Micronutrient Fertilization of Woody Seedlings Essential Regardless of Pine Bark pH[1]

Amy N. Wright, Alex X. Niemiera, J. Roger Harris, and Robert D. Wright[2]
Department of Horticulture
Virginia Polytechnic Institute and State University
Blacksburg, Virginia, 24061

Abstract

The objective of this study was to determine the effect of micronutrient amendments to pine bark on seedling growth over a wide pine bark pH range. *Koelreuteria paniculata* (Laxm.) was container-grown from seed in pine bark amended (preplant) with 0, 1.2, 2.4 or 3.6 kg/m^3 (0, 2, 4, 6 lb/yd^3) dolomitic limestone and 0 or 0.9 kg/m^3 (1.5 lb/yd^3) Micromax™ (micronutrient fertilizer). Initial pine bark pH for each lime rate was 4.0, 4.5, 5.0, and 5.5, respectively. Final pH (week 10) ranged from 4.7 to 6.4. Seedlings were harvested 10 weeks after planting and shoot dry mass and height determined. Pine bark solution was extracted using the pour-through method at 3, 7, and 10 weeks after planting. Solution pH was measured, and solutions were analyzed for Ca, Mg, Fe, Mn, Cu, and Zn. Shoot dry mass and height were greater in Micromax™ amended bark than in bark without Micromax™. Lime had no effect on shoot dry mass or height. In general, adding Micromax™ increased pine bark solution Ca, Mg, and micronutrient concentrations. Adding lime increased pine bark solution pH and Mg concentration and either had no effect on or decreased solution Ca and micronutrient concentrations. Regardless of pine bark pH, Micromax™ additions resulted in better growth, and adding lime was not necessary.

Index words: nutrition, soilless media, lime, container-grown, nursery crops.

Significance to the Nursery Industry

In pine bark substrate, Micromax™ greatly improved growth and quality of containerized *K. paniculata* seedlings regardless of substrate pH, whereas lime additions did not. Lime additions were also not necessary to supply Ca and Mg, since the irrigation water supplied sufficient concentrations of these nutrients. Because *K. paniculata* performed similarly to eight other woody species in a previous study, the results of this study may be applied to a wide range of landscape tree species when produced in containers using a pine bark substrate.

Introduction

Soilless substrates are commonly amended with dolomitic limestone to increase pH and supply Ca and Mg. Plant growth response to lime may be related to one or both of these factors. Increased pH due to lime additions decreases micronutrient availability, increases cation exchange (1), and alters the NH_4-N:NO_3-N ratio by increasing nitrification rate (10). Recommendations for lime and substrate pH vary depending on author, substrate, and species. *Abies fraseri* seedlings in a sphagnum peat substrate grew best in a pH range of 4.2 to 4.5 obtained via lime additions at rates of 1 and 2 kg/m^3 (1.7 and 3.4 lb/yd^3), respectively (2). In the same study, substrate pH of 5.0 and 7.6 [lime rates of 4 and 8 kg/m^3 (6.7 and 13.5lb/yd^3), respectively] decreased seedling growth and resulted in chlorotic plants with blackened roots. *Carya illinoensis* seedlings, in a pine bark-sand substrate, grew best at pH 4.3 [3 kg/m^3 (5 lb/yd^3) lime], while pH 4.7 to 4.9 [lime rates of 6 to 12 kg/m^3 (10 and 20 lb/yd^3)] decreased seedling growth (7). *Buddleia davidii* 'Royal Red' shoot and root dry mass in pine bark were highest when the substrate pH was 5.6 [2.4 kg/m^3 (4 lb/yd^3) lime] (5). Wright and Hinesley (16) showed that *Juniperus virginiana* growth in a pine bark-sand substrate was greatest in a pH range of 5.5 to 6.1 [3 kg/m^3 (5 lb/yd^3) lime]. In all three of the above instances, the authors attributed the positive growth responses to the Ca and Mg supplied by dolomitic limestone and not to substrate pH. In contrast, Keever (7) and Gillman (5) found that high lime rates resulted in decreased growth. Finally, fresh mass of *Photinia* x *fraseri* in a pine bark-sand substrate was highest in the presence of lime addition [4.2 kg/m^3 (7 lb/yd^3)], even though the pH ranges for unamended substrate and substrate with lime were similar (4.2 to 5.1 and 4.4 to 5.2, respectively) (8).

