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Cupric Hydroxide-Treated Containers Affect Growth and Flowering of Annual and Perennial Bedding Plants[1]

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Abstract

Four annual cultivars, *Celosia cristata* L. 'Castle Pink', *Impatiens Wallerana* Hook. 'Super Elfin Red', *Pelargonium* × *domesticum* L.H. Bailey 'Ringo Scarlet' and *Tagetes patula* L. 'Discovery Yellow', and two perennial cultivars, *Chrysanthemum* × *superbum* Bergmans ex J. Ingram 'Alaska' and *Coreopsis lanceolata* L. 'Early Sunrise', of bedding plants were grown in a greenhouse for about 40 days in 0.3–1 (3.5 in.) containers treated with 25, 50, or 100 g $Cu(OH)_2$/1 (approximately 1.8, 3.5, and 7% (wt/wt), respectively) formulated as Spin Out™ or in non-treated containers. Following greenhouse production and a 4-day acclimation period in a shade-house, the plants were transplanted to a field plot. Cupric hydroxide concentrations that resulted in practical levels of control and/or elimination of root deformation (circled, kinked, and matted roots at container wall-media interfaces) were species dependent, varying between 25 and 100 g/l (1.8 and 7%). During greenhouse production $Cu(OH)_2$ treatments of 50 or 100 g/l (3.5 or 7%) increased the vegetative growth of *C. cristata* and increased the number of flowers on *I. Wallerana* compared to plants in non-treated containers. After field planting, *P.* × *domesticum* grown in 50 or 100 g $Cu(OH)_2$/l (3.5 or 7%) and *I. Wallerana* in 100 g $Cu(OH)_2$/l treated containers had increased vegetative growth. The flowering potential of *I. Wallerana* was increased by the 50 g $Cu(OH)_2$/l (3.5%) treatment following field planting.

Index words: Greenhouse production, postharvest quality, root morphology, transplant establishment, flowering potential

Species used in this study: Cockscomb 'Castle Pink' (*Celosia cristata* L. 'Castle Pink'); Coreopsis 'Early Sunrise' (*Coreopsis lanceolata* L. 'Early Sunrise'); Impatiens 'Super Elfin Red' (*Impatiens Wallerana* Hook. f. 'Super Elfin Red'); Geranium 'Ringo Scarlet' (*Pelargonium* × *domesticum* L. 'Ringo Scarlet'); Marigold 'Discovery Yellow' (*Tagetes patula* L. 'Discovery Yellow'); Chrysanthemum 'Alaska' (*Chrysanthemum* × *superbum* Bergmans ex. J. Ingram 'Alaska')

Significance to the Nursery Industry

Copper containing latex compounds applied to the interior surfaces of containers have been shown to reduce woody plant root deformation and increase fibrosity (branching) of roots (1, 2, 4, 5, 7, 11) during production. Copper treated-containers have increased the vegetative growth (1, 2, 5) and flowering (15) during container production and aided in transplant establishment of some species (4). Results of this study indicate that similar root growth control, increased vegetative growth and increased flowering can occur with certain herbaceous bedding plants, but the responses are species and concentration dependent. Additional cultivar testing is needed under varied environmental conditions and production systems before making specific recommendations. However, practical levels of reduction in root deformation occurred with concentrations of 25 or 50 g $Cu(OH)_2$/1 (1.8 or 3.5%) for most species tested.

Introduction

Container produced bedding plants are subject to the same root deformation as woody plants. Root deformation in woody plants can adversely affect plant establishment fol-

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lowing transplanting to the field (12). Recommended root pruning practices to correct root deformations can reduce growth (3, 4, 5). The application of copper compounds to interior container surfaces has been shown to effectively reduce root deformation in woody species (1, 2, 4, 5, 7, 11) and five tropical greenhouse crop species (8) during container production.

Although less studied, similar establishment problems are likely to occur in bedding plants. For instance, root restriction during container production of *Tagetes erecta* L. 'Janie' resulted in adverse long-term effects on landscape performance after transplanting (10). The effects of utilizing copper compounds for controlling root growth of bedding plants during container production and following transplanting are unknown.

