of six species. For a few species, treatment effects on plant growth were seen, though most would be commercially insignificant.

Index words: root pruning, container production, root morphology

Species used in this study: red maple (*Acer rubrum* L.); Calamondin citrus (*Citrofortunella mitis* Blanco.); bald cypress (*Taxodium distichum* (L.) Rich.); Dahoon holly (*Ilex cassine* L.); Savannah holly (*Ilex opaca* Ait. 'Savannah'); East Palatka holly (*Ilex attenuata* 'East Palatka'); crape myrtle (*Lagerstroemia indica* L. 'Potomac'); wax privet (*Ligustrum japonicum* Thunb.); sweet gum (*Liquidambar styraciflua* L.); mahogany (*Swietenia mahogoni* Jacq.); laurel oak (*Quercus laurifolia* Michx.); live oak (*Quercus virginiana* Mill.); Jerusalem thorn (*Parkinsonia aculeata* L.); slash pine (*Pinus elliottii* Engelm.); loblolly pine (*Pinus taeda* L.); weeping willow (*Salix babylonica* L.); Tabebuia (*Tabebuia chrysotricha* L.); windmill palm (*Trachycarpus fortunei* H. Wendl.).

Significance to the Nursery Industry

This experiment expands the list of species for which cupric hydroxide-treated containers appear to inhibit root circling without detrimental effects on shoot growth or quality. It also expands the range of environmental conditions under which this paint mixture is effective. The hot, humid conditions and high media temperatures characteristic of the southeastern United States are perhaps at their extreme in Florida. However, these conditions did not cause excessive release of copper from the paint where growth inhibition or toxic symptoms developed in the shoots.

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Introduction

Since the 1960s, chemical root pruning with heavy metals has been shown to be a viable method to control root circling in containers (13) or root kinking in seedling flats (10). Yet only recently, with the work of Struve and his lab with cupric carbonate, $CuCO_3$, (1, 2, 3, 16) and the commercial development of a copper-based latex polymer, Spin out® (Griffin Co., Valdosta, GA), has this method caught the attention of the nursery industry.

Early studies of copper-treated containers focused on coniferous forest species. These included: *Picea glauca* (13), *Picea mariana* (13), *Pinus contorta* (4, 9), *Pinus echinata* (11), *Pinus palustris* (11), *Pinus ponderosa* (9), *Pinus resinosa* (13), *Pinus strobus* (11, 13), and *Pinus taeda* (11). Later, Burdett and Martin (5) tested cupric carbonate in latex paint on 10 coniferous species. Copper-treated containers were found to prevent root circling in all the above experiments with no adverse effects with cupric carbonate concentrations of 0.1 kg/l (12.3 oz/gal) or less.

Incorporation of copper-treated containers for production of woody landscape plants species began with the work of Furuta et al. (7) with *Eucalyptus viminalis* and *Jacaranda acutifolia*, but was largely ignored. Interest by the nursery industry began to develop with the work of Struve et al. (15) on production of red oak whips in copper-painted containers. Ticknor (17) later reported that copper-painted containers prevented root circling of *Forsythia* sp. This was followed by the report of successful prevention of root circling of container-grown green ash (1). Research in this area of copper-treated containers accumulated in the development of the Ohio Production System (16).

Interest in copper-treated containers has increased, not only due to control of root circling, but also by reported benefits after transplanting. Early on, Burdett *et al.* (6) reported that lodgepole pine and white spruce grew faster and established quicker when transplanted from copper-treated containers, compared to untreated containers. Copper treatment tended to produce a more natural root system compared to untreated plugs. Wenny *et al.* (18) found more lateral root growth in the upper portion of the root plug of ponderosa and western white pines and Douglas-fir when grown in copper-treated containers. Similar superior transplant effects were observed for red oak and green ash (2, 3).