Work has also been done to determine plant growth response when a substrate is amended with both lime and micronutrient fertilizer. Growth of *Juniperus virginiana* was unaffected by micronutrients when added in conjunction with lime and decreased in response to micronutrient only additions (16). In this case, the pH of the unamended pine bark-sand substrate was 3.7 to 4.0. Because micronutrient cation availability increases as pH decreases (1), micronutrients present in a low pH substrate may be adequate to support plant growth (9), and for some species, micronutrient additions may induce toxicity. Cline et al. (3), working with peat-perlite-vermiculite substrate, found that micronutrient additions had no effect on growth of *Prosopis alba* and *P. glandulosa* in the pH range of 6.0 to 8.3 [0 and 1.2 kg/m^3 (2 lb/yd^3) lime, respectively], but increased growth in the pH range of 8.5 to 9.0 [3.6 and 6.0 kg/m^3 (6 and 10 lb/yd^3) lime, respectively]. Hathaway and Whitcomb (6) showed that *Quercus shumardii*, *Betula nigra*, *Pinus thunbergii*, and *Carya illinoensis* shoot height was highest when the pine bark-peat-sand substrate was preplant amended with micronutrients, and that lime decreased growth of these species. Benefits of micronutrient additions to soilless substrates have also been documented with *Pistacia chinensis* and *Pinus thunbergi* in a peat-perlite substrate (13) and *Pinus nigra* in a pine bark-peat-perlite substrate (4). Wright (15), working

[1]Received for publication December 21, 1998; in revised form March 22, 1999.

[2]Graduate Student, Associate Professor, Assistant Professor, and Professor, respectively.

with nine species of landscape trees, showed that adding lime to pine bark decreased growth, whereas adding micronutrients increased growth for pine bark with initial pH values of 4.7 to 5.8. However, there is little information on the growth effects of micronutrient additions for common containerized landscape trees when grown in a substrate with a wide pH range, especially below 4.7. Since micronutrient cation availability increases as substrate pH decreases, the possibility exists that micronutrient amendments may not be necessary at relatively low pH. The purpose of this experiment was to determine the effect of preplant micronutrient amendments to pine bark on growth of *Koelreuteria paniculata* seedlings for a wide substrate pH range. *K. paniculata* was selected since the growth response of this species to micronutrient and lime treatments was representative of several common landscape tree species (15).

Materials and Methods

Pine bark (*Pinus taeda*; Summit Bark Plant, Waverly, VA) was preplant amended with four lime rates [0, 1.2, 2.4, or 3.6 kg/m^3 (0, 2, 4, or 6 lb/yd^3)], which resulted in initial bark pH values of 4.0, 4.5, 5.0, and 5.5, respectively. At each lime rate, bark was also amended either with 0 or 0.9 kg/m^3 (1.5 lb/yd^3) Micromax™, for a 4 (lime) × 2 (Micromax™) factorial arrangement. Ground dolomitic limestone (18% Ca, 10% Mg) (James River Limestone Co., Inc., Buchanon, VA) had a calcium carbonate equivalence of 100%. Proportions of lime passing through indicated mesh size (number of holes per 2.5 cm) were: size 8, 100%; size 10, 100%; size 20, 90%; size 50, 55%; size 60, 50%; and size 100, 35%. Micromax™ (Scotts-Sierra, Marysville, OH) had the following composition: 12% sulfur, 0.1% boron ($Na_2B_4O_7$), 0.5% copper ($CuSO_4$), 12% iron ($FeSO_4$), 2.5% manganese ($MnSO_4$), 0.05% molybdenum (Na_2MoO_4), and 1% zinc ($ZnSO_4$). Micromax™ and lime were preplant incorporated using a substrate mixing apparatus.

Treatments were assigned in a completely randomized design with six single-container replications per treatment. Plastic 11.3 liter (3 gal) containers (26.7 cm dia, 24 cm height) were filled with bark of each lime-Micromax™ combination. Approximately 20 *K. paniculata* seeds (Sheffield's Seed Co., Inc., Locke, NY) per container were sown just below the substrate surface on March 24, 1998 (week 0). Seeds germinated 2 to 3 weeks after planting and were thinned at 8 weeks after planting to five seedlings of uniform size per container. Seedlings were irrigated as needed with 500-ml fertilizer solution of 300 mg/liter N (as NH_4NO_3), 45 mg/liter P (as H_2PO_4), and 100 mg/liter K (as KCl). Calcium, Mg, and alkalinity concentrations in the irrigation water were 10.2, 4.2, and 36 mg/liter, respectively, and micronutrient concentrations (in mg/liter) were 0 Fe, 0 Mn, 0.04 Zn, and 0.002 Cu. Plants were greenhouse-grown on raised benches.

