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Copper Hydroxide Affects Root Distribution of *Ilex cassine* in Plastic Containers

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Summary. The root : shoot ratio for *Ilex cassine* L. grown 7 months in copper-treated containers was less than in nontreated containers. There was less dry weight for roots <5 mm in diameter in copper-treated containers than in nontreated containers in the outer 1 cm of the rootball. Dry weight of roots >5 mm in diameter within the rootball were not affected by copper hydroxide treatment. Coating the interior of a plastic container with cupric hydroxide eliminated coarse roots (> 5 mm in diameter) and significantly reduced fine root weight from the outer 1 cm of the rootball. Fine roots inside the rootball did not replace fine roots lacking in the outer 1 cm.

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Nussbaum (1969) showed that seedlings grown in flats treated with copper naphthenate had more secondary roots per unit length of primary root and a more fibrous root system compared to seedlings grown in nontreated flats. In another study, where no data were presented, the author stated that the roots of cork oak *(Quercus suber* L.) that were mechanically pinched were not as well-developed as those of trees grown in copper-treated flats. This response was supported 20 years later by Arnold and Struve (1989) on 1-year-old seedlings of green ash *(Fraxinus pennsylvanica* Marsh.). The same authors concluded that the rootballs in containers painted on the inside with copper carbonate ($CuCO_3$) were more densely branched than those without copper treatment. An increased root length (Wenny and Woollen, 1989) and increased number of white root tips within the rootball (Arnold and Young, 199 1) have been reported for plants grown in copper-treated containers.

McDonald et al. (1984b) found an increase in the number of short roots of container-grown lodgepole pine *(Pinus contorta* Dougl.) but not of ponderosa pine *(Pinus ponderosa* Laws.) with copper-treated containers. Root dry weight was not affected by the copper treatment in their study. Roots may be distributed more evenly along the sides of the copper-treated container, with less root density at the bottom compared to a nontreated container (Wenny and Woollen, 1989). This distribution pattern may enhance survival and growth after planting (Burdett et al., 1983). There has been no consistent effect of copper treatment on root : shoot dry weight ratio. Many studies showed no change in the ratio (Beeson and Newton, 1992; McDonald et al., 1984a; Ruehle, 1985), whereas others reported a decrease (Arnold and Struve, 1989; Beeson and Newton, 1992; McDonald et al., 1984b) with copper treatment. The effect of copper on root : shoot ratio appears to be species-specific. However, there is a consistent elimination of, or reduction in, root circling on trees grown in copper-treated containers (Arnold and Young, 199 1; Beeson and Newton, 1992), and fewer roots are deflected downward along the container wall (McDonald et al., 1984b; Ruehle, 1985). This study was designed to determine the effect of copper hydroxide application to the inside of the container on root partitioning and root : shoot ratio.

To compare the root system in a conventional container with one from a container coated with copper hydroxide, dahoon holly (*Ilex cassine* L.) propagated by cuttings was planted in 3.8-liter (#l) cylindrical, black plastic containers containing a 3 pine bark: 1 Florida peatmoss :1 sand (by volume) medium in Mar. 1991. Twenty plants were potted into nontreated containers, and an equal number was potted into containers treated on the interior surface with a 100-g $CU(OH)_2$/liter exterior latex paint base (SpinOut, Griffin Corp., Valdosta, Ga). Plants were grown in full sun on a gravel bed in a randomized block design with a single plant replicate of each treatment per block. Osmocote (12 g of 14N-6. lP–7.7K The Scotts Co., Marysville, Ohio) was applied to the medium surface at planting, and plants received 1.5 cm water daily. The Osmocote was reapplied at the same rate in mid-July.

At the conclusion of the study in Oct. 1991, the outer 1 cm of all rootballs was sliced away from the root system with a serrated knife. Medium from the removed portion and from the remaining rootball was hand-washed and removed from the roots. Roots were separated into four diameter classes:0-2 mm, >2–5 mm, >5–10 mm, and >10 mm. The trunk was severed from the roots level with the top of the medium. After drying for 2 weeks at 70C, weights of roots and shoots were recorded.

Shoot weight and total root weight were not different due to treatment (Table 1). However, reduction in root weight in copper-treated containers occurred for roots with a diameter <5 mm in the outer 1 cm of the rootball. Root: shoot dry weight ratio

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Table 1. *Root and shoot weight of* Ilex cassine *grown for 7 months in copper-treated and nontreated 3.8-liter containers.*

Treatment	Shoot dry wt (g)	Total root dry wt (g)	Root : shoot ratio	Root diam class (mm) 0–2 Outer 1 cm	0–2 Within rootball[y]	>2–5 Outer 1 cm	>2–5 Within rootball	>5–10 Outer 1 cm	>5–10 Within rootball	>10 Outer 1 cm	>10 Within rootball
Nontreated	74.5	20.2	0.27*	4.4*	6.1	0.56*	1.5	0	0.24	0	7.4
$CuOH_2$	73.7	16.8	0.22	2.2	5.8	0.02	1.4	0	0.16	0	7.2

[z]*Root dry weight in the outer 1 cm of the rootball.*
[y]*Root dry weight of the entire rootball excluding those in the outer 1 cm.*
**Significantly greater than copper-treated containers by Fisher's protected* LSD (α = 0.05)

in copper-treated containers was less than in nontreated containers, as Arnold and Struve (**1989)** showed.

Forty-one percent of the total weight of roots <2 mm in diameter in nontreated containers was in the outer 1 cm of the rootball (Table 1). In contrast, only 27% of total fine root weight was in the outer 1 cm of the rootball when plants were grown in copper-treated containers. Copper treatment also reduced from 27% to 1.4%the percentage oftotal root weight in the >2–5 mm root diameter class in the outer 1 cm of the rootball.

Many circling roots were evident on rootballs growing in the nontreated containers. In contrast, there were few roots visible on the periphery of the rootballs from copper-treated containers. In addition, coating the interior of the container with copper hydroxide nearly eliminated coarse roots (those with a diameter >2 mm) and significantly reduced fine roots (those with a diameter <2 mm) from the outer 1 cm of the rootball (Table 1). Also, fine roots lacking in the periphery 1 cm of the rootballs from copper-treated containers were not replaced by fine roots inside the root ball. In other words, copper treatment did not stimulate or increase fine root weight inside the rootball. This reduced the weight of roots <5 mm in diameter in the total rootball of copper-treated containers. This finding contrasts the observations of Arnold and Struve (1989), who found that red oak (*Quercus rubra* L.) and green ash *(Fraxinus pennsylvanica)* root systems were distributed more evenly in copper-treated containers than in nontreated containers.

Elimination of circling or downward-deflected roots in the container may increase the stability and growth rate of planted trees once they are established (Wenny et al., 1988), and root systems could develop without the potential girdling effects ofcircling roots. Improved root system form could increase the vigor and life expectancy of planted trees. However, lack of roots at the periphery of the rootballmight increase water stress for a short time following planting until roots grow into landscape backfill soil because few roots are in intimate contact with the backfill soil (E .F. Gilman, unpublished data). Despite this potential, Struve (1994) found that two of four tree species planted from nontreated or copper-treated containers made greater trunk caliper growth after planting in a clay or silty loam soil. More study is needed to determine the effect of post-planting water stress on root growth from containerized trees.

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