# SECTION 2
# CONTAINER-GROWN PLANT PRODUCTION

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# Kenaf Fiber Core as a Vermiculite Substitute in Peat-based Media for Growing Greenhouse Bedding Plants

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**Nature of Work:** Kenaf (*Hibiscus cannabinus*), primarily grown in Asia for cordage and yarn, is an alternative fiber crop being evaluated for production in Mississippi. It can be used in the manufacture of paper, fiber board, acoustical tiles and compost. The plant, which can grow to a height of 5 to 6 meters and 25 to 35 mm in diameter in six months, is an annual with straight unbranched stems in the same family (Malvaceae) as cotton, okra and Chinese hibiscus. Kenaf fiber core, a by-product of processing, comprises 60-65% of the stem dry weight and must be discarded or recycled. A possible use of fiber core is as a component of container media for greenhouse crops. The objective of this study was to determine the feasibility of using kenaf fiber core as a vermiculite substitute in sphagnum peat-based media for growing greenhouse bedding plants.

*Begonia x semperflorens* (begonia), *Impatiens wallerana* (impatiens), *Salvia splendens* (salvia), and *Catharanthus roseus* (vinca) plugs were transplanted into 4 inch (10 cm) pots containing sphagnum peat-based media modified with various forms of kenaf fiber core and/or vermiculite. Finely ground and coarsely ground core was used in fresh and composted form and charged or not charged with 5,000 mg N /liter (5,000 ppm). Core that had been used as chicken litter and composted was also used. Each fiber core preparation was blended with peat and vermiculite (by volume) as follows: 5 peat : 5 vermiculite : 0 kenaf; 5 peat : 4 vermiculite : 1 kenaf; 5 peat : 3 vermiculite : 2 kenaf; 5 peat : 2 vermiculite : 3 kenaf; 5 peat : 1 vermiculite : 4 kenaf; and 5 peat : 0 vermiculite : 5 kenaf. Each preparation was amended with 10 lb. (4.54 kg) dolomitic limestone, 4.5 lb. (2.04 kg) simple super phosphate, 2 lb. (0.90 kg) calcium nitrate and 2 oz. (60 g) fritted trace elements (FTE 555, Grace/Sierra, Fogelsville, PA) per cubic yard of material. The study was directed as a 2x2x2x6 factorial completely randomized design with chicken litter preparation added as an additional variable. All specimens were irrigated and fertilized with 200 mg N/liter (200 ppm) from 20 N-4.4 P-16.6 K (20-10-20 Peters Peat-Lite Special, Grace/ Sierra, Fogelsville, PA).

**Results and Discussion:** Media containing no kenaf produced begonias with the greatest height and weight (Table 1). Reduced weights were found in fresh and composted coarsely ground kenaf with the N charge, while similar weights were found in fresh and composted finely ground kenaf with or without a charge. Maximum plant height and weight of impatiens was found in media containing no kenaf (Table 1). In coarsely ground fresh media, the N charge reduced plant height; however, weight at rates of 10-30% were found to be greater than for media without the N charge. In coarsely ground composted media, heights and weights were similar regardless of charge. Greatest plant height of salvia was produced in coarse composted kenaf with the N charge; however, greatest weight was produced in media with rates of 10-40% of coarse fresh kenaf with the N charge (Table 1). Control media containing no kenaf produced maximum plant heights in vinca with the exception of those in finely ground composted charged kenaf at rates of 10-40%. Maximum weights of vinca were found in control media (Table 1). In general, as the rate of kenaf increased, plant height and weight decreased. Finely ground kenaf appeared to increase the water holding capacity of the media. Composted preparations generally resulted in plants with greater heights and weights. Except for a few incidences, the presence of an N charge resulted in reduced heights and weights. For all species, increasing amounts of composted chicken litter resulted in decreasing plant height and weight. However, at the 10% rate, plant heights and weights were greater than those grown in control media containing no kenaf. At the rate of 50% composted chicken litter plant survival was compromised.

Results from this study suggest that completely replacing vermiculite in sphagnum peat-based media with fiber core of kenaf in the above preparations was not conducive to maximum plant growth. It appeared that charging kenaf fiber core with N was not warranted and may even have been detrimental in some cases. Composted kenaf fiber core after use as chicken litter added to sphagnum peat-based media at the rate of 10% of volume was beneficial to plant growth, but at rates greater than 10% was at best harmful and at worst lethal to plant growth.

**Significance to the Industry:** Inexpensive, readily available growing media components that fulfill the requirements of freedom from disease and insect pests, water holding capacity, cation exchange capacity and proper pH are of prime importance to greenhouse and nursery growers. Successful production and use of kenaf in the south will create an abundant supply of fiber core, which will require disposal. As research provides further information regarding optimum techniques for the use of kenaf fiber core, it will offer growers with an affordable alternative to the traditional growing media components.

Table 1. Plant weight of Begonia x semperflorens (begonia), Impatiens wallerana (impatiens), Salvia splendens (salvia), and Catharanthus roseus (vinca) as influenced by kenaf core, fine or coarse, composted or fresh, charged or not charged with nitrogen, and kenaf used as poultry litter, replacing vermiculite in media.

| | Kenaf (%) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | 40 | 50 |
| | weight (g) | | | | | |
| Begonia | | | | | | |
| Fine Not Composted Not Charged | 3.36 | 2.92 | 2.11 | 1.38 | 0.79 | 0.49 |
| Fine Not Composted Charged | 3.36 | 1.83 | 1.11 | 0.39 | 0.54 | 0.37 |
| Fine Composted Not Charged | 3.36 | 3.08 | 2.67 | 1.85 | 1.72 | 1.12 |
| Fine Not Composted Charged | 3.36 | 1.72 | 1.17 | 1.01 | 0.46 | 0.35 |
| Coarse Not Composted Not Charged | 3.36 | 2.42 | 2.23 | 1.63 | 1.20 | 0.77 |
| Coarse Not Composted Charged | 3.36 | 3.22 | 2.33 | 1.69 | 0.43 | 0.39 |
| Coarse Composted Not Charged | 3.36 | 2.72 | 2.74 | 1.69 | 1.86 | 1.09 |
| Coarse Composted Charged | 3.36 | 2.49 | 2.37 | 1.84 | 1.56 | 1.37 |
| Poultry Litter | 3.36 | 2.54 | 2.65 | 1.50 | 1.03 | 0.20 |
| Least Significant Difference$_{(\alpha=0.05)}$ = 0.33 | | | | | | |
| Impatiens | | | | | | |
| Fine Not Composted Not Charged | 7.32 | 6.40 | 7.32 | 5.68 | 4.35 | 3.93 |
| Fine Not Composted Charged | 7.32 | 7.81 | 7.56 | 7.06 | 0.00 | 2.49 |
| Fine Composted Not Charged | 7.32 | 7.23 | 7.04 | 6.34 | 4.19 | 3.24 |
| Fine Not Composted Charged | 7.32 | 7.18 | 6.37 | 5.46 | 4.48 | 3.76 |
| Coarse Not Composted Not Charged | 7.32 | 5.26 | 5.12 | 4.22 | 3.71 | 2.35 |
| Coarse Not Composted Charged | 7.32 | 7.03 | 6.59 | 5.87 | 3.59 | 4.63 |
| CoarseComposted Not Charged | 7.32 | 8.25 | 7.18 | 6.65 | 5.93 | 4.53 |
| Coarse Composted Charged | 7.32 | 6.83 | 5.89 | 5.32 | 4.60 | 3.34 |
| Poultry Litter | 7.32 | 9.08 | 5.81 | 3.52 | 1.08 | 0.85 |
| Least Significant Difference$_{(\alpha=0.05)}$ = 1.39 | | | | | | |
| Salvia | | | | | | |
| Fine Not Composted Not Charged | 8.82 | 10.10 | 7.17 | 6.98 | 7.08 | 5.47 |
| Fine Not Composted Charged | 8.82 | 11.61 | 11.80 | 11.81 | 11.57 | 4.48 |
| Fine Composted Not Charged | 8.82 | 10.32 | 8.82 | 8.74 | 7.21 | 7.97 |
| Fine Not Composted Charged | 8.82 | 8.18 | 8.43 | 7.10 | 7.04 | 6.03 |
| Coarse Not Composted Not Charged | 8.82 | 8.80 | 8.48 | 8.20 | 6.47 | 5.67 |
| Coarse Not Composted Charged | 8.82 | 8.15 | 7.65 | 5.81 | 6.06 | 6.36 |
| Coarse Composted Not Charged | 8.82 | 7.68 | 7.88 | 8.41 | 7.38 | 5.27 |
| Coarse Composted Charged | 8.82 | 8.86 | 9.26 | 7.34 | 8.53 | 8.08 |
| Poultry Litter | 8.82 | 8.18 | 7.49 | 7.37 | 3.36 | 1.00 |
| Least Significant Difference$_{(\alpha=0.05)}$ = 0.89 | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vinca | | | | | | | |
| Fine Not Composted | Not Charged | 9.81 | 9.61 | 5.97 | 5.32 | 6.45 | 5.22 |
| Fine Not Composted | Charged | 9.81 | 6.09 | 3.18 | 2.02 | 1.08 | 0.00 |
| Fine Composted | Not Charged | 9.81 | 6.23 | 6.43 | 5.59 | 7.63 | 4.45 |
| Fine Not Composted | Charged | 9.81 | 7.31 | 5.65 | 6.18 | 5.42 | 5.62 |
| Coarse Not Composted | Not Charged | 9.81 | 5.14 | 4.82 | 5.06 | 5.86 | 5.32 |
| Coarse Not Composted | Charged | 8.81 | 4.63 | 2.92 | 6.21 | 1.73 | 0.49 |
| Coarse Composted | Not Charged | 9.81 | 7.83 | 3.88 | 6.51 | 7.54 | 5.09 |
| Coarse Composted | Charged | 9.81 | 9.18 | 7.83 | 8.92 | 9.08 | 4.17 |
| Poultry Litter | | 9.81 | 6.39 | 0.74 | 0.48 | 0.10 | 0.00 |
| Least Significant Difference$_{(\alpha=0.05)}$= 1.41 | | | | | | | |

## Rice Hulls as a Vermiculite Substitute in Peat-based Media for Growing Greenhouse Bedding Plants

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**Mississippi**

**Nature of Work:** Rice hulls are a by-product of the rice milling process, a major agricultural industry in Mississippi. With rice hulls in abundant supply, its successful use as a media component will result in an inexpensive media amendment. The objective of this study was to determine the feasibility of using rice hulls as a vermiculite substitute in sphagnum peat-based media for growing greenhouse bedding plants.

Plugs of *Begonia x semperflorens* (begonia), *Impatiens wallerana* (impatiens), *Salvia splendens* (salvia), and *Catharanthus roseus* (vinca) were transplanted into 4 inch (10 cm) pots containing 12 sphagnum peat-based media modified with rice hulls and/or vermiculite. Two rice hull variations were used in this study: fresh rice hulls and composted rice hulls. Each rice hull combination was blended with peat and vermiculite as follows: 5 peat : 5 vermiculite, 5 peat : 4 vermiculite : 1 rice hulls, 5 peat : 3 vermiculite : 2 rice hulls, 5 peat : 2 vermiculite : 3 rice hulls, 5 peat : 1 vermiculite : 4 rice hulls, and 5 peat : 5 rice hulls (by volume). The composted rice hulls were obtained from a five year old static pile. The fresh rice hulls were obtained directly from the mill. Each medium was amended with 10 lb. (4.54 kg) dolomitic limestone, 4.5 lb. (2.04 kg) single super phosphate, 2 lb. (0.90 kg) calcium nitrate, and 2 oz. (60 g) fritted trace elements (FTE No. 555, Grace/Sierra, Fogelsville, PA) per cubic yard of media. The study was conducted as a 2 x 6 factorial completely randomized design for fresh and composted rice hulls. All plants were watered and fertilized with 200 mg N/liter (200 ppm) from 20N 4.4P 16.6K (20-10-20 Peters Peat-lite Special, Grace/Sierra, Fogelsville, PA). Data were analyzed using General Linear Models (SAS Institute, Inc., Cary, NC) for determining linear, quadratic, and cubic response models.

**Results and Discussion:** The addition of rice hulls to the media influenced height and weight of all species tested. Composted rice hulls decreased begonia height in media containing 30 to 50% ; however, plant height in fresh rice hulls was similar at all rates. Dry weight was decreased in media containing 40 to 50% fresh rice hulls in both begonia and impatiens. Fresh and composted rice hull media produced impatiens with heights similar to those of control . Dry weight decreased at 40 to 50% with composted rice hulls in all species except salvia. In salvia, dry weight decreased at 10, 20 and 50% rice hulls . As the rate of both fresh and composted rice hulls increased, plant height decreased.

Results from this study indicated that rice hulls may be a good substitute for vermiculite as a component in sphagnum peat-based media. It appeared that both rice and weed seed germination can be a problem. Media that contained both fresh or composted rice hulls provided better water retention than the control.

**Significance to the Industry:** Production and milling of rice is a large and successful industry in the south and creates a by-product of rice hulls in plentiful supply. The use of rice hulls, either fresh or in composted form, as a component of container growing media shows promise in fulfilling the requirements of good water holding capacity, drainage, and freedom from disease and insect pests. Growers will benefit from having an inexpensive, readily available alternative to current materials in use as plant growth media components.