Pine bark solutions were extracted using the pour-through method (17) from three containers per lime-Micromax™ treatment combination at 3, 7 and 10 weeks after planting. Solutions were extracted by applying 300 ml water to the substrate surface two hours after irrigation and collecting the leachate. Leachate pH was measured, and filtered solutions were analyzed for Ca, Mg, Fe, Mn, Zn, and Cu using inductively coupled plasma analysis. Seedlings were harvested 10 weeks after planting and shoot dry mass and height were determined. All data were analyzed using ANOVA (11); Tukey HSD (α = 0.05%) was used for means separation.

Results and Discussion

Analysis of variance for shoot dry mass and height indicated significant Micromax™ effects (Table 1). Seedling shoot dry mass and height were higher, 74% and 56%, respectively, when grown in pine bark amended with Micromax™ compared to when grown without (Table 1). Lime additions had no effect on shoot dry mass or height (Table 1).

Analysis of variance for pine bark solution concentrations indicated significant lime and Micromax™ effects (Tables 2, 3). Only week 3 pour-through data (Tables 2, 3) are presented since these data were similar to those for weeks 7 and 10. Pour through data were also remarkably similar across treatments. Magnesium solution concentration was highest at the 3.6 kg/m^3 (6 lb/yd^3) lime rate (averaged over Micromax™ treatments, Table 2) and 173% higher (lower mass ÷ higher mass) with Micromax™ compared to without Micromax™ (averaged over lime treatments, Table 2). Iron solution concentration was highest without lime additions and was reduced when lime additions exceeded 1.2 kg/m^3 (2 lb/yd^3) (averaged over Micromax™ treatments, Table 2). Iron solution concentration was 165% higher and Cu solution concentration was 400% higher with Micromax™ than without (Table 2).

In addition to significant main effects for lime and Micromax™, a lime × Micromax™ interaction was significant for pH and Ca, Mn, and Zn pine bark solution concentrations (Table 3). The interaction indicated that lime had no effect on Ca, Mn, and Zn concentrations when no Micromax™ was added. When Micromax™ was added, Ca, Mn, and Zn concentrations were highest at the zero lime rate compared to the three plus-lime rates (Tukey studentized range test (α = 0.05); Table 3). Single degree of freedom contrasts were used to compare the effect of Micromax™ on pH, and Ca, Mn, and Zn concentrations at each lime rate (analysis not shown). At each lime rate, Micromax™ significantly increased Ca, Mn, and Zn solution concentrations compared to corresponding values at each lime rate for bark without added Micromax™.

Table 1. Main effect of lime and Micromax™ (micronutrient fertilizer) on shoot dry mass and height of *K. paniculata*, week 10.

Main effect	Shoot dry mass[zy] (g)	Height (cm)
Lime rate (kg/m^3)		
0	1.1a	10.7a
1.2	1.4a	10.9a
2.4	1.3a	10.7a
3.6	1.2a	10.8a
Micromax™ (kg/m^3)		
0	0.90b	8.4b
0.89	1.57a	13.1a
Significance (p-value)		
Lime	0.3520	0.9973
Micromax™	0.0001	0.0001
Interaction	0.7978	0.3340

[z]Pooled means reported for lime and Micromax™ main effects are for n = 12 and n = 24 observations, respectively.

[y]Pairs of means within main effect are not significantly different when followed by the same letter (Tukey HSD, α = 0.05).

Table 2. **Main effects of lime and Micromax™ (micronutrient fertilizer) on pine bark solution Mg, Fe, and Cu concentrations at week 3.**

Main effect	Substrate solution concentration (mg/l)[zy]		
	Mg	Fe	Cu
Lime rate (kg/m^3)			
0	21.5b	0.64a	0.03a
1.2	22.5b	0.50ab	0.03a
2.4	25.6b	0.31b	0.03a
3.6	35.6a	0.22b	0.04a
Micromax™ (kg/m^3)			
0	14.1b	0.23b	0.01b
0.89	38.5a	0.61a	0.05a
Significance (p-value)			
Lime	0.0095	0.0095	0.7747
Micromax™	0.0001	0.0003	0.0001
Interaction	0.1523	0.3218	0.4351

[z]Pooled means reported lime and Micromax™ are for n = 6 and n = 12 observations, respectively.