The objectives of this experiment were: 1) to determine if $Cu(OH)_2$ (formulated as Spin Out™) effectively controls the formation of matted roots at the interior surfaces of containers on six commercially important bedding plants, and 2) to determine if bedding plants grown in $Cu(OH)_2$-treated containers establish better than plants grown in nontreated containers.

Materials and Methods

While commercial production schedules for growing bedding plant plugs to a salable size varies with the species, environmental conditions, and final size desired (6), and the duration of "storage" on sales lots varies with consumer demand, we assumed a greenhouse production cycle of about 6 weeks followed by a 4-day shade acclimation to simulate "storage" on the sales lot. Total time from transplanting of plugs to field planting was 45 to 47 days, 41 to 43 days in the greenhouse plus 4 days in outdoor shade acclimation.

On March 19 to 21, 1991, plugs of cultivars of six bedding plants, *Celosia cristata* 'Castle Pink', *Impatiens Wallerana* 'Super Elfin Red', *Pelargonium* × *domesticum* 'Ringo Scarlet', and *Tagetes patula* 'Discovery Yellow', *Chrysanthemum* × *superbum* 'Alaska' and *Coreopsis lanceolata* 'Early Sunrise' were transplanted from 112-count Sparkplug trays into Pro-Mix BX media in 0.3–1, 3.5 in. diameter, square plastic pots. *P.* × *domesticum, C.* × *superbum*, and *C. lanceolata* were thinned to one individual per pot, *T. patula* and *I. Wallerana* to two per pot, and *C. cristata* to four per pot. Prior to planting, the interior surfaces of pots were spray painted with Spin Out™ (Griffin Corp., Valdosta, GA), a liquid latex-$Cu(OH)_2$ compound, containing 25, 50, or 100 g $Cu(OH)_2$/l (approximately 1.8, 3.5, and 7%, respectively) or left untreated as a control. Forty pots were used for each species and $Cu(OH)_2$ treatment combination.

Pots were placed in a greenhouse on capillary matting. Each species was arranged in a randomized complete block design with four blocks of 10 pots of each $Cu(OH)_2$ treatment. Standard commercial greenhouse production schedules for temperatures (16 C night (61°F)), fertilizer (300 mg N/l (300 ppm) weekly from a 15N-6.5P-12.5K (15-15-15) water-soluble fertilizer) and pest control were followed. No plant growth regulators were used. Natural day lengths were used throughout the experiment.

On April 29, 1991, one block of each species and treatment combination was harvested to determine root and shoot growth and to assess the effectiveness of $Cu(OH)_2$ treatments in reducing root deformation. Chemical control of root growth was rated on a 0 to 2 scale; 0 indicating little or no restriction on root elongation, 1 indicating that roots had elongated less than 1 cm after contacting treated container surfaces, and 2 indicating no discernible elongation following contact with treated container surfaces. Flower number (any visible non-senescent flower or bud), shoot height, narrowest and widest plant width perpendicular to its vertical axis, shoot and root (after being washed free of the media) fresh and dry (10 days at 70 C (158°F)) weights were recorded. A shoot index (cm^3) was calculated by multiplying the shoot height × narrowest width × widest width. The remaining plants were moved to an outdoor shade house (55% light exclusion) to simulate sales area "storage."

On May 2, 1991, after four days of acclimation, the plants were transplanted to a non-irrigated silty loam field plot on 0.6 m (2 ft) within row and 2.0 m (6.6 ft) between row spacings. A randomized complete block with three blocks of ten pots/species and treatments was used. Plants were watered once at transplanting. A granular topdress fertilizer (10N-4.4P-8.3K (10-10-10)) was broadcast at 100 kg/ha (89 lb/acre) 10 days after transplanting. Thirty-five days after transplanting (June 7, 1991) the plants were harvested to determine flower number, shoot height, narrowest and widest plant width, shoot dry weights and shoot index. Greenhouse and field data for each species were analyzod separately using analysis of variance and polynomial regression (14). Data from the block of plants destructively harvested at the end of the greenhouse phase was analyzed as a completely randomized design.

