Ca, Mg, And Micronutrient Nutrition and Growth of *Pelargonium* In Pine Bark Amended With Composted Hardwood Bark[1]

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Abstract

Growth and foliar nutrient analysis of *Pelargonium* X *hortorum* L. H. Bailey cv. Aurora grown in pine bark (PB) amended with 25%, 50%, or 75% composted hardwood bark (HB) were studied with the bark components mixed either before or after composting. For each ratio of PB to HB, fresh PB was mixed with fresh HB before composting, or composted PB or noncomposted PB were mixed with composted HB. Media physical properties and plant growth and foliar nutrient levels were the same when media were mixed before or after composting. Plants had more shoot growth in media containing 25% or 50% HB. Media containing 25% or 50% HB had a stable pH during the study, while pH increased in other media. Plants grown in media containing 75% or more composted HB showed symptoms of Mn toxicity during the first month of growth. Except for Cu, plants grown in media containing composted HB had normal or above normal foliar tissue Ca, Mg, and micronutrient levels.

Index words: *Pelargonium* X *hortorum*, container media, composting, physical properties, Mn toxicity, geranium

Significance to the Nursery Industry

This study showed that similar quality blended PB and composted HB media can be obtained by mixing the components before or after composting, suggesting that the faster procedure of mixing before composting would be beneficial. Compared to production using pine bark-based media, using blended PB and HB media may reduce the amount of Ca and Mg fertilization required to produce *Pelargonium* or other container-grown crops. Mixing PB with HB before composting produces the same quality growing media while shortening the amount of time required to prepare the hardwood bark for use as a media component.

Introduction

Pine bark (PB) is the major component used in container media in the southeastern United States. Some nurseries are using a 100% PB growing medium (19). While noncomposted PB can be used as a growth medium component (3,

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19), hardwood bark (HB) is usually composted before use (7). Problems with toxic substances (9, 12), plant nutrition (7), and shrinkage of the medium in the container (19) frequently occur with noncomposted HB, although successful production in media containing noncomposted HB has been reported (4).

Increasing quantities of available Ca can decrease the availability of micronutrients (19). Composted HB has a plentiful supply of available Ca and Mg (13), which may influence the proportion of plant-available micronutrients in PB amended with composted HB. Furthermore, the lower pH of PB is roughly compensatory with the higher pH of HB (1), possibly reducing changes in media pH during production.

Hardwood bark will compost faster when mixed with softwood barks (12), increasing the efficiency of composting HB (13, 14). Except for a preliminary report (15), no information is available on plant growth in PB and HB media mixed before composting, compared to mixing after the HB was composted separately.

The objectives of this research were to determine the growth and foliar Ca, Mg, and micronutrient analysis of *Pelargonium* 'Aurora' grown in media composed of varying ratios of PB and composted HB. *Pelargonium* was selected as a fast-growing and economically important test species (5, 8).

Materials and Methods

Five media were prepared by composting fresh PB, fresh HB [all bark obtained locally and milled through a 25.4 mm (1 in) screen], and fresh PB amended with 25%, 50%, or 75% (v/v) fresh HB in 2.7 m^3 (3.5 yd^3) piles in a partitioned windrow system (13), using techniques adapted from Hoitink and Poole (7). Six media were prepared by mixing either composted PB or noncomposted PB (stored 4 months in an unprotected outdoor location) with 25%, 50%, and 75% (v/v) composted HB. Two additional media examined were 100% noncomposted PB, and a commercially used medium consisting of noncomposted PB:canadian moss peat:sand (3:1:1 by vol.). Before planting, all 100% PB media and the commercial medium were amended with 3.6 kg/m^3 (6 lb/yd^3) dolomitic limestone, 1.2 kg/m^3 (2 lb/yd^3) KNO_3, and 0.6 kg/m^3 (1 lb/yd^3) Micromax (trademarked micronutrient product of Grace/Sierra, Milpitas, CA). Media samples collected before amendments were added were analyzed for extractable nutrients using a saturation extraction technique (18).