Table 1. Plant dry weight of *Begonia x semperflorens*, *Impatiens wallerana*, *Salvia splendens*, and *Catharanthus roseus* as influenced by rice hulls composted or fresh, replacing vermiculite in the media.

| | Rice hulls (%) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | 40 | 50 |
| ------------ height (cm) ------------ | | | | | | |
| Begonia | | | | | | |
| Not Composted | 11.00 | 7.60 | 7.66 | 8.16 | 9.02 | 7.81 |
| Composted | 11.00 | 10.34 | 10.90 | 10.15 | 8.15 | 5.80 |
| Impatiens | | | | | | |
| Composted | 14.16 | 20.36 | 22.75 | 22.72 | 23.12 | 20.09 |
| Not Composted | 14.16 | 23.04 | 26.90 | 26.00 | 25.68 | 20.72 |
| Salvia | | | | | | |
| Composted | 29.72 | 32.10 | 34.18 | 33.80 | 33.56 | 33.42 |
| Not Composted | 29.72 | 31.58 | 33.08 | 31.62 | 34.00 | 30.08 |
| Vinca | | | | | | |
| Composted | 18.68 | 20.04 | 20.30 | . | 20.05 | 13.70 |
| Not Composted | 18.68 | 21.36 | 17.74 | 19.78 | 17.42 | 15.38 |

Least Significant Difference$_{( =0.05)}$= 4.57 ∞

| | | | | | | |
|---|---|---|---|---|---|---|
| ------------- weight (g) ---------- | | | | | | |
| Begonia | | | | | | |
| Not Composted | 3.36 | 2.36 | 2.54 | 2.81 | 3.02 | 2.05 |
| Composted | 3.36 | 2.57 | 3.48 | 2.87 | 2.49 | 1.41 |
| Impatiens | | | | | | |
| Composted | 7.32 | 6.51 | 6.65 | 7.47 | 6.31 | 5.81 |
| Not Composted | 7.32 | 7.64 | 8.24 | 8.00 | 7.39 | 6.33 |
| Salvia | | | | | | |
| Composted | 8.82 | 5.49 | 6.37 | 5.55 | 6.87 | 5.47 |
| Not Composted | 8.82 | 6.88 | 6.84 | 8.57 | 9.00 | 5.51 |
| Vinca | | | | | | |
| Composted | 9.81 | 4.65 | 7.18 | 0.00 | 2.67 | 1.64 |
| Not Composted | 9.81 | 4.96 | 3.64 | 4.31 | 1.82 | 4.23 |

Least Significant Difference$_{( =0.05)}$= 1.17

# Cotton Gin Trash as a Medium Component in Production of 'Golden Bedder' Coleus

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**Nature of Work:** The utilization of waste materials for use in horticultural production media has recently been receiving considerable attention. One potential agronomic waste product having potential utilization in this area is composted cotton gin trash. Primarily, cotton gin trash is being investigated as a peat moss substitute. The objective of a recent research project was to determine the influence of varying proportions of pine bark and composted cotton gin trash on the growth of Coleus x hybridus 'Golden Bedder'.

A completely randomized experiment was initiated in a greenhouse September 24, 1992. Rooted cuttings of Coleus x hybridus 'Golden Bedder' were pinched to 3 nodes and planted into 6" azalea pots (1 cutting/pot) containing varying volumetric proportions of composted cotton gin trash and pine bark. Media evaluated included 100% pine bark, 80% pine bark with 20% cotton gin trash, 60% pine bark with 40% cotton gin trash, 40% pine bark with 60% cotton gin trash, 20% pine bark with 80% cotton gin trash, and 100% cotton gin trash. Dolomite and Micromax were incorporated into each media at the rate of 8 and 1.5 lbs/yd$^3$, respectively. Water soluble fertilizer was applied weekly at 200 ppm N.

Plant height was measured October 19, 1992 (25 days after potting) and at experiment termination on November 5, 1992 (42 days after potting). Visual quality ratings (1 =worst, 9=best) and shoot dry weights were also determined at experiment termination.

**Results and Discussion:** Coleus growing in media containing 20-40% (by volume) composted cotton gin trash had increased plant height at 25 days after potting when compared to plants growing in 100% pine bark or 80-100% cotton gin trash (Table 1). By 42 days after potting, variations in plant height were not as great; however, coleus growing in 100% cotton gin trash had significantly lower plant heights tnan coleus growing in all other media.

Coleus in media containing 20-40% cotton gin trash has the significantly highest visual quality ratings (Table 1). Quality was especially decreased when cotton gin trash constituted 60% or greater of the media.

Shoot dry weight accumulation was highest for plants growing in 40% cotton gin trash/60% pine bark, although this was not significantly different from plants growing in 20, 60 or 80% cotton gin trash (Table 1). Coleus growing in 100% cotton gin trash had a significantly reduced shoot dry weight when compared to plants growing in all other media.

**Significance to Industry:** The potential utilization of cotton gin trash in the horticulture industry would assist the cotton industry by rernoval of a waste product. Cotton gin trash can be successfully used as a peat moss replacement in container production of 'Golden Bedder' coleus as long as the total volume of cotton gin trash in the medium does not exceed 40%.

Table 1. Growth characteristics of 'Golden Bedder' coleus as influenced by volumetric percentages of cotton gin trash and pine bark in growing medium.

| % volume | | Plant Height (cm) | | Shoot Dry Wt. | Visual |
|---|---|---|---|---|---|
| Cotton Gin Trash | Pine Bark | 25 DAP[x] | 42 DAP[x] | (g) | Quality[z] |
| 0 | 100 | 12.8 b[y] | 20.0 ab | 2.47 b | 6.3 ab |
| 20 | 80 | 15.0 a | 20.8 ab | 2.80 ab | 6.8 a |
| 40 | 60 | 14.8 a | 21.7 a | 3.10 a | 7.2 a |
| 60 | 40 | 13.2 ab | 20.7 ab | 2.82 ab | 5.7 bc |
| 80 | 20 | 11.5 bc | 19.2 b | 2.68 ab | 5.2 cd |
| 100 | 0 | 10.0 c | 16.2 c | 1.79 c | 4.3 d |

[z]Visual quality ratings based on a scale from 1 to 9 (1 = worst, 9 = best).
[y]Means within columns separated by Duncan's multiple range test (alpha = 0.05).
[x]DAP = days after potting.

# Response of 'Burfordii Compacta', 'Parsonii' Juniper, and Indian Hawthorn to Fertilizer Rate

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**Nature of Work:** Application rates for fertilizers containing urea-formaldehyde have not been established for container production of woody landscape plants; although, limited information is available on their response to urea-formaldehyde. Furuta and Martin (2) evaluated the response of several woody plants to surface applications of urea-formaldehyde or 8-0-8 plus superphosphate (20% $P_2O_5$, 6 g per container). Greater shoot fresh weights occurred for 11 of 17 plant cultivars and species when a total of 11.4 g of N as urea-formaldehyde per 3 quart
container were split into monthly applications, than when 11.4 g of N from 8-0-8 was applied as weekly applications. Benjamin et al. (1) fertilized *Weigela* 'Bristol Ruby' with surface applications of urea-formaldehyde or an ammonium nitrate solution. *Weigela* shoot dry weights were greatest when a total of 9.5 g of N from urea-formaldehyde were applied every 30 days during the growing season. A total of 8.7 or 11.4 g of N applied as bimonthly applications of urea-formaldehyde did not result in shoot dry weights different from 4.0 g of N applied as weekly applications of the ammonium nitrate solution. The purpose of this study was to determine an optimal application rate for surface applications of Marico 18-4-10-2, a fertilizer with N as urea-formaldehyde.

Five hundred multiple branched liners of *Ilex cornuta* 'Burfordii Compacta', *Juniperus chinensis* 'Parsonii', and *Raphiolepis indica* Indian Hawthorn (white) were potted in Mar. 1989 in trade 1 gal containers using a 47.5% native peat : 27.5% pine bark : 17.5% cypress mulch : 7.5% sand (by volume) growth medium amended with dolomitic limestone (7 lb/yd$^3$), urea-formaldehyde (0.9 lb/N yd$^3$), and Rally micronutrients (3 lb/yd$^3$, Growers Fertilizer Cooperative, Lake Alfred, Florida). Plants were grown on polypropylene ground cover at Greenbriar Nurseries, Inc., Dunnellon, Florida in a randomized complete block design with 10 replicate plants for each fertilizer treatment in each of 10 blocks. Marico 18-4-10-2 (Seminole Stores, Inc., Ocala, Florida) granular fertilizer containing urea-formaldehyde N was surface-applied at 4 rates (Table 1) and Prokote 20-3-10 (O. M. Scott and Sons Co., Marysville, Ohio) was incorporated (14.4 lb/yd$^3$) into the growth medium of 1 treatment. Plants received one-third inch of water by overhead irrigation as needed and on Oct. 17 plants were rated on a scale of 1 (poor) - 7 (outstanding) by 20 nursery operators. Ratings were based on the operator's perception of plant quality related to expectations for plants of similar age. On 29 Dec. 1989 growth measurements were made for 3 plants of each block for each treatment (30 plants per treatment per species). *Ilex* and *Raphiolepis* shoot heights were measured to tip of tallest shoot and maximum shoot width and perpendicular width were measured for Juniperus.

Plants fertilized with Prokote and 5.76 and 8.64 g N from Marico were repotted Jan. 1990 using a 54% native peat : 27% pine bark : 9.5% cypress sawdust : 9.5% sand (by volume) growth medium in trade 3 gal containers. Growth medium amendments, cultural protocols and experimental design were the same as in 1989. Marico 18-4-10-2 and Prokote 20-3-10 application rates are given in Table 1. On 16 Oct. 1990 plants were rated by 33 nursery operators and on 26 Nov. 1990 growth measurements were made as in 1989 with additional determinations for *Raphiolepis* widths.

**Results and Discussion:** Height of *Ilex* and *Raphiolepis* and width of *Juniperus* grown in 1 gal containers increased as Marico N application rate increased to 8.64 g N per container (Table 2). Heights of Ilex and Raphiolepis fertilized with Marico at 4.31 g N per container were not significantly different from heights of plants receiving 4.20 g of N from Prokote, even though Prokote was incorporated in growth medium at beginning of experiment and Marico was surface- applied 5 times. Plant quality rankings were not consistent with N application rates (Table 3). *Juniperus* and *Raphiolepis* rankings were highest for Marico applied at 8.64 g N. *Ilex* plants fertilized with Marico at 5.76 g of N received the highest ranking.

After 10 months in 3 gal containers, heights of *Ilex* and widths of Juniperus were not significantly different for plants that received 12.4 g N from Prokote 20-3-10 surface-applied once or a total of 14.76 or 22.14 g N from 5 applications of Marico 18-4-10-2 (Table 2). However, growth index for *Raphiolepis* was greater for plants fertilized with Marico at 14.76 or 22.14 g N per container. Plant quality rankings for the 3 genera in 1989 and 1990 (Table 3) indicated that amount of N needed to produce marketable plants of good to excellent quality varies with genera. Consequently, nursery operators should evaluate plant response to fertilizer applications rates in order to use fertilizers efficiently and minimize nutrient loss from the production area.

**Significance to Industry:** Our data indicate that response to fertility regime varies with genera. One and 3 gal Indian Hawthorn growth (heights and growth index, respectively) was greatest when 5 applications of Marico 18-4-10-2 were used that provided 19 to 105% more total N per container than a single application of Prokote 20-3-10 controlled-release fertilizer. However, heights of 1 and 3 gal 'Burfordii Compacta' and widths of 3 gal 'Parsonii' juniper were not different for these treatments.

## Literature Cited

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Florida Agricultural Experiment Stations Journal Series No. N-00795. The authors thank Greenbriar Nurseries, Inc., Dunnellon, Florida for their cooperation. Trade names and companies are mentioned with the understanding that no endorsement is intended nor discrimination of similar products implied.

Table 1. Fertilizers applied to *Ilex comuta* 'Burfordii Compacta', *Juniperus chinensis* 'Parsonii', and *Raphiolepis indica* Indian Hawthorn.

***Plants potted Mar. 1989 and grown in trade 1gal containers***

| Grams N/container per year | Marico 18-4-10-2 surface application date (g/container) | | | | |
|---|---|---|---|---|---|
| | Apr. 5 | May 10 | July 14 | Aug. 29 | Oct. 31 |
| 2.88 | 3.50 | 3.13 | 3.13 | 3.13 | 3.13 |
| 4.31 | 5.25 | 4.68 | 4.68 | 4.68 | 4.68 |
| 5.76 | 7.00 | 6.25 | 6.25 | 6.25 | 6.25 |
| 8.64 | 10.50 | 9.38 | 9.38 | 9.38 | 9.38 |
| 4.20 | Prokote 20-3-10 incorporated in growth medium (21 g per container) | | | | |

***Plants potted In Jan. 1990 and grown In trade 3 gal containers***

| Grams N/container per year | Marico 18-4-10-2 surface application date (g/container) | | | | |
|---|---|---|---|---|---|
| | Apr. 16 | June 15 | July 25 | Sep. 6 | Oct. 30 |
| 14.76 | 16.4 | 16.4 | 16.4 | 16.4 | 16.4 |
| 22.14 | 24.6 | 24.6 | 24.6 | 24.6 | 24.6 |
| 12.40 | Prokote 20-3-10 surface-applied (62 g per container) | | | | |

Table 2. Growth parameters of *Ilex cornuta* 'Burfordii Compacta', *Juniperus chinensis* 'Parsonii', and *Raphiolepis indica* Indian Hawthorn.