Results and Discussion

Greenhouse Studies By the end of the greenhouse stage, all plants were well rooted with controls exhibiting a matting of roots at the bottom of containers and numerous deflected roots along the sides of the containers. The extent of reduction in root deformation and the concentration of $Cu(OH)_2$ which resulted in a given level of reduction varied among species (Fig. 1A). Circled, kinked, and matted root formation (Fig. 1A, Table 1) was almost completely eliminated on *P.* × *domesticum* at 25 g $Cu(OH)_2$/l (1.8%) on *C. cristata* at 50 g $Cu(OH)_2$/l (3.5%), and on *I. Wallerana* and *C. lanceolata* at 100 g $Cu(OH)_2$/l (7%). Cupric hydroxide treatments substantially reduced circled, kinked, and matted roots at the container wall-media interface (Fig. 1A) with *T. patula* and *C.* × *superbum*, but complete elimination of root deflection was not achieved even at 100 g $Cu(OH)_2$/l (7%). From a practical perspective root deflection ratings of 1 to 2 indicated sufficient inhibition of root elongation to prevent matting and spiraling of the roots. This level of control was achieved at 25 or 50 g $Cu(OH)_2$/l (1.8 or 3.5%) on all species, except perhaps *C.* × *superbum* (Fig. 1A). In general, root systems of plants grown in $Cu(OH)_2$-treated containers appeared more fibrous than those from non-treated containers, with numerous higher order lateral roots originating for several cm behind the inhibited root tips.

Concentrations of $Cu(OH)_2$ that effectively controlled root deformation on the herbaceous species in this study were lower than those for woody plants grown in $Cu(OH)_2$- or $CuCO_3$-treated containers (1, 2, 4, 11, 13, 16, 17). While no foliar signs of copper toxicity were observed, the roots that contacted treated surfaces exhibited typical copper tox-

Table 1. **Polynomial regression equations for Fig. 1. In the following equations C = g $Cu(OH)_2$/l applied to interior container surfaces.[z] Regression equations are based on 10 observations per species and $Cu(OH)_2$ treatment combination.**

Graph	Species	Characteristic	Intercept	C	C^2	C^3	R^2
A	Impatiens	Root rating	5.90×10^{-2}	5.07×10^{-2}	-3.15×10^{-4}		0.82
			1.36×10^{-1}	7.14×10^{-3}	6.78×10^{-5}		
A	Coreopsis	Root rating	5.20×10^{-2}	3.67×10^{-2}	-1.74×10^{-4}		0.88
			8.10×10^{-2}	4.22×10^{-3}	4.02×10^{-5}		
A	Celosia	Root rating	5.50×10^{-2}	6.29×10^{-2}	-4.36×10^{-4}		0.90
			8.43×10^{-2}	4.28×10^{-3}	3.97×10^{-5}		
A	Chrysanthemum	Root rating	2.45×10^{-2}	2.83×10^{-2}	-1.56×10^{-4}		0.68
			1.03×10^{-1}	5.23×10^{-3}	4.85×10^{-5}		
A	Pelargonium	Root rating	1.94×10^{-1}	6.85×10^{-2}	-5.09×10^{-4}		0.88
			1.01×10^{-1}	5.02×10^{-2}	4.57×10^{-5}		
A	Tagetes	Root rating	6.93×10^{-2}	4.51×10^{-2}	-2.90×10^{-4}		0.71
			1.29×10^{-1}	6.70×10^{-3}	6.21×10^{-5}		
B	Celosia	Plant Index	2.75×10^{3}	-2.86×10^{1}	1.69×10^{0}	-1.30×10^{-2}	0.25
		(cm^3)	2.83×10^{2}	3.86×10^{1}	1.16×10^{0}	8.06×10^{-3}	0.45
C	Chrysanthemum	Root:shoot dry	1.16×10^{0}	-1.90×10^{-2}	1.65×10^{-4}		
		weight (g/g)	6.85×10^{-2}	3.48×10^{-3}	3.23×10^{-5}		
D	Impatiens	Flower number	3.81×10^{1}	-3.36×10^{0}	1.35×10^{-1}	-9.88×10^{-4}	0.45
		per container	1.06×10^{1}	1.43×10^{0}	4.37×10^{-2}	3.06×10^{-4}	

[z]Regression equations are presented only for significant main effects and significant regression equations ($p < 0.05$). Plots of the equations are presented in Fig. 1

[y]Coefficient.