The present study was undertaken to expand the number of woody ornamental species evaluated for growth in copper-treated containers and to determine the efficiency of copper-treated containers on root circling impedance under hot, humid conditions. A commercial preparation of a copper hydroxide paint mixture (Spin out®; Griffin Co., Valdosta, Ga.) as evaluated on 18 woody landscape species generally grown in the southeastern United States. Cupric hydroxide is more effective in root circling inhibition than cupric carbonate (16). Copper-treated containers were also compared with commercial square containers designed to prevent root circling (Rootmaker; Lacebark, Inc., Stillwater, OK) for several species.

Material and Methods

During the third week of March 1991, 20 rooted cuttings or potted seedlings of 18 woody landscape species were transplanted per treatment into 3.8 l (#1) round black plastic containers. Most liners were initiating active growth at transplanting. Species included: *Acer rubrum* L. (red maple), *Citrofortunella mitis* Blanco. (calamondin citrus), *Taxodium distichum* (L.) Rich. (bald cypress), *Ilex cassine* L. (dahoon holly), *Ilex opaca* Ait. 'Savannah' (Savannah holly), *Ilex attenuata* 'East Palatka' (East Palatka holly), *Lagerstroemia indica* L. 'Potomac' (crape myrtle), *Ligustrum japonicum* Thunb. (wax privet), *Liquidambar styraciflua* L. (sweet gum), *Swietenia mahagoni* Jacq. (mahogany), *Quercus laurifolia* Michx. (laurel oak), *Quercus virginiana* Mill. (live oak), *Parkinsonia aculeata* L. (Jerusalem thorn), *Pinus elliottii* Engelm. (slash pine), *Pinus taeda* L. (loblolly pine), *Salix babylonica* L. (weeping willow), *Tabebuia chrysotricha* L. (Tabebuia), and *Trachycarpus fortunei* H. Wendl. (windmill palm). Treatments consisted of containers as manufactured (control) or containers painted on interior surfaces with 7% (w/w) cupric hydroxide in a latex carrier (Spin out®). Twenty additional liners of ligustrum, live oak, loblolly pine, Savannah holly, weeping willow, and windmill palm were transplanted into 16.5 cm (6.5 in) square containers. Medium used was a pine bark fine:Florida peat moss:coarse sand mixture (3:1:1 by vol) amended with Micromax micronutrients at a rate of 0.87 kg/m^3 (1.5 lb/yd^3) of media. Root and shoot dry weights of five additional representative liners of each species were measured at transplanting.

Plants were grown in full sun and irrigated daily with 1.0 cm (0.4 in) of water during the early morning. On April 9, 1991, all containers received 12 g (0.4 oz) of Osmocote 14N-6.1P-7.7K (14-14-14). Trees were pruned and staked where necessary to maintain a central leader. Weeds were removed by hand when required.

Initial and final heights and stem diameters (at 3 cm [1 in]) were recorded for all plants. During growth, plant height was measured monthly on the same subset of 10 plants per treatment per species. For species such as ligustrum, the longest branch was extended vertically for maximum height. Final measurements were made when root systems of control plants of each species had developed such that in commercial operations they would be repotted to larger containers. Thus, the length of the experiment ranged from 4 months for weeping willows to 7 months for about half of the remaining species. At the repotting stage, 5 plants of each species and treatment were selected at random, the exteriors of the root ball examined visually for circling roots, and root and shoot dry weights determined.

Eight plants of each treatment of calamondin, crape myrtle, bald cypress, live oak, loblolly pine, red maple, sweet gum, tabebuia and weeping willow were repotted when required into 11.4 l (#3) round black plastic containers. Plants produced in copper-treated containers were repotted into copper-treated containers, control and square container-produced plants were transplanted into untreated containers. Final height and stem diameter of the repotted plants were measured in January 1992.

Height and caliper growth for each species were subjected to analysis of variance using SAS (12) using a randomized design with single plant replications. Where appropriate, means were separated using Fisher's Protected LSD (α = 0.05). Height growth rates were analyzed by regression analysis. Differences in regression lines between treatments within a species were tested by comparisons of the slopes of the regression lines (14).