***Growth parameters affer 9 months growth in trade 1gal containers***

| | Ilex | Juniperus | Raphiolepis | |
|---|---|---|---|---|
| Grams N/container peryear | Height (cm) | Width[y] (cm) | Height (cm) | Growth index[x] |
| Marico 18-4-10-2[z] | | | | |
| 2.88 | 34*[w] | 47 | 20 | - |
| 4.31 | 37 | 51* | 20 | - |
| 5.76 | 40 | 49* | 23* | - |
| 8.64 | 42 | 55* | 23* | - |
| Prokote 20-3-10 incorporated in growth medium | | | | |
| 4.20 | 40 | 44 | 19 | - |

***Growth parameters after 10 months growth in trade 3 gal containers***

| | Ilex | Juniperus | Raphiolepis | |
|---|---|---|---|---|
| Grams N/container peryear | Height (cm) | Width[y] (cm) | Height (cm) | Growth index[x] |
| Marico 18-4-10-2[z] | | | | |
| 14.76 | 74 | 79 | - | 101* |
| 22.14 | 76 | 78 | - | 101* |
| Prokote 20-3-10 surface-applied once | | | | |
| 12.40 | 72 | 76 | - | 92 |

[z] Marico divided into 5 surface applications. Data are mean of 30 plants.
[y] Width = (width 1 + width 2)/2
[x] Growth index = height + (width1 + width2)/2
[w] *= Significantly different from Prokote by Dunnett's test (5% level) within container size.

Table 3. Plant quality rankings for Ilex comuta 'Burfordii Compacta', *Juniperus chinensis* 'Parsonii', and *Raphiolepis indica* Indian Hawthorn.

***Rankings after 7 months growth In trade 1 gal containers***

| Grams N/container per year | *Ilex* | *Juniperus* | *Raphiolepis* |
|---|---|---|---|
| Marico 18-4-10-2[z] | | | |
| 2.88 | 3[y] | 1 | 4 |
| 4.31 | 1 | 4 | 3 |
| 5.76 | 5 | 2 | 2 |
| 8.64 | 4 | 5 | 5 |
| Prokote 20-3-10 incorporated in growth medium | | | |
| 4.20 | 2 | 3 | 1 |

***Rankings after 9 months growth In trade 3 gal containers***

| Grams N/container per year | *Ilex* | *Juniperus* | *Raphiolepis* |
|---|---|---|---|
| Marico 18-4-10-2[z] | | | |
| 14.76 | 4 | 4 | 5 |
| 22.14 | 3 | 5 | 4 |
| Prokote 20-3-10 surface-applied once | | | |
| 12.40 | 5 | 3 | 3 |

[z] Marico divided into 5 surface applications.

[y] Rankings (5 = highest) within container size were calculated from ratings based on 1 = poor, 7 = outstanding.

# Root Modification of Container-Grown Azaleas using Spin Out™

**Bonnie Lee Appleton and Audrey 8alzman**
**Virginia**

**Nature of Work:** One of the major reasons for decline and death of many azaleas planted to the landscape is failure of their roots to grow out from the root ball into the surrounding soil. While several factors, including narrow planting holes and clay soil, contribute to this problem, a major factor is the mat of roots that often forms on the outside of root balls of container-grown azaleas.

Numerous containers have been designed with modifications that reduce or prevent circling root formation on trees (1). Some of these containers have been tried with azaleas. While these modified containers "significantly reduced root circling", the percent of the root ball surface covered with roots was unaffected by container design (6). Since azalea roots are fine and fibrous and tend to mat, surface covering is probably far more a concern than circling roots.

Another method proving successful for modifying circling tree roots involves the use of copper coatings on container interior surfaces (2, 3, 4, 5). The objective of this study was to determine whether copper-coated containers would reduce or eliminate root matting on the balls of container-grown azaleas.

Uniform liners of Rhododendron 'Sherwood Red' were potted 22 June 1992 in a 3:1:1 (v:v:v) pine bark:peat moss:sand medium. Four one gallon container treatments were used: fiber containers (Keiding Inc., Milwaukee, WI) with or without copper incorporated into the fiber, and 'Poly-tainer' smooth wall plastic containers (Nursery Supply, Fairless Hills, PA) with or without the copper-containing product Spin Out™ (Griffin Corporation, Valdosta, GA) painted on the interior container surface. Plants were topdressed with 18 g. Osmocote 17-6-10 and grown under overhead irrigation.

Each container treatment was replicated 10 times in a randomized complete block. Five replications were harvested on 11 November 1992 for growth measurements, with the remaining five replications planted to the landscape to evaluate transplant root growth. Additional liners were directly field planted on 22 June 1992 to be added to the November transplant evaluation to compare the landscape establishment of container-grown vs. field-grown azalea roots.

**Results and Discussion:** After five and a half months, azaleas grown in either the fiber or the plastic containers without copper had heavily matted roots on the outside of the medium root ball. Virtually no roots were visible on the outside of the medium root ball for the azaleas grown in either copper-treated container. There were no significant differences in plant growth measurement or shoot or root dry weight, although plants from copper-treated containers were slightly heavier.

The five November-transplanted replications were dug on 15 July 1993. Root ball differences were very visually evident. Azaleas from both copper-treated containers had field soil adhering to their roots, whereas azaleas from untreated containers pulled easily from the soil with no adhering soil. All container-grown azaleas were significantly larger (root and shoot dry weight) than the field-grown azaleas.

Dry root weights were not significant different for any container-grown azaleas. Azaleas grown in either fiber container had significantly more shoot dry weight than those grown in the copper-treated plastic containers, presumably due to a slightly larger medium volume and better root system aeration. Greater differences might develop with a longer field evaluation period.

**Significance to Industry:** Use of a copper-treated container (fiber or plastic) appears to be highly effective in eliminating the problem of matted root systems developing on the outside of container-grown azalea root balls. Use of azaleas grown in copper-treated containers should improve the success of transplanting azaleas to the landscape.

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## Wood Waste Compost As A Potting Medium Amendment

**William G. Lord, T.E. Bilderback and Lia Hight**
**North Carolina**

**Nature of Work:** Diversion of yard waste and other organic wastes from landfills has created a boom in public and private composting operations. While there is considerable diversity in finished products, some composts show promise as components of commercial nursery potting substrates. Wood waste compost used in this study was produced from ground particle board, plywood, pine dimensional lumber, and swine lagoon effluent. Wood waste was composted for eighteen months and was biologically stable. The purpose of this study was to compare physical and chemical properties and plant response to a commercial nursery's standard mix and two compost amended mixes under commercial nursery conditions.

Ilex x 'Nellie R. Stevens' liners were potted into 1 gal. (3.8.1) containers on 4 May 1992 with one of three substrates. The Cedar Creek Standard media consisted of pine bark and sand (5:1, v/v) amended with 1.5 lbs micronutrients (C-Trel; Coor Farm Supply Service, Inc., Smithfield, NC), 3 lbs 0-46-0, 3 lbs gypsum, 12 lbs dolomitic lime, 4 lbs Osmocote 20-16-18 and 3 lbs 0-0-60 per yard. The wood waste compost mix was formulated as 90:10 (v/v) Standard mix plus wood waste compost. A pine bark/turkey litter/rock wool mix was formulated as 70:15:15 by (v/v/v). Liners were transplanted in 10 replications in a completely random block design on a polypropylene fabric growing area under full sun. Containers were overhead irrigated daily with approximately 1 inch (2.54 cm.).

Six fallow pots of each substrate were treated as containers with plants and used to evaluate for physical properties at the end of the study. Electrical conductivity, pH, nitrate-N, ammonium-N, and P levels were determined by water extraction (VTEM) at potting and every three weeks thereafter. Foliar tissues samples were taken midway through the study and analyzed for N, P, K, Ca, and Mg. At the end of the study plant shoot and root dry weights were measured.

**Results and Discussion:** Particle size distributions of the three substrates were very similar. Physical properties, including container capacity, unavailable water, and available water values were similar for the three substrates though the PTR mix had lower bulk density. The pH of the Cedar Creek Standard was generally lower that pH of the two compost substrates, but pH rose throughout the study for all substrates, probably due to pH 6.6 irrigation water.

Electrical conductivity (E) was excessive on the day of potting for all substrates (Table 1). After 22 days, the EC levels remained very high. The prolonged period of high EC levels could have injured roots, stunted plant top growth and reduced survival of the plants. EC levels throughout the remaining portion of the study were within the published guidelines for container solutions; however, they were generally higher than normally found with slow release fertilizers in containers. Irrigation water contribution to EC was negligible.

Ammonium nitrogen levels appeared to be one of the major sources for the high EC values after potting. All substrates had excessively high ammonium-N levels. Because the compost substrates also had elevated nitrate-N levels, nitrification from ammonium had probably begun and contributed to high EC values. On day 22, compost substrates had N levels that were nearly evenly distributed between ammonium-N and nitrate-N, but thereafter most nitrogen was present as nitrate-N. Although N values from day 1 to 42 were in the very high range, N levels after day 42 were considered deficient.

As with nitrogen levels, phosphorus levels in leachates immediately after potting appeared to be excessive in all substrates, although the WWC and the CCS leachates contained much less phosphate than the PTR. These levels of P also contributed to elevated EC levels. Phosphate levels for the PTR substrate generally remained higher than the other substrates throughout the study. Liquid fertility guidelines recommend 10 to 15 ppm P in container solution. All substrates exceeded this level until day 77, fell within this range on day 77, and were generally below this level thereafter.

Top and root weights were not different among substrates. In general, the growth of the plants in all three substrates was less than desirable. Although there were differences between tissue nutrient content of plants grown in all substrates, nutrient levels fell within mid-season-suggested levels for each element.

**Significance to Industry:** Physical properties were similar between substrates and did not contribute greatly to differences in chemical properties affected by drainage and water movement, or to plant growth differences. The major finding of this study was excessive EC values observed initially and through day 22. With these excessive EC levels irrigation management would have required frequent and thorough irrigations, possibly three irrigations per day. In the absence of this management, high soluble salts undoubtedly injured roots and reduced top growth.

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Table 1. Container leachate electric conductivity (EC) levels from 3 substrates on 7 sampling dates.[z]

| Substrate | Sampling Dates (Days after potting) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 22 | 42 | 77 | 99 | 120 | 141 |
| | EC (mmhos/cm) | | | | | | |
| | ns | ns | | ns | ns | | ns |
| CCS | 10.9 | 3.3 | 0.9a | 0.3 | 0.15 | 0.20b | 0.21 |
| WWC | 11.3 | 3.4 | 0.6b | 0.2 | 0.13 | 0.18b | 0.21 |
| PTR | 11.6 | 3.8 | 0.9a | 0.2 | 0.15 | 0.25a | 0.21 |

[z]Suggested liquid fertilizer solution EC levels: 0.5 to 2.0 mmhos/cm for VTEM leachates. Each value represents the mean of 3 leachate samples.

# Effects of $Cu(OH)_2$-Treated Containers on the Leaf Water Potential of Greenhouse-Grown Tropical Hibiscus

**Gary N. Case and Michael A. Arnold**
**Tennessee and Texas**

**Nature of the Work:** If ornamental crops are grown for an extended period of time in containers, a substantial amount of roots will develop at the container wall-media interface, i.e. they become pot-bound. Pot-bound plants become increasingly difficult to maintain at adequate moisture levels. Coating interior surfaces of containers with various copper-containing compounds reduces formation of circled, kinked, and matted roots at the container wall-media interface (1, 2, 3, 4, 5), induces a more fibrous root system ( 1, 2), and in some cases alters root distribution within the rootball (3). Some species (cultivars?) grown in copper-treated containers have increased growth (1, 2, 3, 4) or flowering (1, 5) compared to those grown in non-treated containers. Flowering of chenille plants (Acalypha hispida Burm.) in copper-treated containers was maintained or continued to increase while the flowering of similar aged pot-grown plants in non-treated containers was reduced (5). This suggested that copper-treated containers might influence water utilization during production. The objective of the current study was to determine if cupric hydroxide-treated containers altered leaf water potential of tropical hibiscus (Hibiscus rosa-sinensis L.), an important greenhouse and tropical landscape species, during container production.

Two experiments were initiated on 22 August 1992. The first experiment measured effects of $Cu(OH)_2$-treated containers on growth, flowering, and mid-day and pre-dawn leaf water potentials during hibiscus production. Fifteen hibiscus liners (2" pots, Burgess Falls Nursery, Cookeville, TN) were transplanted to 6-inch plastic containers painted on interior surfaces with 100 9 $Cu(OH)_2$/1iter (7.1% wt/wt; Spin Out™;Griffin Corp., Valdosta, GA) and 15 non-treated containers using Pro-Mix BX media (Premier Brands, Stamford, Conn.). Plants were grown in a greenhouse under natural photoperiods (Cookeville, TN) with day/night temperatures set at 75/65°F, in a completely random design. Weekly fertilizations of 300 ppm 19-19-19 water-soluble fertilizer were applied. Plants were watered by hand in the early morning. Water potentials of the most recently fully expanded leaves of each plant were measured (Model 600 pressure chamber, PMS Instrument Cp., Corvallis, OR) at mid-day and prior to dawn of the following morning at about 14 day intervals for the next 140 days. Shoot height, crown diameter and flower number were recorded at 14 day intervals. Root and shoot dry weights were determined at the end of the study.

In the second experiment, designed to determine if $Cu(OH)_2$-treated containers altered the time course of daily changes in leaf water potential compared to plants grown in non-treated containers, 40 liners were transplanted to 20 $Cu(OH)_2$-treated and 20 non-treated containers. Cultural conditions were as described in the first experiment. On day 21 after planting, leaf water potentials of five plants of each container treatment were measured at two hour intervals from pre-dawn to dusk and again prior to dawn of the following day. These plants were then harvested for morphological measurements as described in the first experiment. This procedure was repeated at 70, 112, and 147 days after planting.