[x]Standard error of coefficient.

icity symptoms, i.e. reduced elongation, thickened, swollen or darkened root tips. Studies with woody plants (2, 9) have shown that inhibition of root growth by copper-treated containers is via a mild copper toxicity confined to the apical few cm of the root tips.

With the exception of *C. cristata*, $Cu(OH)_2$ treatments had little effect on vegetative shoot growth characteristics during the greenhouse studies. Although height growth of *C.* × *superbum* and *C. cristata*, and the number of flowers on *C. cristata*, were statistically increased ($p \leq 0.05$) with increased $Cu(OH)_2$ concentration, the magnitude of these increases were not of commercial significance (data not presented). Height, shoot, root, and total plant dry weight measures of *C. cristata* all responded similarly to the plant index (Fig. 1B, Table 1). With *C. cristata* moderate $Cu(OH)_2$ levels (50 g/l, 3.5%) substantially increased vegetative growth, but optimal levels may have been surpassed at high $Cu(OH)_2$ concentrations (100 g/l, 7%).

The root:shoot dry weight ratio of *C.* × *superbum* was reduced when plants were grown in $Cu(OH)_2$-treated containers (Fig. 1C, Table 1). Similar results in which shoot growth of copper-treated plants increased at an equal or greater rate than non-treated plants while the root:shoot ratio was reduced has been reported for some tree species (4, 13) and for *Asparagus setaceus* (Kunth) Jessop (8). No significant adverse responses in vegetative growth during the greenhouse phase were found with $Cu(OH)_2$ concentrations up to 100 g/l (7%) for any of the species tested.

Cupric hydroxide treatments of 50 and 100 g/l (3.5 and 7%) improved the flowering potential of *I. Wallerana* (Fig. 1D, Table 1). Why these treatments induced greater flowering of *I. Wallerana* is unknown. Improved flowering of *Forsythia* Vahl. in response to copper-treated containers has been reported (15). Increases in the number of flower spikes on *Acalypha hispida* Burm. plants grown in $Cu(OH)_2$-treated containers, 100 g/liter (7%), compared to plants in non-treated containers corresponded in time with the development of a pot-bound condition that made it difficult to maintain plants in a turgid condition with hand watering (8). An increase in root system fibrosity, greater numbers and/or dry weight of lateral roots (2, 4) and non-suberized root tips (5), in response to copper-treated containers has been reported. Perhaps the more fibrous root systems of copper-treated plants are better able to utilize available water in the pots. Increased nitrogen content of plants grown in $Cu(OH)_2$-treated vs. those in non-treated containers has been observed for *Acer rubrum* L. and *Quercus acutissima* Carruth. (author's unpublished data) suggesting that improved mineral nutrition might also be involved in bedding plant responses to $Cu(OH)_2$-treated containers.

Field Studies. Statistical, but not commercially important, increases were observed for height, plant index, and shoot dry weight of *P.* × *domesticum* with 50 or 100 g $Cu(OH)_2$/l (3.5 or 7%) and the plant index of *C. cristata* with 25 and 100 g $Cu(OH)_2$/l (1.8 and 7%) treatments in the field (data not presented). Substantial increases in the shoot dry weight (21.39 g or 20.27 g vs. 16.25 g) of *P.* × *domesticum* at the 50 or 100 g $Cu(OH)_2$/l (3.5 or 7%) and the plant index (26637 cm^3 vs. 18234 cm^3) of *I. Wallerana* at 100 g $Cu(OH)_2$/l (7%) treatments were found relative to control plants in the field. Increases in vegetative shoot growth of woody plants grown in copper-treated containers following transplanting to larger containers and/or the field have been reported, but the response varied among species (4, 5). As in the greenhouse, flowering of *I. Wallerana* in the field was increased for plants grown in the 50 g $Cu(OH)_2$/l (3.5%) treated containers compared to the control (217 vs. 165 flowers/container). Field data on *C. lanceolata* was eliminated from the analysis due to damage to numerous plants by rabbit (*Sylvilagus sp.*) predation. The other species were not affected by rabbit predation.