Particle size distribution for all media was tested by screening 250 ml (0.5 pt) of oven-dried (80°C for 24 hours) media for 5 min with a Ro-Tap shaker. Three replicate oven-dried samples (2.25 l or 0.6 gal) from each medium were placed in 2.5 l (0.7 gal) plastic containers, and percent total pore space, percent water holding capacity and percent air space were determined using the volume-loss method described by Whitcomb (19). Dry bulk density was calculated from the weight of the 2.25 l (0.6 gal) samples.

Uniform 5 cm (2 in) plugs of *Pelargonium* 'Aurora' were planted in 2.5 l (0.7 gal) containers filled with 2.25 l (0.6 gal) of medium, and grown in a double-poly quonset greenhouse in a randomized complete block design (10 blocks of 13 media). Day/night temperatures averaged 24°C/17°C (76°F/63°F), and maximum photosynthetically active irradiance was approximately 600 umol $m^{-2}s^{-1}$ (4620 ft-c). At planting, pots were top-dressed with Osmocote 14N-6.2P-11.6K(14-14-14) at 12 g per pot. Plants were watered daily using irrigation dribble rings (Dramm Co., Manitowoc, WI) placed in each pot, and plants were fertilized every fourth watering with 20N-9.8P-16.6K(20-20-20) at 300 ppm N. Nutrient solution pH was 6.8, and pH of irrigation water was 7.2. Leachate pH was monitored every 4 weeks.

Plants were harvested after 12 weeks. Shoot size was characterized with a size index calculated at height + (widest width + narrowest width)/2. Shoots were severed from roots at the medium surface and fresh and dry weight recorded. Three pooled samples of youngest fully expanded leaves were analyzed for nutrients using dry-ash analysis. Data were subjected to analysis of variance (ANOVA), and percentile data were transformed to arcsin values before ANOVA (10).

Results and Discussion

There were no significant differences among media mixed before or after composting, so data were pooled for analysis. The same quality growing medium is produced if PB and HB are mixed before composting or if they are composted separately before mixing.

There were no significant differences between noncomposted and composted pine bark, so data were pooled for analysis. Previous studies have found no need to compost pine bark before use in growing media (3, 19).

HB had more pre-plant extractable Ca and Mg than all other media except the 25% PB medium (Table 1). Media containing HB had more extractable Ca and Mg than media without HB. PB had less extractable Mn than other media. There were no differences in extractable Fe, B, Cu, or Zn.

More fine particles [particles <0.5 mm (<0.001 in)] were found in HB and the commercial medium than in other media (Table 2). PB had fewer coarse particles [>8.0 mm (>0.2 in)] and fewer fine particles than HB. Media containing more than 25% HB had more coarse particles than other media. The PB and HB used in this study had more small particles than barks used in other studies (2, 17). Our media having equal volumes of PB and HB were similar to those of Tilt and Bilderback (17), except their media had fewer particles <0.5 mm (<0.1 in).

Media containing equal volumes of PB and HB had a

Table 1. Preplant extractable nutrient analysis of pine bark and hardwood bark media in which Pelargonium 'Aurora' were grown.

Media %PB:%HB[y]	Available nutrients[z] (ppm) Ca	Mg	Mn
0:100	254.2 a[x]	34.7 a	4.7 a
25.75	219.8 ab	28.4 ab	4.6 a
50:50	166.3 b	23.9 b	5.1 a
75:25	120.5 b	20.0 b	4.7 a
100:0	24.6 c	7.2 c	1.5 b
Commercial[w]	13.5 c	4.6 c	4.2 a

[z]Saturation extraction method.

[y]Ratio of pine bark to hardwood bark (percent by volume).

[x]Least squares mean separation within columns using paired T-tests (P = 0.01). There were no differences in extractable Fe, B, Cu, and Zn, which averaged 0.94, 0.24, 0.03, and 0.10 mg/liter, respectively.

[w]Commercially used medium having 3:1:1 (v/v/v) pine bark:canadian moss peat:sand.

Table 2. Particle size distribution of pine bark and hardwood bark media in which Pelargonium 'Aurora' were grown.