**Results and Discussion:** As previously reported (5) $Cu(OH)_2$-treated containers nearly eliminated development of circled, kinked, and matted roots and resulted in a root system with a more fibrous appearance. In experiment 1, both mid-day and pre-dawn leaf water potentials for plants grown in treated and non-treated containers were similar the first 84 days after planting (Fig. 1). As plants became pot-bound, days 98 to 140 after planting, those grown in $Cu(OH)_2$-treated containers tended to have less negative mid-day leaf water potentials (Fig. 1). At 140 days after planting, plants grown in non-treated containers did not appear to recover from the mid-day water stress as fully as those grown in $Cu(OH)_2$-treated containers (Fig. 1).

Container treatments did not appear to alter the timing of peak mid-day water deficits (data not presented). Water potential measurements throughout the study would be characterized as mild to moderate, probably due to the moderate climate and well-watered conditions in the greenhouse. No significant differences in shoot growth or flowering were observed among treatments (data not presented). This would be consistent with the lack of severe water stress observed. While water potential differences under these mild greenhouse conditions did not result in growth or flowering differences, if the same pattern of moderation of mid-day water potentials holds under more stressful outdoor container production conditions, significant effects on growth or flowering might occur.

**Significance to Industry:** Cupric hydroxide-treated containers were shown to moderate mid-day leaf water potential deficits as tropical hibiscus plants became pot-bound under mild greenhouse conditions. If similar patterns of leaf water stress moderation hold under more stressful outdoor conditions, $Cu(OH)_2$-treated containers might provide a means of moderating water stress without the application of additional quantities of water.

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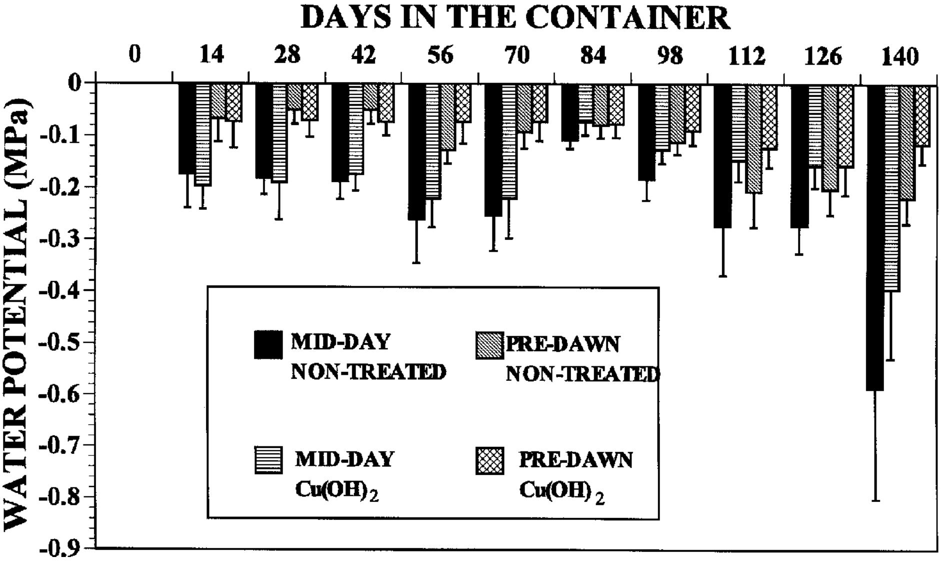
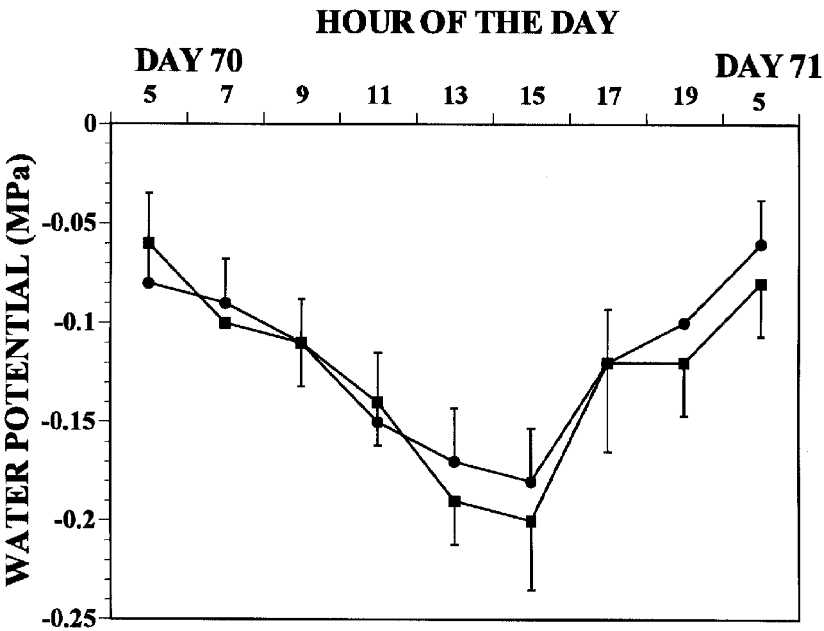
Fig. 1. Mid-day and subsequent pre-dawn leaf water potentials, at bi-weekly intervals from 14 to 140 days after transplanting, of tropical hibiscus grown in 6 in. plastic Cu(OH)2-treated or non-treated containers. Data points are means + standard deviations of 15 observations.






## Slow Release Fertilizer Evaluations on Coral Bells Azalea

**James T. Midcap**
**Georgia**

**Nature of Work:** Slow release fertilizers are an integral part of the fertilization programs of most container nurseries. Plant growth and nutrient release characteristics are dependent upon the product used, fertilization rate, plant species and environmental conditions[1,2,3]. Product evaluations continue to illustrate a need to improve fertility programs to promote growth and reduce negative environmental impact(4).

The objective of the study was to compare slow release fertilizer products at three rates on the growth of *Rhododendron obtusum* 'Coral Bells'. Uniform second year gallons of Coral Bells azalea were grown in a 9:1 pine bark:sand medium. The medium was topdressed in the fall with micro elements. Fertilizer treatments of Prokote 20-3-10, Sierra 17-6-10, Sierrablen 17-7-10 and High N 24-4-7were applied on March 12.

Sierra and Prokote materials are eight to nine month products while Sierrablen and High N are twelve to fourteen month products. The materials were applied at low, medium and high rates derived from manufacturers recommendations and presented in Table 1. Plants were produced at McCorkle's Nursery in Dearing, Georgia, under normal production practices.

Table 1.

| Fertilizer Products | Rates In Grams | | |
|---|---|---|---|
| | Low | Medium | High |
| Prokote 20-3-10 | 13 | 18 | 22 |
| Sierra 17-6-10 | 10 | 15 | 20.5 |
| Sierrablen 17-7-10 | 12 | 18 | 24 |
| High N 24-4-7 | 9 | 12 | 16 |

Plant growth was evaluated by determining top dry weight in July and November of ten replicated samples. Each treatment was visually evaluated and ranked in November. Treatment means were compared by Student-Newman-Keuls Test at the 0.05 significance level. Leaf tissue was analyzed for major and minor nutrients in July and November. Nursery medium samples for all treatments (four replicates each) were analyzed for soluble salts and all macro elements every two weeks throughout the growing season. Only the nitrate levels are reported.

**Results and Discussion:** Plant growth based on top dry weight showed little difference by July for all treatments. The Sierrablen (medium rate) produced significantly more growth (top weight) than Sierra (low rate) but was not different from all other treatments. By November Prokote (medium rate) had produced more growth than Sierra (medium rate) and Sierrablen (low rate) but was not different from all other treatments (Figure 1). The visual ratings assigned in November were greatest for Prokote (medium and high rate) and Sierra (high rate) but not different from High N (high rate) (Figure 2).

The composite leaf tissue samples exhibited a dramatic nitrogen decrease from July to November for all treatments (Figure 3). In July all treatments were above 1.5%, the minimum recommended nitrogen level, while in November only Prokote (medium rate), High N (low, medium and high rates) were above 1.5%. The High N treatments, which released increased nitrogen at mid season, and Prokote (medium rate) maintained tissue nitrogen above the minimum levels.

Nitrates recovered from the medium throughout the growing season illustrate various patterns of release for the treatments (Figure 4). Prokote exhibited a high initial release the first eight weeks prior to the end of July. Prokote (medium and high rate) released considerably more nitrate nitrogen than the low rate of application. Nitrate from Sierra released low initially and built to higher levels in May, June and July, but rates were extremely low from August 17 to the end of the sampling. Sierrablen released at a very high initial rate and exhibited a short peak in June and mid-July through mid-August. High N released nitrates slowly for the first six weeks. Release rates increased from June 7 until August 3, when rates dropped dramatically except for a brief increase on September 18. All nitrate levels by the end of the season were extremely low.

In summary Prokote (medium and high rate) and Sierra (high rate) produced better quality plants with acceptable growth. Prokote and Sierra treatments released heavier the first half of the season. Sierrablen release heavy very early with a mid season rebound. High N, however, peaked at mid season with low levels early and late. Nitrogen levels from leaf tissue in November were much lower than those taken in July with several treatments having deficient levels. The nitrate levels from the medium were extremely low by November. Optimum nutrient levels were not maintained by any treatment throughout the production season. Improved products are needed to promote growth and quality.

**Significance To The Industry:** Evaluation of slow release fertilizers indicates that mid season fertilization may be necessary to promote maximum growth of the products evaluated. Additional research will be necessary to determine if costly slow release fertilizers are economically feasible.

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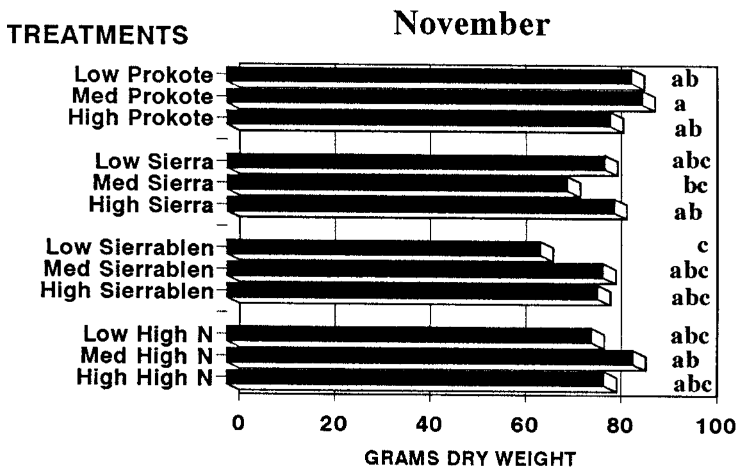
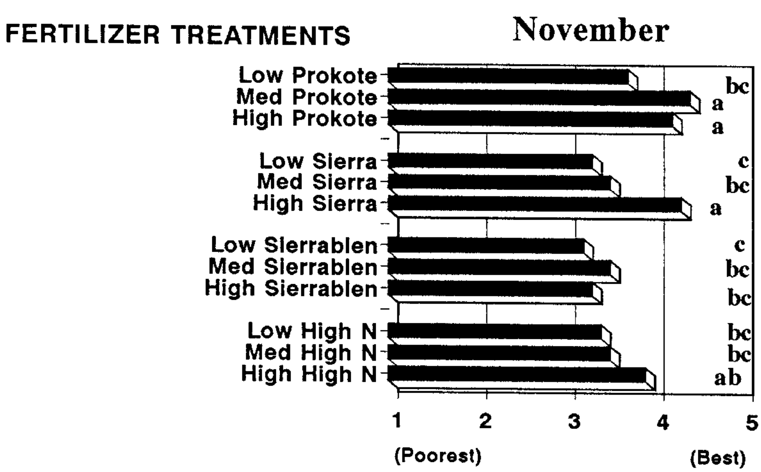
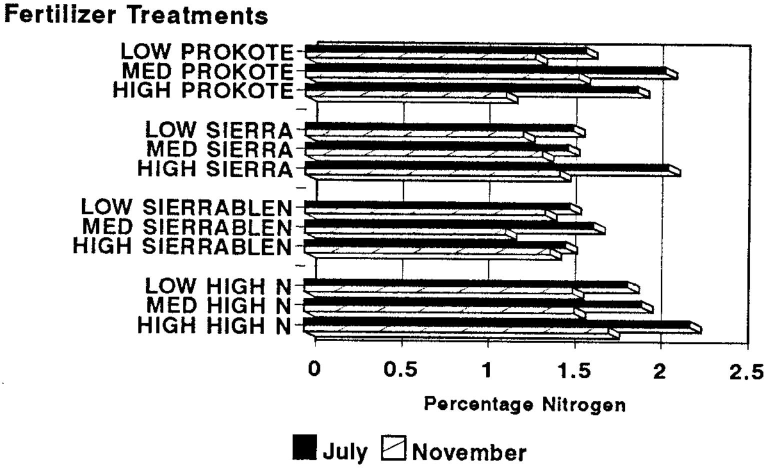
# Figure 1. DRY WEIGHTS
## GRAMS TOP GROWTH