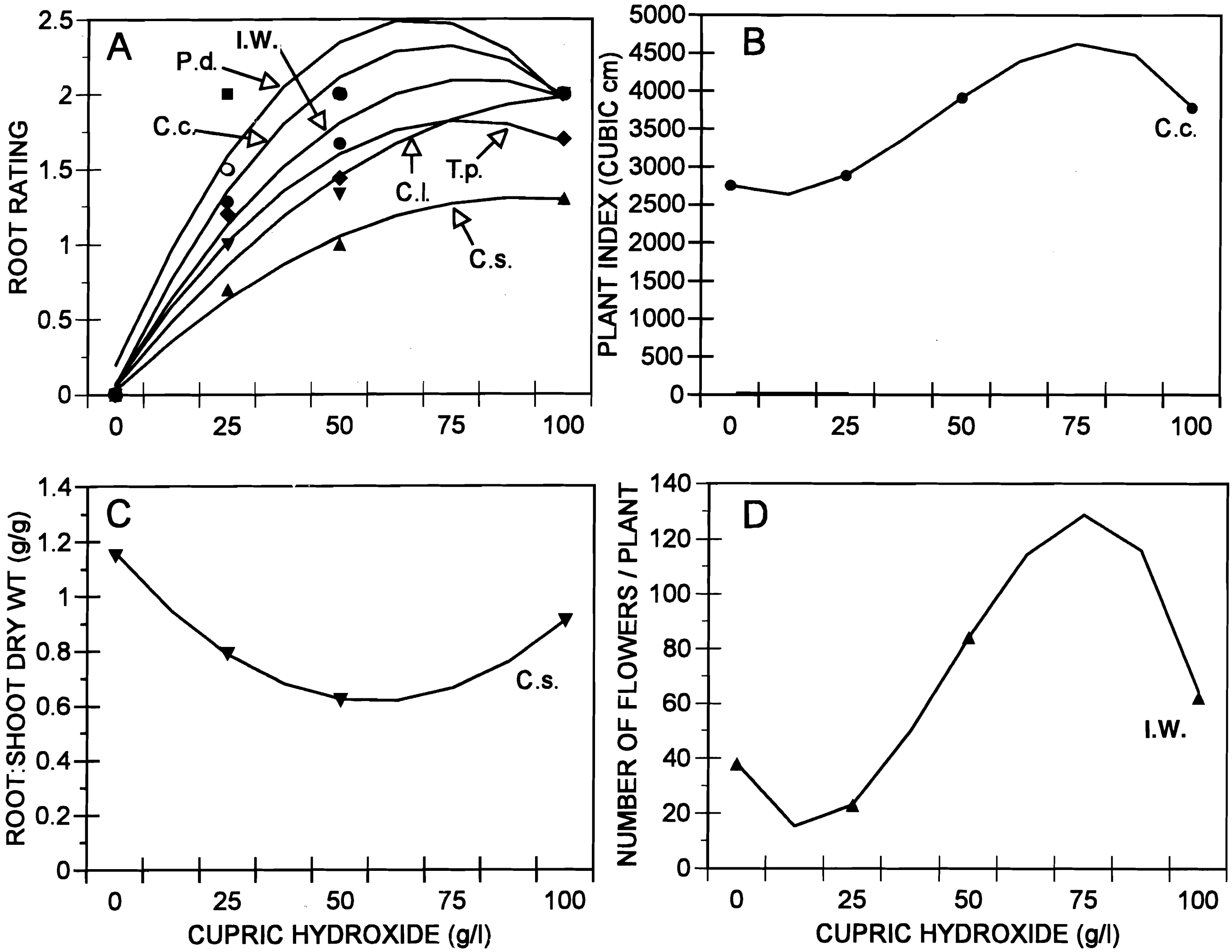

Fig. 1 **Significant ($p \leq 0.05$) polynomial regression equations (see Table 1) for the effects of increasing $Cu(OH)_2$ concentrations applied to interior container surfaces of 0.3–1 containers on growth and flowering of selected bedding plants after 39 to 41 days in the greenhouse. Means of 10 observations per treatment and species combinations are indicated by a ●, ▼, ○, ▲, ■, and ◆ for *Celosia cristata* (C.c.), *Chrysanthemum* × *superbum* (C.s.), *Coreopsis lanceolata* (C.l.), *Impatiens Wallerana* (I.W.), *Pelargonium* × *domesticum* (P.d.), and *Tagetes patula* (T.p.) respectively.**

The field responses of bedding plants to $Cu(OH)_2$ treatments appear promising. However, caution must be exercised in intepreting the field results as variation in the field was considerably greater than in the greenhouse studies. Additionally, the data represents plant responses during a single season. While the field plots were not irrigated, rainfall during the study was slightly greater than the long term average. Plant responses under more favorable irrigated conditions or more adverse drought conditions are unknown.

This study demonstrates that $Cu(OH)_2$ in a latex carrier applied to interior surfaces of containers can effectively reduce the circling, matting, and kinking of roots at container wall-medium interfaces at concentrations that do not induce copper toxicity symptoms in foliar portions of the bedding plants tested. The lowest effective $Cu(OH)_2$ concentration necessary to achieve practical control of root deformation varied in the species tested from 25 to 100 g/l (1.8 to 7.0%). With moderate $Cu(OH)_2$ concentrations, the vegetative growth of *C. cristata* and flowering potential of *I. Wallerana* during greenhouse production were increased. Field results suggest that improvements in vegetative shoot growth and/or flowering potential in response to $Cu(OH)_2$-treated containers may be possible, but testing under a wider range of environmental conditions and plant materials are needed. Plant growth and flowering responses to $Cu(OH)_2$-treated containers were both species and concentration dependent.

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Trends in Plant Material Requirements of Landscape Architects[1]

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Abstract