Media %PB:%HB[z]	*Mean percent weight on sieve* mm sieve size					
	8.0	4.0	2.0	1.0	0.5	pan
0:100	6.3 a[y]	16.4 a	16.1 d	15.6 d	18.7 b	26.2 a
25:75	6.3 a	16.7 a	21.1 c	18.4 c	17.9 b	19.6 b
50:50	4.5 ab	15.3 a	22.4 c	20.0 b	17.8 b	19.8 b
75:25	1.6 bc	14.6 a	26.0 b	21.0 ab	17.9 b	19.1 b
100:0	0.0 d	12.8 a	30.0 a	21.8 a	17.5 b	17.9 b
Commercial[x]	1.1 dc	8.1 b	15.8 d	15.6 d	30.2 a	29.2 a

[z]Ratio of pine bark to hardwood bark (percent by volume).

[y]Mean separation within columns by Duncan's Multiple Range Test for arcsin transformed means, $P = 0.01$.

[x]Commercially used medium having 3:1:1 (v/v/v) pine bark:canadian moss peat:sand.

higher percent total pore space than all other media, and higher percent air space than other media except PB (Table 3). The commercial medium had the highest water holding capacity and bulk density, and the lowest air space compared to other media. All media used in this study had lower percent total pore space, water holding capacity, and air space, and higher bulk densities than other studies (1, 16). Bilderback (2) reported that bulk density increased linearly with the percent of HB in the medium, and reported higher percent total pore space in 75% and 100% HB compared to 50% HB. Differences can be attributed to differing bark sources, particle size distributions, composting procedures and analytical techniques.

At planting, leachate pH was higher in media containing HB (Table 4). There was little change in leachate pH from media containing 25% and 50% HB after 12 weeks, indicating a potential buffer capacity against changes in leachate pH induced by medium decomposition, irrigation water quality, or fertilization. Leachate pH slowly increased in all other media. In other studies using PB amended with lime before it was mixed with composted HB, equal volumes of PB and composted HB produced pH values of 6.2 (2) and 6.6 (1).

Pelargonium grown in equal volumes of PB and HB had more shoot dry weight and a larger shoot size index compared to plants grown in other media (Table 5). *Pelargonium* grown in PB had more shoot dry weight compared to plants grown in media containing more than 50% HB, or the commercial medium. The commercially used medium produced the smallest plants, possibly due to limited air space (Table 3) relative to the irrigation regime used in this study.

Equal volumes of PB and HB produced superior shoot growth in previous studies (1, 2), and our study confirms these reports. The similarity in growth response to composted and noncomposted pine bark has been previously noted (3, 19), leading to claims that PB need not be composted before use in container media. However, endogenous growth regulating compounds or exogenously applied chemicals sprayed on trees or logs during timber production, such as pyrogallol and Lindane, respectively, may influence plant growth in noncomposted bark (12). Growth enhancing or inhibiting compounds that may be in noncomposted bark need additional study (9, 12).

After two weeks growth, youngest leaves of plants grown in media having more than 50% HB exhibited interveinal yellow blotches, leaf distortion, short internodes, upward cupped leaves, and brown spots on leaf margins. These symptoms are consistent with the description of manganese toxicity (5, 12). Symptoms were not visible after 6 weeks, but leaf samples taken at 12 weeks still had above average (>174 ppm) concentrations of Mn (5, 8). Leaching, increased plant size from growth, and increased absorption of available Ca with increased transpiration as plants grew, may have contributed to the disappearance of Mn toxicity symptoms. Addition of Ca was not a useful option since pH and Ca levels were already high. Mn toxicity of *Pelargonium* (11) and other crops (12) grown in bark-based media has been reported.

Table 3. Total pore space, water holding capacity, air space, and bulk density of pine bark and hardwood bark media in which Pelargonium 'Aurora' were grown.

Media %PB:%HB[z]	Total pore space (% vol)	Water holding capacity (% vol)	Air space (% vol)	Dry bulk density (g cm^{-3})
0:100	58.6 b[y]	38.4 b	20.2 d	0.32 b
25:75	57.8 bc	37.6 c	20.1 d	0.30 c
50:50	61.3 a	35.4 c	25.9 b	0.29 cd
75:25	57.0 bc	33.9 d	23.1 c	0.28 d
100:0	58.9 b	29.3 e	29.7 a	0.26 e
Commercial[x]	56.7 c	41.9 a	14.8 e	0.50 a

[z]Ratio of pine bark to hardwood bark (percent by volume).

[y]Mean separation within columns by Duncan's Multiple Range Test, $P = 0.01$. Arcsin transformations for statistical analysis of percentile data.