# Figure 2. VISUAL RATINGS
## ADJUSTED RANKING AVERAGES

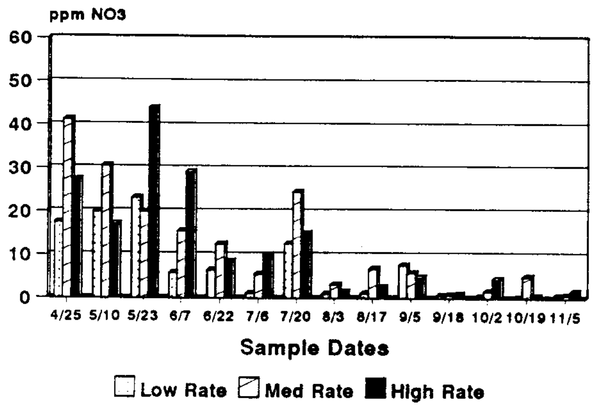


# Figure 3. TISSUE ANALYSIS
## PERCENT NITROGEN

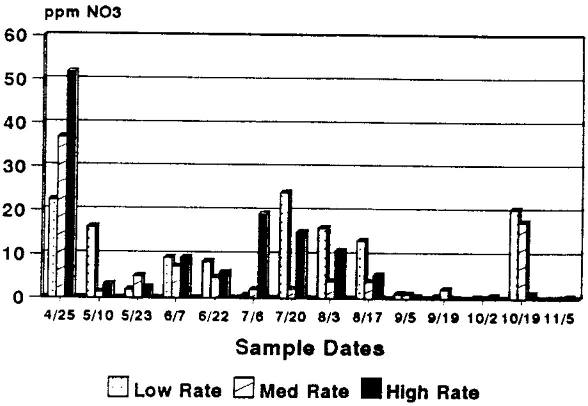



# Figure 4. NITRATE RECOVERY

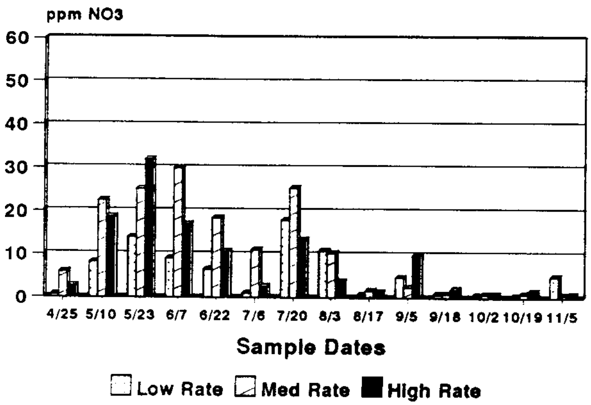
## PROKOTE TREATMENTS



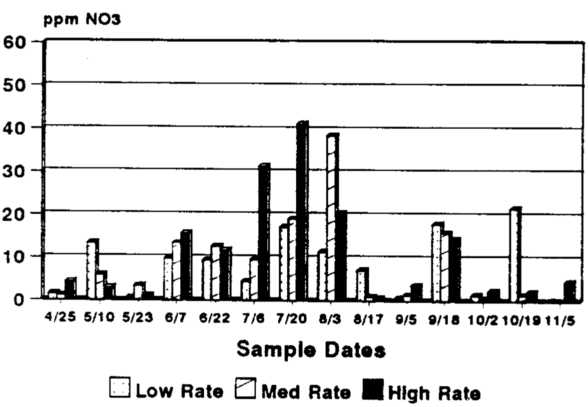
## SIERRABLEN TREATMENTS




## SIERRA TREATMENTS




## HIGH N TREATMENTS



# Monitoring $NO_3$- Losses In Leachates From Controlled-Release Fertilizers During Azalea Production

**Kevin Tucker and Don Wagner**
**South Carolina**

**Nature of Work:** Current concerns regarding nitrate concentrations in runoff from container nurseries prompted this study(1,2,3). Our objectives were: (a) to determine the influence of some controlled-release N-source fertilizers on the efficiency of N utilization, and (b) to quantify the amounts of nitrate lost to ornamentals, as leachate from containerized plants, that would potentially impact surface water runoff. Thirty-five azalea liners *(Mrs.G.G.Gerbing)* were potted in nursery gallon (2.8 liters) plastic containers filled with 34 oz (965 g) oven dry weight (ODW) pine bark growing medium (pH 6.37) on March 19, 1992. Fertilizer treatments; (1) Osmocote 18-6-12, (2) extra coarse IBDU (XCIBDU), (3) Escote 400, (4) XCIBDU + Escote 400 (1:1), and (5) a control (0% N); were top-dressed at the rate of .706 oz (20 gms)/pot (3600 mg N/pot) on March 26. P and K were supplied to treatments 2, 3, 4 and 5 only, at a rate comparable to that of the Osmocote treatment. The pots were placed in a glass greenhouse with shade (50%) at Clemson University and replicated five times in a completely randomized design. An initial leaching was performed on March 26 and weekly for sixteen weeks, thereafter. Visual plant ratings ( 1-9, with 9 best) were made on a biweekly basis. Roots were observed and visual evaluations ( 1-9) made at study termination. Above ground portions of plants were harvested at study termination, dried for two weeks at 176 F (80°C) and analyzed for total N using Kjeldahl digestion. Media pH were determined to be within an acceptable range for azalea at study termination (Data not shown). Air temperatures were monitored and found to be between 100 - 59°F (37.7 - 14.9°C) and media temperatures between 89 - 59°F (31.7 - 15.0°C), respectively, during the study.

**Results and Discussion:** The following trends were observed involving treatments 1-5. Osmocote began losing significant amounts of nitrate-N in the leachate within the first few weeks of the study, with the losses peaking about week six, then starting a downward trend for the duration of the experiment (Fig 1). The leachate loss curves for the Escote, XCIBDU, and XCIBDU + Escote were similar to each other and peaked around week twelve. Total N lost through leachate at termination was less in the Escote treatments, but the same in the XCIBDU, XCIBDU + Escote, and Osmocote treatments. Stem dry weights were not significantly different among the four main treatments. There was a slight statistical advantage of Osmocote over Escote and XCIBDU + Escote for leaf weight, and N levels in both tissues were the same, except that the Escote treatment N level in the stem tissue was slightly less. Both root (RR) and top (VR) visual plant ratings, at the termination of the experiment, were well within the values (7.0 or greater) deemed consumer acceptable (Table 1).

**Significance to Industry:** All the products did an excellent job of growing superior plants. The Escote product did exhibit a tendency to have the lowest N levels lost to the plants through the leachate. Potentially, this reduced N loss could impact the environment positively from this factor alone.

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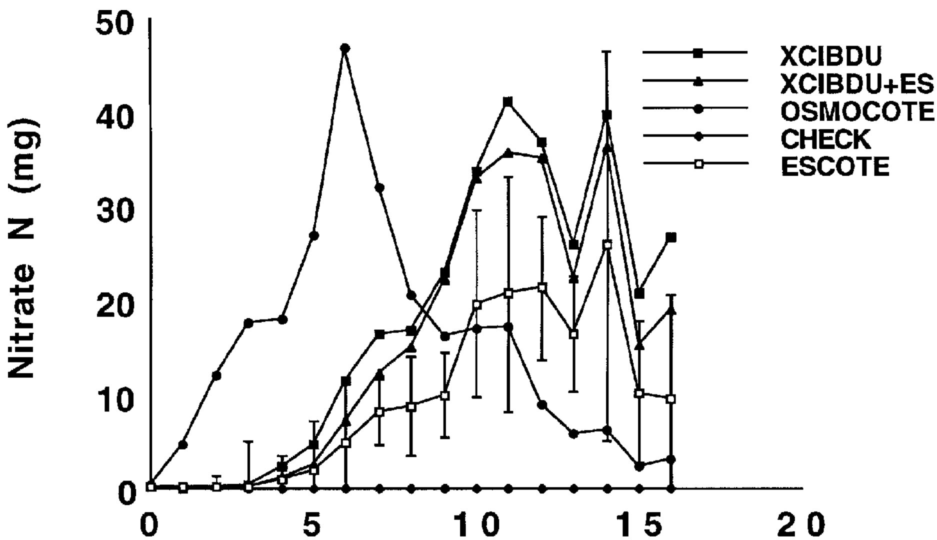


Figure 1. Nitrate nitrogen levels (mg) from leachate losses collected and analyzed at weekly intervals. The Escote product did demonstrate a tendency for the least amount of nitrogen lost to the plants through the leachate.

| TRT | XCIBDU | XCIBDU+ES | ESCOTE | OSMOCOTE | CHECK | LSD |
|---|---|---|---|---|---|---|
| VR 4/28 | 8.2a | 7.6ab | 7.5b | 7.6ab | 3.5c | 0.64 |
| VR 5/12 | 8.5a | 8.0a | 8.0a | 8.2a | 4.4b | 0.51 |
| VR 5/26 | 8.8a | 8.1b | 8.5ab | 8.8a | 3.3c | 0.51 |
| VR 6/6 | 8.8ab | 8.4b | 8.7ab | 8.9a | 3.3c | 0.45 |
| VR 6/23 | 8.8a | 8.5a | 8.7a | 8.8a | 2.9b | 0.37 |
| VR 7/7 | 8.4a | 8.6a | 8.8a | 8.8a | 2.6b | 0.57 |
| VR 7/16 | 8.5a | 8.6a | 8.7a | 8.8a | 2.6b | 0.51 |
| RR 7/16 | 8.2a | 8.0a | 8.4a | 8.5a | 3.3b | 0.88 |

Table 1. Azalea top visual ratings (VR) at six biweekly intervals and study termination, and root visual ratings (RR) at study termination (1-9, with 9 best). Both VR and RR were well within the values (7.0 or greater) deemed consumer acceptable, at the termination of the experiment.

# Initial Growth of Seedlings of Mountain Laurel as Influenced by Day/Night Temperature

**Asiah A. Malek, Frank A. Blazich, Stuart L. Warren, and James E. Shelton**
**North Carolina**

**Nature of Work:** Seedlings of mountain laurel (Kalmia latifolia L.) were grown in controlled-environment chambers for 16 weeks under long-day conditions with days at 18, 22, 26, or 30° C (64, 72, 79, or 86° F) for 9 hr in factorial combination with nights at 14, 18, 22, or 26° C (57, 64, 72, or 79° F) for 15 hr (1).

**Results and Discussion:** Total plant dry weight, top dry weight, and dry weights of leaves, stems, and roots were influenced by day and night temperatures. The night optimum for all dry weight categories was 22° C (72 o F). Dry matter production was lowest with nights at 140° C (57° F). Total plant dry weight and dry weights of tops, leaves, and stems were maximized with days at 26° C (79° F), but for roots the optimum was 220 C (720F). Dry weight accumulation was lower with days at 18 or 30° C (64 or 86° F). Responses of leaf area were similar to that of total plant dry weight, with optimum days and nights at 26 and 22° C (79 and 72° F), respectively. Within the optimal day/night temperature range of 22-26/22° C (72-79/72° F) for dry weights, there was no evidence that alternating temperatures enhanced growth. Shoot:root ratios (top dry weight:root dry weight) increased with day temperatures up to 30° C (86° F) and were highest with nights at 14 or 26° C (57 or 79° F). Leaf weight ratio (leaf dry weight:total plant dry weight) decreased with increasing night temperature, and increased curvilinearly in response to day temperature with the minimum at 26°C (79° F). Stem weight ratio (stem dry weight:total plant dry weight) increased with increasing day or night temperature. Root weight ratio (root dry weight:total plant dry weight) was highest with nights at 18 or 22° C (64 or 72° F) and decreased with days > 22° C (72° F). Net leaf photosynthetic rate was maximized with days at 26° C (79°F).

**Significance to Industry:** Results reported herein should be of benefit to nurserymen who raise seedlings of mountain laurel, not only under greenhouse conditions but also when seedlings are moved outdoors for acclimation and further growth. These findings should be particularly useful in accelerating and maximizing growth of seedlings which can be achieved by growing seedlings under long-day conditions at day/night temperatures of 22-26/22° C (72-79/72° F).

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## Nitrogen Nutrition of Containerized Eastern Redcedar

**Paul H. Henry, Frank A. Blazich, L. Eric Hinesley, and Robert D. Wright**
**North Carolina**

**Nature of Work:** Containerized seedlings of eastern redcedar (Juniperus virginiana L.) were fertilized weekly with a complete nutrient solution containing 0, 5, 10, 20, 40, 80, 160, 320, or 640 ppm nitrogen. Data were collected to investigate the manner in which nitrogen nutrition affected growth, mineral nutrient concentrations and carbohydrate status in the species over a 175 day growing season (1).

**Results and Discussion:** Nitrogen fertility strongly affected growth and nutritional status of containerized eastern redcedar. Foliar concentrations of nitrogen, phosphorus and potassium increased in treated plants over the duration of the experiment, while calcium, magnesium and manganese decreased or remained constant. After 180 days, height, stem diameter and root dry weight were optimal (90% of maximum) at 115, 155, and 105 ppm applied nitrogen, respectively, agreeing with recommendations of 100-150 ppm nitrogen for most container-grown conifers (2). Higher concentrations of 230 ppm nitrogen were required for optimal shoot dry weight. Height growth was negligible until foliar nitrogen concentrations reached 1.2%, at which point growth increased sharply. The foliar nitrogen concentration resulting in 90% height yield (critical level) was 1.5%.

Foliar concentrations of starch, sucrose, and hexose increased in an asymptotic manner with increasing nitrogen supply. Starch accumulation in treated plants was high during spring but decreased sharply after initiation of the experiment. Controls showed little change in starch concentration during the first 120 days, but dropped with the onset of cooler temperatures. Sucrose concentrations remained constant over the summer but increased sharply in late fall. Accumulation of sucrose during the fall and winter months may be associated with the onset of cold hardiness in woody plants (3).

**Significance to Industry:** The demand for eastern redcedar is increasing because of its value as a timber and Christmas tree species and also as an ornamental. As there are no data available concerning nitrogen nutrition of the species, this research should benefit growers of eastern redcedar who may wish to meet this growing demand.