[y]Pairs of means within main effect are not significantly different when followed by the same letter (Tukey HSD, $\alpha = 0.05$).

Pine bark solution pH at each lime rate increased approximately one unit from week 0 to week 10. Increases in pH from week 0 to week 10 for the 0, 1.2, 2.4, and 3.6 kg/m^3 lime treatments were 4.0 to 4.7, 4.5 to 5.8, 5.0 to 6.0, and 5.5 to 6.4, respectively. In bark both with and without Micromax™, pH increased due to lime additions (Tukey studentized range test ($\alpha = 0.05$); Table 3). However, the lime × Micromax™ interaction for pH (previously mentioned) indicated that the increase in pH due to lime additions was greater in the plus Micromax™ treatments (pH 4.0 to 5.9) than when no Micromax™ was added (pH 4.5 to 6.0; data pooled over lime rate; Table 3). Micromax™ additions decreased pH only in bark without lime addition (contrast analysis not shown).

The increase in shoot dry mass and height (Table 1) due to preplant Micromax™ additions to pine bark may be explained by the increased solution Fe, Mn, Zn, and Cu concentrations associated with Micromax™ additions (Tables 2, 3). At the zero lime rate, substrate solution pH values for with and without Micromax™ were 4.0 and 4.5, respectively (Table 3). The reason for the lower pH of pine bark with added Micromax™ compared to bark without was likely due to release of H^+ during hydrolysis reaction of the sulfate forms of Fe, Mn, Cu, and Zn present in Micromax™. The decrease in pH may have resulted in the micronutrients inherent in the bark becoming more soluble, also contributing to increased solution concentration. Ca and Mg concentrations were also higher in plus Micromax™ treatments (Tables 3). Because Micromax™ contained only trace amounts of Ca or Mg, the increased concentration of these elements is attributed to increased dolomitic lime solubility as well as increased Ca and Mg availability from the irrigation water (10.2 and 4.2 mg/liter, respectively), due to the decrease in pH that accompanied Micromax™ addition.

The lack of growth response to lime additions may be attributed to the overall solution micronutrient concentrations of this experiment. In a similar experiment, Wright (15) showed that pine bark amended with 3.6 kg/m^3 (6 lb/yd^3) lime decreased shoot dry mass and height of *K. paniculata*. Although not legitimate to statistically compare the current work to that of Wright (15), current solution micronutrient concentrations in the 3.6 kg/m^3 (6 lb/yd^3) lime treatment (Tables 2, 3) were as much as six times higher than those given by Wright (15) for the 3.6 kg/m^3 (6 lb/yd^3) lime treatment. Even though lime additions decreased solution micronutrient concentrations in both experiments, the possibility exists that concentrations in the current work were above threshold levels that would inhibit growth.

Lime additions decreased Fe solution concentration both in the presence and absence of Micromax™, thus the decreased concentration when averaged over Micromax™ treatments. This decrease in solution concentration was likely due to the increase in pH associated with lime additions. Increased solution pH decreases solubility and increases adsorption of cations to substrate particle (1), thus decreasing concentration in solution. The reason for the overall one unit increase in pH from week 0 to week 10 at each lime rate may be due to the alkalinity of the irrigation water (36 mg/liter). Williams et al. (14) found that in some cases, even moderately alkaline irrigation water (38 mg/liter) may raise the substrate solution pH more than a lime amendment.

Results of this experiment illustrate that micronutrient amendments to pine bark can increase growth regardless of substrate pH (pH range 4.0 to 5.5, values commonly encountered by nurseries). In addition, the need for micronutrient additions was consistent for all lime rates used in this experiment. Although the experiment was conducted using seedlings, we do not expect plant response to change with time. Because *K. paniculata* performed similarly to other common landscape tree species in previous experiments (15), results of this experiment suggest that optimal growth of containerized landscape trees grown in pine bark requires a micronutrient amendment. In addition, we found no positive influence of lime on growth and question the routine use of this amendment if the irrigation water or substrate supplies ample Ca and Mg.