Results and Discussion

Throughout the study, no copper toxicity leaf symptoms nor other shoot abnormalities were observed for any species. Root circling was impeded in the copper-treated containers for all species, except bald cypress and laurel oak. There were very few root deflections, none in most species. Those roots that were deflected, of the rootballs examined, were not longer than 1.5 cm (0.5 in). For both laurel oak and bald cypress, root circling was observed in the bottom of the container for all plants examined. Root circling was more pronounced for bald cypress than laurel oak. However, for both species, the degree of root circling was less in the copper-treated containers than the controls. Upon washing the medium from the rootballs of these two species, 1 to 4 major lightly branched roots grew directly to the bottom. Root circling, both on the sides and on the bottom, was observed in every control pot examined. Root circling was also observed in the bottom of the square containers, and occasionally on the sides.

Most species maintained similar height growth rates among treatment (data not shown). However, when grown in copper-treated containers, mahogany, East Palatka holly and Savannah holly had greater height growth rates than untreated controls (Table 1). For Savannah holly, there were no differences in height growth rates between copper-treated and square containers or square and control containers. Weeping willows grown in control containers maintained similar growth rates to copper-treated and square containers. However, plants in copper-treated containers grew at significantly ($\alpha = 0.05$) slower rates than those in square containers.

In 5 species, final height in #1 containers was significantly affected by treatment (Table 2). Of these, loblolly pine and East Palatka holly produced greater growth in the copper-treated containers than in the control or square containers. This agrees with increased height of lodgepole and ponderosa pine seedlings when grown in copper-treated containers (9). In contrast, red maple, sweet gum and weeping willow achieved greater heights in the untreated and square containers. Final height was unaffected by treatment (results not shown) for the other 13 species.

Final stem diameter was similarly unresponsive to container treatment. Only bald cypress stems obtained larger final diameters in the copper-treated containers, whereas the opposite was true for sweet gum (Table 2). Loblolly pine and windmill palm grown in the square containers had smaller final stem diameters than the other two treatments. However, for weeping willow, final stem diameter was greatest in the square containers and least in the copper-treated containers.

Plants selected for the final dry weights were representative of each treatment. Of the selected plants for dry weight, height was only significant in weeping willows and was comparable to the treatment means. In contrast to treatment means, height differences were not found in plants selected for dry weights for East Palatka holly, loblolly pine, red maple or sweet gum. Final stem diameters of selected plants was significantly different only in windmill palms compared to five species based on treatment means.

For most species, root dry weights were the same among container treatments at transplanting from #1 containers (data not shown). Similar root dry weights among treatments were found for other species (2, 5). Of the 5 species where significant ($\alpha = 0.05$) effects were observed, copper-treated containers increased root dry weight only in crape myrtle (Table 3). For bald cypress and weeping willow grown in copper-treated containers root dry weight was reduced. Root dry weights were nearly double in the control containers of Dahoon holly compared to copper-treated containers.

Shoot dry weight and total plant dry weight in #1 containers were similar among treatments for all species except weeping willow. Shoot dry weight was less in the copper-treated containers (35.7 g; 1.2 oz) than either square (53.0 g; 1.9 oz) or control (54.3 g; 1.9 oz) treatments. Total dry weight was similar in control (73.4 g; 2.6 oz) and square

Table 1. Plant height growth rates during production in 3.8 liter (#1) containers for species where differences among treatments were significant ($\alpha = 0.05$).

Species	Height growth rate (cm/day)		
	Control	Copper	Square
mahogany	0.43 b[z,y]	0.57 a	—
East Palatka holly	0.66 b	0.71 a	—
Savannah holly	0.60 b	0.73 a	0.68 ab
weeping willow	1.50 ab	1.35 b	1.70 a

[z]Mean separation by Fisher's Protected LSD. Means with different letters are significantly different ($\alpha = 0.05$) within a species.

[y]Means are the average of 10 plants per treatment.

Table 2. Plant height and caliper at transplanting from 3.8 liter (#1) containers for species where differences among treatments were significant ($\alpha = 0.05$).