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# Composted Turkey Litter: Effect on the Thermal Characteristics of an Amended Pine Bark Substrate

**Helen H. Tyler, Katharine B. Perry, and Stuart L. Warren**
**North Carolina**

**Nature of Work:** Substrate temperatures in excess of 49°C (120°F) can be reached when containers are exposed to direct solar radiation with 38°C (100°F) root-zone temperatures maintained for 7 or more hours in nursery containers (1). The relatively large surface area to volume ratio, wide spacing, and dark color of nursery containers contribute to the high temperatures found in the root-zone (1,5,6). Substrate temperatures in black plastic pots warm quickly during the morning, remain above 40°C (1 04°F) for most of the day, and then drop rapidly in the evening (4,7).

Thermal conductivity within a substrate is a function of temperature, water content, and bulk density (3). Thermal diffusivity is a function of thermal conductivity, bulk density, and specific heat (9). Therefore, any changes in container water capacity, bulk density, and air space of a substrate will impact substrate temperatures. Composted turkey litter added to a pinebark substrate increased bulk density and container water capacity while it decreased airspace (10). Addition of sand to a pine bark substrate increased air space, decreased water holding capacity, and decreased container substrate temperature gradients resuiting in higher overall substrate temperatures due to increased thermal diffusivity (8).

Milled pine bark l(<13 mm) (0.5 in)] was amended on a m3 (yd3) basis with five rates of composted turkey litter (compost) (0, 4, 8, 12, 16% by vol.). Uniform bare root divisions of Hemerocallis sp. ‘Red Magic’ daylily were potted into black plastic, 3.8 liter (#1 ) containers on May 1 3, 1 991. Plant growth response has been reported elsewhere (11). Plants were spaced 40 x 60 cm (1 6 x 24 in) apart to prevent shading from adjacent containers.

Beginning May 24,1991, substrate temperatures were measured by copper-constantan thermocouples inserted through the substrate on the south side of the container, 3.8 cm (1.5 in) from the edge of the container to a depth of 7.5 cm (3 in). Each compost amended substrate was equiped with one thermocouple. Substrate temperature was measured every 5 minutes using a micrologger (Model 21 X, Campbell Scientific, Inc., Logan, Utah). Maximum, minimum, and average temperatures were recorded every two hours. Thermocouples were removed on September 11, 1991.

All variables were subjected to analysis of variance procedures and regression analysis (12). Maximum, minimum, and average substrate temperatures exhibited similar responses to compost rate; therefore, only maxima data will be reported. A 4 day period was chosen and represent days with similar weather conditions. The early season period (May 30 to June 2) was chosen to characterize the substrate's effect on temperature patterns within containers before plants impacted the container environment.

**Results and DIscussion:** From May 30 to June 2, compost addition affected maximum substrate temperature for 16 hours each day; however, the effect was time-dependant (Fig. 1). From1600 hr until 600 hr the next morning, increasing percent compost increased maximum substrate temperature. On each day, between 800 hr and 1400 hr container temperatures increased approximately 15°C (27°F) but were similar regardless of percent compost addition. From 0 to 600 hr and 1600 to 2200 hr, maximum substrate temperature increased with increasing compost content. Adding compost to pine bark resulted in a substrate with decreased air space and increased bulk density (10) which may have increased thermal conductivity and diffusivity compared to pine bark alone (2). Lower thermal conductivity and diffusivity of the 0% compost substrate may explain the lower temperatures present in this substrate during the 1600 hr to 2000 hr time period. In addition, container water capacity increased quadratically with increasing compost with the maximum occurring at 8% compost (10). The increased water held in the substrate seemed to buffer daily temperature cycles. The 8% compost substrate had the smallest difference between the highest and lowest points on the diurnal temperature curve while the 0% compost substrate had the largest. Hopmans and Dane (3) reported that thermal diffusivity and conductivity increased with increasing water content to a maximum value and then gradually decreased. All substrates reached maximum temperatures of 40°C (104°F) by 1200 hr and maintained these temperatures for 8 to 10 hours (Fig. 1). In addtion, 12 and 16% compost substrates reached temperatures greater than 45°C (113°F) for approximately 2 hours. The 0% compost substrate cooled to a temperature below 40°C (104°F) slightly before the compost amended substrates. Temperature in all substrates decreased from 0 to 600 hr and 1800 to 2200 hr. The largest difference in maximum temperature between 0% and 16% compost during a 24 hour period was approximately 4°C (7°F).

Since the precise impact of these high temperatures on the plant is not known, longer exposure to higher temperatures could significantly affect seasonal plant growth. Similarly, Wong et al. (13) reported that the duration of daily exposure to high temperatures had more of an effect on root growth of peach and black locust than repeated exposures on 2 and 4 successive days.

**Significance to the Nursery Industry:** Increasing the percent of compost added to a pine bark substrate resulted in increased maximum temperatures in the substrate during certain times of the day. Maximum temperatures above 40°C (104°F) were maintained by all containers regardless of compost rate for at least 7 hours a day. Decreased plant growth and metabolic activity may result from these high temperature exposures. Cultural practices that will reduce these temperatures need to be investigated further.

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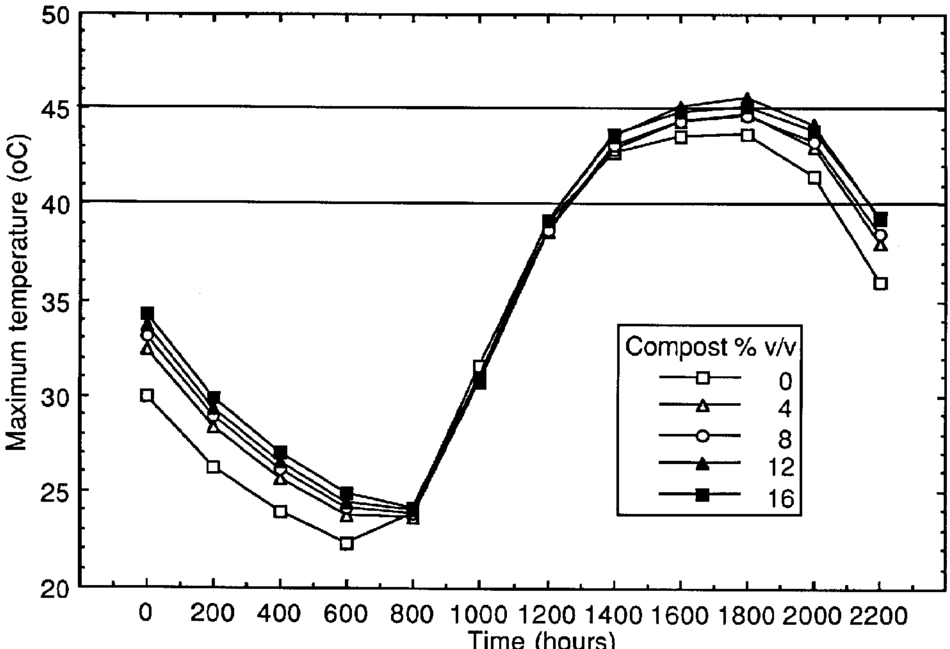


Figure 1. Effect of compost on maximum substrate temperature on May 30, 1991 (air temperature: Max. 33C, Min. 22C, Avg. 28C).

# Nitrogen and Phosphorous Efficacy of Commercial Synthetic and Organic Fertilizers in Container Production

**Helen Tyler, Stuart L. Warren, and Ted E. Bilderback**
**North Carolina**

**Nature of work:** Contaminated runoff water and its potential pollution of surface and ground water are primary concerns of the nursery industry (6). The Safe Drinking Water Act sets the maximum $NO_3$ contaminant level at 10 ppm. Due to the porous nature and limited water reserves of most container substrates, container production requires large amounts of water to produce rapid plant growth. A significant proportion of the applied water passes through the container carrying nutrients with it (8). Techniques that reduce potential contaminated runoff include capturing and recycling runoff, improving irrigation management, and optimizing fertility regimes such as with the use of slow release fertilizers, and/or limiting fertilizer application to concentrations that provide optimum plant growth (7).

Nitrogen is required in large quantities by plants and is easily leached during irrigation, making it the most difficult nutrient to manage in a container production system (1). Overhead irrigation can result in sufficient $NO_3$ loss to contaminate ground water even with the use of slow release fertilizers (3). However, information is limited on nutrient efficacy in typical container production systems. Therefore, the objective of this experiment was to detemmine the fertilizer efficacy of 2 commercial synthetic and one organic fertilizers.

The experiment, a randomized complete block design with 3 replications was conducted at North Carolina State University, Horticultural Field Laboratory, Raleigh. Treatments consisted of 3 different fertilizers, Osmocote 18-6-12 (Grace/Sierra Hort. Prod. Milpitas, Calif.), Woodace 20-4-11 (Vigoro Industry, Inc. Fairview Heights, Ill.), and Sustane 5-2-4 (Sustane Corp. Cannon Falls, Minn.). Osmocote and Woodace are commercial synthetic fertilizers. Osmocote is 10.4% ammoniacal N and 7.6% nitrate N. Woodace is 0.80% ammoniacal N, 1.35% nitrate N, 15.15% urea N, and 2.7% water insoluble N. Sustane is a commercial composted turkey litter product with 1.5% ammoniacal N and 3.5% in a water insoluble form. Osmocote utilizes resin-coated ammonium and calcium phosphate as the P sources. Sulfur-coated ammonium phosphate is the P source in Woodace fertilizer. The phosphorus source in Sustane is derived from the composted turkey liter. Each fertilizer was top-dressed at a rate to achieve 3.5 g (0.12 oz) of N per container.

A container production area was constructed for collection of all irrigation water leaving the growing area. This area was divided into 9 separate beds where effluent could be collected from each bed. The study was initiated on June 3, 1992 and terminated 100 days later. All fertilizer was top dressed at inaiation (Day 0).

Uniform rooted cuttings of azalea ‘Sunglow’ (Rhododendron sp. ‘Sunglow’) were potted into 3.8 liter (#1 ) containers in a 6:1 pine bark:sand (by vol.) substrate on May 14. Thirty containers were placed in each growing bed for a total of 90 containers per fertilizer treatment. The substrate of plants receiving Osmocote fertilizer was amended on a $m^3$ ($yd^3$) basis with 2.4 kg (4.0 Ibs) dolomitic limestone and 0.9 kg (1.5 Ibs) Micromax micronutrient fertilizer. Plants receiving Woodace fertilizer were potted into a substrate amended with 2.4 kg (4.0 Ibs) dolomitic limestone only since the fertilizer contained micronutrients. Plants fertilized with Sustane were potted into an unamended substrate as this product adequately replaces dolomitic limestone and micronutrients (5).

At 5:00 AM daily, 1.3 cm (0.5 in) of water was applied by overhead irrigation. At 8:00 AM daily, the volume of effluent was measured and sub-samples were collected, filtered, and frozen for future $NO_3$, $NH_4$, and P analyses using a spectrophotometer (Spectronic 1001 Plus, Milton Roy Co., Rochester, NY).

One hundred days after initiation, shoots were removed, dried at 62°C (144°F), and weighed. Roots were washed to remove substrate and similarly dried. Shoots and roots were ground in a Wiley mill to pass a 40 mesh (0.425 mm) screen. Each tissue sample (1.25 g) was combusted at 490°C (914°F) for 6 h. The resulting ash was dissolved in 10 ml (0.03 oz) 6 N HCI and diluted to 50 ml (1.5 oz) with distilled deionized water. Phosphorus concentration was determined by inductively coupled plasma emission spectroscopy. Nitrogen was determined using 10 mg (0.03 oz) samples in a Perkin Elmer 2400 CHN elemental analyzer. Nutrient content expressed each nutrient in grams of total shoot or root dry weight.

All variables were subjected to analysis of variance (4) with mean separations by least significant difference (LSD) at p = 0.05.

Results and Discussion: Fertilizer source affected total grams of $NO_3$ and P lost in the effluent, while the total grams of $NH_4$ were not affected (Fig. 1). Osmocote and Woodace fertilizer sources lost more $NO_3$ in runoff water than Sustane fertilizer. Woodace and Sustane lost greater amounts of P to leaching than Osmocote. Of the N applied, 13%, 12%, and 9% was accounted for in the effluent leached from containers fertilized with Osmocote, Woodace, and Sustane, respectively. Similar $NO_3$ losses were reported with Alberta spruce and junipers fertilized with a slow release fertilizer and irrigated as needed by overhead irrigation (3). Jarrell et al. (2) reported 32% of N applied was leached from the containers fertilized with Osmocote 18-6-12 with 79% of the total N lost in the leachate as $NO_3$. Of the P applied, 8%, 27%, and 15% was accounted for in effluent leached from containers fertilized with Osmocote, Woodace, and Sustane, respectively.

Azalea shoot dry weight was affected by fertilizer source while root dry weight was not (data not shown). Osmocote and Woodace fertilizers produced greater shoot growth on a dry weight basis than the Sustane fertilizer source (data not shown). For Osmocote, 48% and 8% of the accountable N and 34% and 9.6% of the accountable P was contained in the shoots and roots, respectively. With Woodace, 17% and 27.5% of the accountable N and 9% and 3% of the accountable P was contained in the shoots and roots, respectively. Sustane produced plants with 27% and 9% of the accountable N and 12% and 5% of the accountable P in the shoots and roots, respectively.

Efficiency can be described as grams of nutrient that a plant can absorb divided by total grams of the accountable nutrient. Osmocote and Woodace were equally efficient (56%) in providing N to a plant. Sustane had an N efficiency value of 36%. Osmocote had the highest efficiency value (43%) with regard to providing P to the plant. Woodace and Sustane had similar P efficiency values of 12% and 17%, respectively.