Table 3. **Pine bark solution pH and Ca, Mn, and Zn concentrations at week 3.**

Treatment	pH	Substrate solution concentration (mg/l)[zy]		
		Ca	Mn	Zn
+ Micromax™				
Lime rate (kg/m^3)				
0	4.0d	118a	6.9a	1.2a
1.2	5.1c	57b	2.1b	0.32b
2.4	5.5b	45b	0.98b	0.18b
3.6	5.9a	55b	1.1b	0.17b
– Micromax™				
Lime rate (kg/m^3)				
0	4.5d	21a	0.41a	0.16a
1.2	5.0c	22a	0.34a	0.11a
2.4	5.4b	27a	0.27a	0.07a
3.6	6.0a	29a	0.22a	0.05a
Significance (p-value)				
Lime	0.0001	0.0001	0.0001	0.0001
Micromax™	0.0305	0.0001	0.0001	0.0001
Interaction	0.0003	0.0001	0.0001	0.0001

[z]Pooled means reported are for n = 3 observations.

[y]Column means within treatment are not significantly different when followed by the same letter (Tukey HSD, $\alpha = 0.05$).

Literature Cited

1. Brady, N.C. 1990. The Nature and Properties of Soils. 10th ed. Macmillan, New York.

2. Bryan, J.A., J.R. Seiler, and R.D. Wright. 1989. Influence of growth medium pH on the growth of container-grown fraser fir seedlings. J. Environ. Hort. 7:62–64.

3. Cline, G., D. Rhodes, and P. Felker. 1986. Micronutrient, phosphorus and pH influences on growth and leaf tissue nutrient levels of *Prosopis alba* and *Prosopis glandulosa*. For. Ecol. and Mgt. 16:81–93.

4. Field, J. and C.E. Whitcomb. 1981. Effects of Osmocote, Micromax and dolomite during propagation on growth and quality of Chinese pistache and Austrian pine seedlings. Okla. Agr. Expt. Sta. Res. Rpt. 818. pp. 46–47.

5. Gillman, J.H., M.A. Dirr, and S.K. Braman. 1998. Effects of dolomitic lime on growth and nutrient uptake of *Buddleia davidii* 'Royal Red' grown in pine bark. J. Environ. Hort. 16:111–113.

6. Hathaway, R.D. and C.E. Whitcomb. 1977. Effect of nutrition during propagation on future growth of shumard oak, Japanese black pine, pecan and river birch. Okla. Agr. Expt. Sta. Res. Rep. 760. pp.23–30.

7. Keever, G.J., W.D. Goff, and M.S. West. 1991. High dolomitic lime rates induce mouse-ear symptoms in container-grown pecan trees. HortScience 26:1494–1495.

8. Nash, V.E., A.J. Laiche, and F.P. Rasberry. 1983. Effects of amending container growing media with dolomitic limestone on the growth of *Photinia* x *fraseri*. Commun. Soil Sci. Plant Anal. 14:497–506.

9. Niemiera, A.X. 1992. Micronutrient supply from pine bark and micronutrient fertilizers. HortScience 27:272.

10. Niemiera, A.X. and R.D. Wright. 1986. Effect of liming rate on nitrification in a pine bark medium. J. Amer. Soc. Hort. Sci. 111:713–715.

11. SAS Institute. 1985. SAS User's Guide: Statistics, Version 5th ed. SAS Inst. Inc., Cary, NC.

12. Starr, K.D. and R.D. Wright. 1984. Calcium and magnesium requirements of *Ilex crenata* 'Helleri'. J. Amer. Soc. Hort. Sci. 109:857–860.

13. Whitcomb, C.E. 1979. Effects of Micromax micronutrients and Osmocote on growth of tree seedlings in containers. Okla. Agr. Expt. Sta. Res. Rep. 791. pp. 42–48.

14. Williams, B.J., J.C. Peterson, and J.D. Utzinger. 1988. Effects of dolomitic lime and alkaline water in sphagnum peat-based container growing media. HortScience 23:168–169.

15. Wright, A.N. 1998. Influence of lime and micronutrient amendments on growth of containerized landscape trees grown in pine bark. M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA.

16. Wright, R.D. and L.E. Hinesley. 1991. Growth of containerized eastern redcedar amended with dolomitic limestone and micronutrients. HortScience 26:143–145.

17. Yeager, T.H., R.D. Wright, and S.J. Donohue. 1983. Comparison of pour-through and saturated pine bark extract N, P, K, and pH levels. J. Amer. Soc. Hort. Sci. 108:112–114.