Species	Final height (cm)		
	Control	Copper	Square
East Palatka holly	125.7 b[z,y]	137.0 a	—
loblolly pine	80.8 b	87.0 a	74.0 c
red maple	120.7 a	102.5 b	—
sweet gum	106.1 a	93.5 b	—
weeping willow	191.1 a	174.3 b	191.7 a
	Final stem diameter (cm)		
bald cypress	1.236 b	1.323 a	—
loblolly pine	1.309 a	1.268 a	1.082 b
sweet gum	1.315 a	1.233 b	—
windmill palm	2.967 a	2.883 a	2.291 b
weeping willow	0.958 b	0.838 c	1.010 a

[z]Mean separation by Fisher's Protected LSD. Means with different letters are significantly different ($\alpha = 0.05$) within a species.

[y]Means are the average of 20 plants per treatment.

Table 3. Root dry weights and root:shoot ratios for species grown in #1 containers where significant differences ($\alpha = 0.05$) among treatments within a species were calculated. Measurements occurred when control plants were at the stage requiring repotting to larger containers.

Species	Root dry weight (g)		
	Control	Copper	Square
bald cypress	14.86 a[z,y]	12.70 b	—
crape myrtle	16.50 b	22.50 a	—
dahoon holly	23.30 a	12.00 b	—
weeping willow	19.00 a	11.67 b	17.50 a
	Root:shoot ratio		
dahoon holly	0.28 a	0.18 b	—
Jerusalem thorn	0.30 b	0.35 a	—
loblolly pine	0.24 a	0.17 c	0.21 b

[z]Mean separation by Fisher's Protected LSD. Means with different letters are significantly different ($\alpha = 0.05$) within a species.

[g]Means are based on 5 replications per treatment.

containers (70.5 g; 2.5 oz) and greater than copper-treated (47.4 g; 1.7 oz) containers.

Root:shoot ratios were modified with the copper treatment in only 3 species (Table 3). For both Dahoon holly and loblolly pine, the copper treatment decreased the root:shoot ratio whereas for Jerusalem thorn, the root:shoot ratio was increased. Similar declines in the root:shoot ratio of copper-treated containers were found for lodgepole pine (4), white spruce (5), Scott pine (5) and western hemlock (5). However, for other conifer species, copper-treated containers did not affect the root:shoot ratio (5). Root:shoot ratios were also reduced in green ash and red oak grown in copper-treated containers (2). For both green ash and red oak, this decrease in the root:shoot ratio was more due to increased shoot growth than reduced root growth (2). According to Harris (8), such reductions in the root:shoot ratio are almost always in response to more favorable growing conditions.

In January 1992, only calamondin citrus grown in the copper-treated containers (75.8 cm) were taller than the controls (62.0 cm). This continued a trend from repotting where plants in the copper-treated containers (69.5 cm) were taller than the controls (55.6 cm). Sweetgum in untreated containers were taller at transplanting as were copper-treated bald cypress. By January, there were no differences among treatments for any species except calamondin citrus. Stem diameters of loblolly pine were larger in copper-treated containers (2.0 cm; 0.79 in) and square containers (1.9 cm; 0.75 in) in January than trees grown continuously in untreated containers (1.6 cm; 0.63 in).

The use of cupric hydroxide to inhibit root circling was successful for most of the species tested in this study. Root circling was completely arrested with no visual damage to the shoots. With a few exceptions, plants produced in the copper-treated containers were identical in root and shoot mass and canopy size to those produced in normal round containers, except for the absence of circling roots. Though there were some statistically significant differences in plant height and caliper, all are most likely commercially insignificant. Square containers suppressed circling roots on the sides, but circling roots were still pronounced at the container bottom. The two species in which root circling was not completely inhibited, laurel oak and bald cypress, are native to wet sites. The dominant, deep root systems observed for these two species may have developed in response to the low water holding capacity of the potting medium used. Even with daily irrigation, most of the moisture would have resided in the bottom of the container. A medium with a greater water holding capacity may have elicited a better inhibition of root circling in these two species.

Late summer and early fall growth of the upcanned plants tended obscure any growth differences that developed while in 3.8 l (#1) containers. Canopy heights and stem calipers were similar among all container treatments when measured in January.

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