**Significance to the Industry:** Osmocote and Woodace fertilizer sources lost more $NO_3$ in the nunoff water than Sustane fertilizer. Woodace and Sustane lost greater amounts of P in the nunoff water than Osmocote. Osmocote and Woodace fertilizers produced greater shoot growth on a dry weight basis than Sustane fertilizer source. Osmocote and Woodace were equally efficient (56%) in providing N to the plant. Osmocote had the highest efficiency value (43%) with regard to providing P to the plant.

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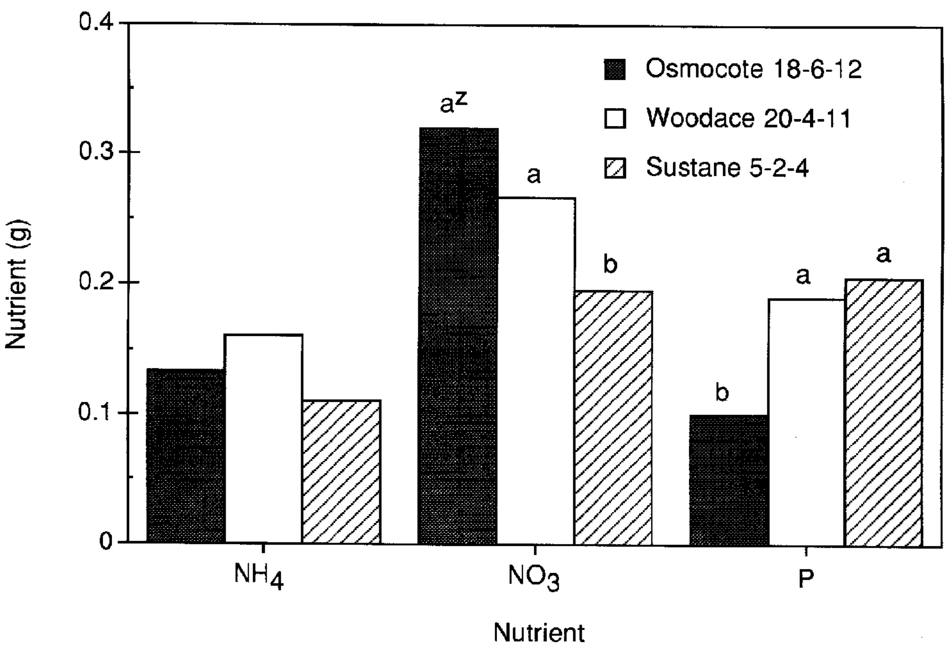


Figure 1. Total nutrient losses per container in runoff water from 1 to 100 days after application.

[z] Columns with the same letter within each nutrient are not significantly different as determined by LSD, $p = 0.05$.

# Growth of Three Species Produced in a Pot-In-Pot Production System

**John M. Ruter**
**Georgia**

**Nature of Work:** A problem associated with production of container-grown plants is exposure of root systems to high temperatures. Roots are not as hardy as foliage or stems and extreme temperatures limit the production of container-grown plants. Root systems of plants growing in-ground are insulated by surrounding soil and are not exposed to the large fluctuations in root-zone temperature which occur in container-grown plants.

To address some of the problems associated with container production, the idea for a “pot-in-pot” (PIP) production system was developed (1). With this production system, a holder pot is permanently placed in the ground. The container-grown plant is then placed inside the holder pot. Using this system, roots are protected from extreme temperatures and windthrow problems are reduced. The purpose of this study was to compare the growth of three landscape plants grown in a PIP system to that of plants grown in a conventional above-ground container production.

The experiment was conducted outdoors under full sun at the University of Georgia Coastal Plain Experiment Station in Tifton, Georgia. Uniform liners in #1 containers of *Ilex x attenuata* Ashe ‘Savannah’, *Lagerstroemia indica x fauriei* ‘Natchez’, and *Magnolia x Soulangiana* Soul.-Bod. were potted into #7 containers (#070, Lerio) on 18 March 1991. Potting medium consisted of milled pine bark and sand (4:1; v/v) amended with micronutrients (Micromax) at 1.5 $lb/yd^3$ and dolomitic limestone at 6.0 $lb/yd^3$. Plants were top-dressed with High-N 24-4-7 at the rate of 1.5 lb $N/yd^3$ on March 25 and June 3, 1991. Holder pots (Lerio #070) were placed in the ground with the top of the container remaining above grade. Plants were irrigated daily with 160° low volume spot spitters at a rate of 1.0 gal per container.

The experiment was a randomized complete block with three species, two container production systems (PIP and conventional above-ground) and ten replications. On July 1, 1991, container medium temperatures from 10 containers in each production system were measured using a thermocouple thermometer. The thermocouple probe was placed one inch from the container wall on the north, south, east, and west quadrant and in the center quadrant of a container to a depth of 6 inches. Temperatures were recorded between 4 to 5 PM EST. At termination of the study in October 1991, measurements of shoot dry weight, root dry weight, and root dry weight between the holder pot and the planted container were taken for five replications. A root rating (1 = 0-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, and 5 = 81-100% of the rootball covered with white roots) was taken for the north, south, east and west quadrants (n=5). For *Magnolia,* final height, caliper and branch number measurements were taken. With *Ilex* and *Lagerstroemia,* growth index measurements were taken. Data analysis for all growth indices were evaluated by analysis of variance using SAS. Mean separation was conducted using a Waller-Duncan K-Ratio T-Test.

**Results and Discussion:** Production system had no effect on height or caliper of *Magnolia. Magnolia* plants grown in the PIP system had more branches (22.8±0.6) per plant compared to the conventional production system (20.0±0.8). Height and growth index of *Ilex* were also not affected by production system. While growth index for *Lagerstroemia* was not affected by production system, plants grown in the conventional system were taller (46.8±1.6 inches) than in the PIP system (40.9±1.2 inches).

Shoot dry weight and the root:shoot ratio of *Magnolia* were not affected by production system. Root dry weight inside the planted container, total root dry weight and total plant biomass were all greater for plants grown in the PIP system (70%, 74%, and 65%, respectively) compared to the conventional system. Production system had no effect on the growth of *Ilex* in this experiment.

Shoot dry weight and total biomass of *Lagerstroemia* were not affected by production system. Root dry weight inside the planted container, total root dry weight and root:shoot ratio were all greater for the PIP system compared to the conventional system. Root dry weight inside the planted container increased 47% while the root:shoot ratio increased 87% for plants grown in the PIP system. The percentage of roots on a dry weight basis found outside of the planted container but within the holder pot were 2.1%, 0.4% and 3.6% for *Magnolia, Ilex,* and *Lagerstroemia;* respectively.

The temperature of the medium in the western quadrant of containers in the conventional system were approximately 13°C (23°F) warmer than containers in the PIP system between 4 and 5 PM. Mean container medium temperature across all quadrants was 39°C (102°F) for the conventional system in contrast to 33°C (9l°F) for the PIP system.

The root ratings for all species were influenced by interactions between production system and quadrant of solar exposure. For all species in the conventional system, the south, west and east quadrants had less root coverage compared to the north quadrant. There were no differences between quadrants for species grown in the PIP system.

**Significance to Industry:** This study demonstrates that *Lagerstroemia indica x fauriei* 'Natchez' and *Magnolia x Soulangiana* benefit from being grown in a "pot-in-pot" (PIP) production system by producing more root dry weight and uniform root systems. Improved root system development appears related to lower container medium temperatures during the growing season. Growers should be aware of problems with certain species *(Lagerstroemia* and *Nagnolia)* which have vigorous root systems that root-out through the planted container and holder pot and into the surrounding soil. Periodic rotation of planted containers within the holder pot or use of fabrics and root pruning compounds may also be useful.

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## Interactive Effect of Potting Media and Slow-Release Fertilizer on Growth of Photinia

**James B. Aitken**
**South Carolina**

**Nature of Work:** The use of slow release fertilizers in production container woody ornamentals is not new (2), but various techniques for their use are relatively new (1,3). A comparison of various slow release fertilizers in combination with several potting media was undertaken in this study.

The slow release fertilizers and potting media descriptions are found in Table 1 with the data. Stagreen 12-6-6 was applied at 6 week intervals with all other treatments applied once at the given rate. The four potting media were commercial mixes obtained from the same source to reduce the variability of pine bark composition.

Rooted liners of Photinia sp. were planted into 4 qt plastic pots containing the respective potting media. Fertilizer treatments were surface applied except for the Sierra tablets, which were placed below the rooted liner. Statistical design consisted of a 6 x 4 factorial with 6 replications. This study was maintained in the greenhouse throughout the duration of the experiment.

**Results and Discussion:** Several weeks into this study a marked nutrient deficiency was noticed in most treatments. The symptom appeared to be similar to Mn and Fe deficiency. A rating system was used to evaluate the severity of the deficiency symptoms (Table 1). Treatments with minor elements showed less of the symptom. Analysis of the interaction between media and fertilizer revealed lower ratings with the minor element treatments, with media having little effect. Reduction of water application decreased the intensity of this symptom.

Potting media had a significant effect (Table 1) on stem caliper increase. Media containing 90% pine bark had the lowest increase. Fertilizer treatments had little effect on stem caliper. The total length of all branches on each plant was measured to give an indication of total growth capacity. The multiple application of Stagreen 12-6-6 resulted in the lowest total branch length (Table 1), with the other treatment being significantly higher. Potting media had no signficant effect on the total length of branches per plant.

The interactive effect of the slow release fertilizer and the potting media was not significant in any of the three measured indices. This would indicate that any of the slow release fertilizers tested could successfully be used with any of the media types without having a detrimental effect on the growth of Photinia sp. However, when measured across all treatments and combinations, some of the fertilizer and media treatments were superior in promoting growth or reducing nutrient deficiency symptoms.

**Significance to Industry:** The results of this study show that a wide range of slow release fertilizer formulations can be successfully used with several types of potting media without having a detrimental effect on the growth of Photinia sp.. This concept would probably be true with most woody ornamental plants grown in containers.

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Table 1. Influence of potting media and slow release fertilizer formulations on several growth indices of Photinia .

| | Total Br. Length, cm | Caliper Increase, mm | Deficiency Rating[z] |
|---|---|---|---|
| Formulation:Rate/pot | | | |
| Stagreen 12-6-6, 7gx3 app | 101.80 D[y] | 2.46 B | 2.48 B |
| Sierrablen 17-7-10, 42g | 130.15 C | 2.64 AB | 2.60 AB |
| Sierra 16-8-10 tab, 3 ea | 134.91 BC | 2.63 AB | 1.80 C |
| Sierra 17-6-10, 30g | 141.57 AB | 3.02 A | 1.67 C |
| Prokote Plus 20-3-10, 32g | 145.86 A | 2.79 AB | 2.79 AB |
| SREF II, 20-4-10, 21g | 134.68 BC | 2.67 AB | 3.01 A |
| LSD, P= | 0.05 | 0.10 | 0.05 |
| Potting Media: | | | |
| 80/20, bark/sand | 125.44 A | 2.88 AB | 2.13 B |
| 90/10, bark/sand | 128.95 A | 2.47 C | 2.45 A |
| 80/10/10, bark/peat/sand | 125.99 A | 2.55 BC | 2.49 A |
| 50/5/35/10, bark/peat/ peanut hulls/sand | 145.61 A | 2.92 A | 2.51 A |
| LSD, P= | 0.05 | 0.10 | 0.10 |

[z]Deficiency rating using scale of 1= none, 2= slight, 3= moderate and 4= severe symptoms.

[y]Means within a column and field followed by a common letter are not significantly different at the P value given at the bottom of the field column using the LSD test.

# Effects of Soil Media Composition, Nutrient Charge and Nitrogen Source on Growth of Catharanthus roseus.

**Paul A. Thomas and Joyce G. Latimer**
**Georgia**

**Nature of Work:** The 1991 and 1992 growing seasons were marked by numerous reports of poor growth of vinca. Reasons given for this poor growth ranged from conditions being too wet or too cold, to poor genetic vigor in new cultivars, despite numerous reports of excellent quality vinca grown by nearby growers using the same cultivar. Recently, we have found that vinca do not respond well to high levels of nutrient charge in soilless medium (1). Many bark-based soil mixes used in southern states contain fairly high soluble salt levels, trace elements and urea formaldehyde as the nitrogen source (1,5). Cultural recommendations included growing plants with minimal water use, thus maximizing salt, pH and nitrogen effects (1,2,3).

The objective of this study was to ascertain if any of the above materials might by itself retard growth of vinca. Plugs of vinca 'Grape Cooler' were grown according to standard methods. Main plot treatments consisted of planting plugs in a peat-lite mix or a 25% bark mix both manufactured by the same company. The effect of micronutrients was tested by planting vinca plugs in the peat-based medium left uncharged without pH adjustment to 5.5, or prepared with sulfate-based micronutrients, chelate-based micronutrients, or in sulfate or chelate-based soil mix pH adjusted to 5.5.

The effect of nitrogen source was tested by growing vinca in sand culture and fertilizing biweekly with a modified Hoagland and Arnon's nutrient solution where ratios of nitrate to ammonium was adjusted from 0% nitrate / 100% ammonium nitrogen to 100% nitrate / 0% ammonium. Split-plot designs were incorporated with three plants per each of six replications.

**Results and Discussion:** Presence of pine bark in medium significantly reduced stem length, stem dry weight, and root dry weight (Table 1). Analysis of the effect of micronutrient source in the peat-lite mix revealed that stem length was greater when sulfated micronutrients or standard chelated micronutrients in medium adjusted to pH 5.5 were used (Table 2). Shoot dry weight of vinca grown in sulfated micronutrients or in chelate based/pH 5.5 medium was significantly higher than that of other treatments. Vinca grown in sulfate-based/pH 5.5 medium exhibited significantly greater root dry weight than did plants from the other four treatments. Root dry weights were not significantly different between other treatments.