Landscape architects influence the demand for plant material when specifying plants for landscape projects. A survey of landscape architects in Georgia identified the value of plant material specified for nine plant-types: deciduous trees (> 3" caliper), deciduous trees ≤ 3" caliper), evergreen trees, coniferous shrubs, broadleaf shrubs, perennials/groundcovers, native herbaceous, bedding plants, and turf. As a plant category, trees represented the largest proportion of plant material, approximately 50% of the total value for all firms. With the exception of turf, landscape architects are expected to specify the same or greater value of plant material over the next five years, a positive economic sign for the nursery industry. The frequency of plant substitution due to lack of availability was greatest for the five plant-types generally produced as container nursery stock in Georgia; coniferous shrubs, broadleaf shrubs, perennials/ground covers, native herbaceous, and bedding plants. The two trends identified by landscape architects as most likely to affect the type of plants specified over the next five years are water availability and need for low maintenance landscapes.

Index words: market research, ornamentals, landscape trends, nursery crops, xeriscape

Significance to the Nursery Industry

This study was conducted to determine the current and future plant specification plans of landscape architects. The study identifies the current mix of plant material utilized by landscape architects as represented by the value of nine categories of plants. The anticipated demand for each of the nine categories and landscape trends that could affect the type of plants specified are also identified. The information in this study could be utilized by the industry to make business decisions including, (1) the quantity of deciduous trees versus evergreen trees in the product mix, (2) production procedure(s) for supply of trees, (3) decisions on specific plant cultivars to delete or add to the product mix based on the identified trends and projected demand for the nine plant-types and, (4) groupings of plants for garden center display and promotion to consumers that relate to the identified landscape trends.

Introduction

Landscape architects play an important role in selecting plant material for the landscape industry. They influence which plant varieties are used in the landscape and usually initiate demand for plant material since they specify plant types prior to purchase by landscape contractors (1, 2, 3). In addition, approximately 60% of the landscape architectural firms determine or recommend the production nursery where landscape contractors obtain plants (4, 5). The implication is that landscape architects not only influence demand for specific plants but also influence sales of specific nurseries.

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