[x]Commercially used medium having 3:1:1 (v/v/v) pine bark:canadian moss peat:sand.

Table 4. Monthly leachate pH of pine bark and hardwood bark media in which Pelargonium 'Aurora' were grown.

Media %PB:%HB[y]	Week 0 pH	Week 4 pH	Week 8 pH	Week 12 pH
0.100	5.96 a[y]	6.23 a	6.37 a	6.46 a
25:75	5.96 a	6.07 a	6.21 a	6.35 a
50:50	5.83 a	5.83 ab	5.85 b	5.85 c
75:25	5.60 a	5.60 b	5.60 c	5.61 d
100:0	5.10 b	5.15 c	5.21 d	5.31 e
Commercial[x]	4.83 c	4.88 d	4.94 e	4.98 f

[z]Ratio of pine bark to hardwood bark (percent by volume).

[y]Mean separation within columns by Duncan's Multiple Range Test, $P = 0.01$. Actual hydrogen ion concentrations were used for statistical analysis.

[x]Commercially used medium having 3:1:1 (v/v/v) pine bark:canadian moss peat:sand.

Table 5. **Shoot size index, shoot fresh weight, and shoot dry weight of Pelargonium 'Aurora' grown in pine bark and hardwood bark media.**

Media %PB:%HB[z]	Shoot size index[y]	Shoot fresh weight (g)	Shoot dry weight (g)
0.100	73.2 cd[x]	287.4 bc	34.4 cd
25:75	72.3 de	313.8 b	36.4 bc
50:50	79.0 a	356.6 a	41.8 a
75:75	76.1 bc	334.4 ab	39.7 a
100:0	75.1 bc	328.8 ab	38.1 b
Commercial[w]	69.8 e	263.2 c	31.1 d

[z]Ratio of pine bark to hardwood bark (percent by volume).

[y]Plant size index computed as height + (width + width)/2.

[x]Mean separation within columns by Duncan's Multipe Range Test, $P = 0.01$.

[w]Commercially used medium having 3:1:1 (v/v/v) pine bark:canadian moss peat:sand.

Pelargonium grown in media containing HB had the same or higher Ca, Mg, Mn, Fe, and B compared to other media, without the addition of dolomite or micronutrients (Table 6). Plants grown in media containing HB contained less Cu and Zn than plants grown in other media. Plants grown in media containing more than 50% HB had higher Mn and Fe compared to plants grown in other media.

Foliar Ca and Mg were near normal for plants grown in all media (5, 8). Plants grown in media containing HB had average or above average concentrations of Fe and B (5). Plants grown in PB or in the commercial medium had low tissue Fe and B (5, 8), but no deficiency symptoms were observed. Except for plants grown in PB, all plants were low in Cu (5), but no deficiency symptoms were observed. Kofranek and Lunt (8) reported severe Cu deficiency symptoms on *Pelargonium* 'Irene' at 4 ppm Cu. *Pelargonium* 'Aurora' may have a lower requirement for Fe, B, And Cu, or the levels reported may be normal for dry ash analysis techniques.

Media physical properties alone may not provide an explanation of increased growth in equal volumes of PB and HB, but the greater total pore space may have permitted greater root growth, which then supported greater shoot growth. PB may have had low Fe and B, and HB had excessive Mn and low Cu. Plants grown in equal volumes of PB and HB may have benefited from having neither low nor excessive concentrations of any micronutrient, with the possible exception of Cu. Growth responses may have been different if different watering and fertilization regimes were used.

Mixing PB with HB before composting did not alter media physical properties or plant growth response compared to composting PB and HB separately before mixing. PB amended with HB supplied sufficient Ca, Mg, and micronutrients to support plant growth (with the possible exception of Cu), assuming micronutrient contamination of applied fertilizers was negligible. Nutrient availability may vary with different bark sources. Equal volumes of PB and HB supported superior plant growth, and had optimal pH conditions that resisted changes introduced by irrigation or fertilization. Growth and nutrition of different species, the pH buffer capacity, and the potential for pathogen suppression (6) in blended PB and composted HB media need further study.

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Table 6. **Tissue nutrient analysis of *Pelargonium* 'Aurora' grown in pine bark and hardwood bark media.**

Media %PB:%HB[z]	Ca, %	Mg, %	Mn, ppm	Fe, ppm	B, ppm	Cu, ppm	Zn, ppm
0:100	1.22 a[y]	0.28 a	453.2 a	349.4 a	30.7 a	1.81 b	41.9 c
25:75	1.07 bc	0.24 bc	342.2 ab	266.4 b	31.9 a	1.94 b	42.1 c
50:50	0.87 d	0.23 c	300.3 b	192.1 c	29.0 a	1.49 c	40.4 c
75:25	0.91 cd	0.20 cd	289.7 b	181.0 c	26.2 a	1.86 bc	38.4 c
100:0	0.89 cd	0.16 d	69.6 c	62.0 d	12.3 b	5.26 a	53.0 a
Commercial[x]	1.01 cd	0.17 d	61.3 c	59.2 d	10.8 b	2.05 b	47.5 b

[z]Ratio of pine bark to composted hardwood bark (percent by volume).

[y]Mean separation within columns by Duncan's Multiple Range Test, $P = 0.01$.

[x]Commercially used medium having 3:1:1 (v/v/v) pine bark:canadian moss peat:sand.

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Effects of Seed Priming on Plug Production of *Coreopsis lanceolata* and *Echinacea purpurea*[1]

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Abstract

Seeds of *Coreopsis lanceolata* (coreopsis) and *Echinacea purpurea* (purple coneflower) were primed to determine whether improved plug production of these herbaceous perennials would result. Experiments were conducted at two locations: Texas A&M University (TAMU), College Station, Texas; and Buell's Inc., Cibolo, Texas. Location had a significant effect on emergence, with both species having greater emergence percentages at Buell's Inc. than at TAMU. This effect is attributed mainly to watering systems and plug aeration. Priming significantly increased emergence of only *E. purpurea* grown at TAMU. Seedlings from seeds primed in 50 mM potassium salts for nine days at 15°C (59°F) had more than twice the emergence percentage (47%) of seedlings from nonprimed seeds (21%). Priming did have a significant effect on the root development of both species. *Echinacea purpurea* seedlings from primed seeds had a 44 to 51% increase in total root area compared to nonprimed seeds. *Coreopsis lanceolata* seedlings from primed seeds had up to an 85% increase in root area compared to seedlings from nonprimed seeds. In plug systems, relatively developed root systems may result in positive growth response after transplanting.

Index words: perennials, coreopsis, purple coneflower

Significance to the Industry

The same factors enhancing the usefulness of plugs in nursery production, i.e. small, compartmentalized cells reducing competition between plants and making transplanting easier, also intensify problems such as saturated soils and poor soil aeration not associated with standard production procedures (2, 11). Seed priming has demonstrated an ability to improve germination and emergence of seeds under stress conditions such as extreme temperature and excessive moisture (4, 8, 15, 16). In this study, when plugs were grown under less than ideal conditions, primed seeds of *E. purpurea* performed better than did nonprimed seeds even though germination was greatly reduced. When greenhouse conditions were ideal, the benefits of priming were not as obvious because the germination of all treatments improved. Priming did result in greater root development for both species, which may be significant in terms of improved transplanting and response to transplanting.

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Introduction

One of the greatest opportunities for economic success in the nursery industry in recent years has been the production and sale of potted perennials (13, 14, 17). The use of plug production systems can enable growers to take advantage of this opportunity by producing great quantities of perennials economically and efficiently (2, 7, 11).

One of the keys to successful plug production is vigorous, uniform seedlings produced from quality seed germinating rapidly and uniformly (2, 7, 11). Unfortunately, many herbaceous perennials have complex dormancy systems creating problems for commercial producers (12). Seed priming is a pregerminative treatment used to improve germination performance of two perennial species, *C. lanceolata* (coreopsis) and *E. purpurea* (purple coneflower) (15, 16). Yet, no research has been done to evaluate the benefits of priming perennial seed for use with plug production systems.

The purpose of this study was to determine whether priming improves emergence and growth during perennial plug production under normal greenhouse conditions.

Materials and Methods

Greenhouse experiments were conducted at Texas A&M University (TAMU) in College Station, Texas and at Buell's