Vinca grown in sand and fertilized with half-strength Hoagland's solution containing various ratios of nitrate and ammoniacal nitrogen showed optimal stem length at 75 and 100% nitrate levels (Table 3). Optimal shoot dry weight was obtained from vinca grown in the 100% nitrate treatment. Root dry weight was also significantly reduced as percentage of ammonium increased. Visual assessment of roots showed a dramatic reduction in the size and volume of roots as ammonium levels increased.

**Significance To The Industry:** Our data suggest that some growth problems associated with vinca are due to production inputs. Our data show that even 25% bark, non-pH adjusted media with standard chelated micro-elements or ammoniacal nitrogen ratios higher than 1:3 may cause growth reductions. Avoiding these materials may increase chances of better vinca crops next spring.

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TABLE 1. EFFECT OF MEDIUM SOURCE ON GROWTH OF VINCA MEDIUM

| Soil Medium | Shoot Length (cm) | Shoot Dry Wt. (mg) | Root Dry Wt. (mg) |
|---|---|---|---|
| Peat-Lite Mix | 14.5 a | 1588 a | 178 a |
| 25% Bark Mix | 12.9 b | 1459 b | 145 b |

TABLE 2. EFFECT OF MEDIUM SOURCE OF ROOT DRY WEIGHT OF VINCA

| Soil Medium | Shoot Length (cm) | Shoot Dry Wt. (mg) | Root Dry Wt. (mg) |
|---|---|---|---|
| High Porosity Mix | 13.80 a | 1611 ab | 219 a |
| Peat Lite Mix | 13.75 a | 1550 b | 183 b |
| 25% Bark | 13.60 a | 1708 a | 144 c |

TABLE 3. EFFECT OF MICRONUTRIENT SOURCE ON GROWTH OF VINCA GROWN IN PEAT BASED MEDIUM

| Micronutrient Source | Shoot Length (cm) | Shoot Dry Wt. (mg) | Root Dry Wt. (mg) |
|---|---|---|---|
| Sulfated Micros | 15.41 a | 1724 a | 183.4 b |
| Chelated Micros | 13.75 b | 1550 b | 183.8 b |
| Chelated/pH 5.5 | 15.13 a | 1751 a | 167.4 b |
| Sulfated/pH 5.5 | 13.78 b | 1611 b | 219.0 a |
| Control (none) | 13.61 b | 327 c | 176.8 b |

TABLE 4. EFFECT OF NITRATE/AMMONIUM RATIO ON GROWTH OF VINCA IN PEAT BASED MEDIUM

| Nitrogen Ratio (%) | Shoot Length (cm) | Shoot Dry Wt. (mg) | Root Dry Wt. (mg) |
|---|---|---|---|
| 0 $NO_3$ : 100 $NH_4$ | 7.6 d | 378 e | 138 c |
| 25 $NO_3$ : 75 $NH_4$ | 7.9 c | 847 d | 244 b |
| 50 $NO_3$ : 50 $NH_4$ | 11.0 b | 1089 c | 312 b |
| 75 $NO_3$ : 25 $NH_4$ | 12.0 a | 1285 b | 411 a |
| 100 $NO_3$ : 0 | 12.3 a | 1458 a | 474 a |

# Livite - A New Clay Aggregate for Amending Container Media

**Kenneth C. Sanderson and John A. McGuire**
**Alabama**

**Nature of Work:** Modern media for growing container plants generally consists of an organic amendment and a diluent or an organic component alone. The organic component is usually sphagnum peat moss or pine bark, however numerous other materials are used (2). Diluents are usually mineral materials with builders' sand, perlite and vermiculite being the most commonly used (5). Mineral media components influence media water retention, nutrient retention, aeration, weight, and cost (3). Baked clays have been successfully used as mineral media amendments for over 30 years (6). Their disadvantages may be weight, cost, and availability. Arcillite, a montmorillonite clay calcined at high temperatures, was found to be an excellent mineral amendment for container media (3) and golf greens (6), for which it is marketed as Turface™ (Aimcor, Inc.). When arcillite was added to pinebark media, irrigation frequency was reduced and satisfactory Cotoneaster plants were produced (4). Another light-weight clay aggregate (used in concrete products (Arkalite; Light Weight Aggregate Corp., West Memphis, Ark.) yielded similar growth in Rhododendron, Juniperus, Raphiolepsis, and Ilex as sand amendment (1). A similar clay aggregate, Livite™ (American Resource Recovery, Forest Park, GA.) has a similar chemical composition to Turface™ (6, Mr. Michael Wheelus), but has a lower bulk density (32 lbs versus 38 lbs per $ft^3$).

The objective of these studies was to determine the effect of Livite™ on the growth of container-grown plants.

Livite™ is available in 3 grades ranging from 1.3 cm (0.5 inch) to #8 sieve. Ungraded Livite™ (0.5 inch to #8 sieve) was used as is or screened (0.8cm or 0.25 inch) in separate experiments on azalea, Rhododendron cv. Patapsco (Scott's Lavender) and chrysanthemum, Dendranthema grandiflora (Ramat) Kitamura cv. Davis. Azalea liners were sheared to 20 cm (8 inches) and transplanted into 1 gal nursery containers on 17 June 1991. Media treatments by volume were: 1) 100% pinebark, 2) 80% pinebark:20% screened Livite™ and 3) 80% pinebark:20% unscreened Livite™. Treatments were replicated 10 times and arranged in randomized blocks. Plants received a surface broadcast of 8 g (2 tsp) of an equal mixture of Osmocote 14-14-14 and 16-8-12. Plants were grown outside in partial sun under prevailing temperatures and irrigated weekly. On 18 September plant height, shoot number, canopy area (product of diameter measured in 2 directions) and quality were recorded.

On 8 February 1991 four rooted cuttings of chrysanthemum were potted per 15 cm (6-inch) pots containing the following media: 1) Fafard No. 2 (Fafard of South Carolina, Anderson, SC), 2) 2 sphagnum peat moss (SPM):1 vermiculite (VER):1 Perlite (PER) 3) 2 SPM:1 Livite™ (LIV):1 VER, 4) 2 SPM:1 LIV:1 PER, and 5) 1 SPM:1 LIV (per volume). Media treatments were replicated 5 times and arranged in a randomized block design. All media except Farad had 84 g (3 oz.) of dolomitic limestone incorporated per ft3. Standard commercial cultural procedures for flowering potted chrysanthemums were used (7). Plants were fertilized (Peters Peatlite 20-10-20) at 2.2 g per liter or 2 lbs. per 100 gal every 2 weeks from 10 February until flower buds showed color. To compact growth, a 2,500 ppm spray of daminozide (B-Nine SP, Uniroyal Chemical, Bethany, CT) was applied until runoff. When half of the flowers on a pot were open, plant height, canopy area, number flowers per pot, date of flowering, and a quality rating were determined.

**Results and Discussion:** Azalea plant height, canopy area, number of shoots and quality rating were unaffected by the addition of 20% Livite™ to the pinebark medium (data not shown). Twenty percent Livite™ amended media produced comparable growth to 100% pinebark.
Plant height and canopy area of potted chrysanthemum were significantly affected by media (Table 1). Media did not affect the number of flowers per pot, plant quality rating and date of flowering (data not shown). Plants grown in a 2 SPM:1 VER:1 LIV were taller than other plants. The 2 SPM:1 VER:1 PER medium yielded the shortest plants with the smallest canopy area. Canopy area for plants grown in Farad and Livite™ media was similar. Generally, Livite™-amended media produced the best plant growth. Livite contains (by weight) 6.5% $Fe_2O_3$, 0.25% CaO, 0.6% MgO and 1.6% $K_20$ and this may explain its result (Mr. Wheelus).

**Significance to the Industry:** Screened (0.8 m or 0.25 inch) Livite™ is an acceptable container media amendment. It is especially recommended for potted Livite™chrysanthemum culture since it contains micro- and macro-nutrients that are often limiting in chrysanthemum production. Although not measured here, it appeared to add the bulk density necessary for stabilizing the pot and anchoring the plants.Livite™

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## Acknowledgement:

The authors thank Mr. Michael Wheelus of American Resource Recovery, Forest Park, GA for furnishing Livite™, Yoder Brothers, Inc., Barberton, OH for chrysanthemum cuttings and Dr. William Campbell, Dean of the School of Pharmacy, Auburn University, AL for greenhouse facilities to conduct this research.

Table 1. Growth indices of potted chrysanthemum cv. Davis grown in Livite™ amended and two other media.

| Media[z] | Plant height (cm)[y] | Plant canopy area ($cm^2$)[x] |
|---|---|---|
| Farad No. 2 | 30b[w] | 1689a |
| 2 SPM:1 VER:1 PER | 27c | 1298b |
| 2 SPM:1 LIV:1 PER | 29b | 2013a |
| 2 SPM:1 VER:1 LIV | 33a | 1837a |
| Livite™1 SPM:1 LIV | 31b | 2004a |

[z] media amendments by volume. SPM = sphagnum peat moss, VER = vermiculite, PER = Perlite, LIV - Livite™.

[y] Metric conversion: 2.5 cm = 1 inch.

[x] Width of a pot of p2lants measured in 2 directions and multiplied. Metric conversion: 6.5 cm = 1 inch.

[w] Means in columns followed by the same letter(s) are not significantly different at the 5% level according to Duncan's multiple range test.

# Comparison of the Growth of Fleurettes, Garden Chrysanthemums and Florist Chrysanthemums Grown in Hanging Gardens

**Kenneth C. Sanderson and John A. McGuire**
**Alabama**

**Nature of Work:** Hanging baskets containing chrysanthemums, Dendranthema grandiflora (Ramat) Kitamura have received extensive use in homes, restaurants and interior and exterior landscapes (4), contributing to doubling the production of flowering baskets during 1985-89 (3). Both garden and florist chrysanthemum cultivars are grown in hanging baskets and hanging gardens with selection based on landscape evaluations (5) and supplier recommendations (2). Previously, florist cultivars were found superior to garden cultivars for production in Belden hanging gardens (7). In 1991, Yoder Brothers introduced Fleurettes for hanging basket production (1). Fleurettes were developed from a cross between a domestic chrysanthemum, D. grandiflora (Ramat) Kitamura and a wild Asiatic variety. Fleurettes grow 15 to 20 cm (6 to 8 inches) tall and produce a profusion of small, 2.5 to 3.75 cm (1 to 1.5 inches) diameter, flowers. This study compared the growth of fleurettes, and garden- and florist-chrysanthemums for production in hanging gardens.

Rooted cuttings of Fleurettes, garden- and florist-chrysanthemums (Table 1) were potted into 6.5 cm (22 inch) plastic cells on 14 February 1991. Two weeks later, plants were transplanted into 8-inch Belden Hanging Gardens™ (Belden Plastics, St. Paul, MN) with a medium of 2 sphagnum peat moss:1 vermiculite:1 perlite (v/v/v) amended with 54 g (3 oz) of dolomitic limestone, gypsum and Osmocote 14-14-14 per ft.$^3$. Four plants were placed in both the walls and top of the garden. Plants were fertilized every 2 weeks until buds showed color (Peters Peatlite; W.R. Grace Inc., Fogelsville, PA) 2.3 g per liter (2 lbs per 100 gal). On 9 March, 4 g of (1 teaspoon) Osmocote 14-14-14 was broadcast on the medium surface of each garden. Commercial procedures for the production of chrysanthemum hanging baskets were followed (3,4). Plants were grown in full sun at 17C (62°F) minimum night temperature in a glasshouse. Supplementary light was provided by incandescent light (10 PM to 2 AM) from 14 February until 26 February for all cultivars except ‘Pert’, which received lighting until 4 March. After the supplementary lighting period, plants were covered daily to initiate flowering and were pinched on 26 February. The florist chrysanthemums were sprayed with 2,500 ppm daminozide (B-Nine™, Uniroyal Chemical, Bethany, CT) growth retardant on 12 March. Five replications (hanging gardens) of each cultivar were arranged in a randomized complete block design. When half of the flowers on a cultivar were open, plant height and canopy area (product of plant diameter in two directions), number of flowers per garden, and a quality rating were measured.

**Results and Discussion:** Generally, Fleurettes were shorter than florist chrysanthemums and similar in height to garden chrysanthemums (Table 2). 'Pert' plants were the tallest and were taller than all Fleurettes except 'Blondell', and all garden chrysanthemums. Only 'Blondell', 'Davis', 'Pert', 'Solo', and 'Adorn' plants met the criterion of 1.5 times the height of the container for potted plants established by Sachs and Kofranek (6). 'Pert' and 'Davis' plants had the largest canopies and were larger than all cultivars except 'Chantal' and 'Solo'. Fleurettes produced the most flowers per garden with 'Chantal' producing more flowers than any other cultivar. Fewest flowers were produced by 'Pert', 'Adorn', and 'Allure' plants. Flower size should be consider in judging flowering quality. Fleurette flowers are slightly larger than a penny. The floriferiousness of Fleurettes may be useful in chrysanthemum breeding. The garden chrysanthemum 'White Stardom' had the highest quality of any cultivar and was significantly better than 'Chantal', 'Adorn' and 'Allure'.

**Significance to Industry:** This study shows that some Fleurette cultivars are acceptable for production of Belden hanging gardens, especially the cultivar 'Blondell'. The Fleurette cv. 'Chantal' may be too short, as is 'Desiree', which also lacked canopy area and flower numbers but ranked high in quality. Without growth retardant treatments, all florist chrysanthemums tested would be too tall for gardens. Even with one retardant treatment, 'Davis' was too tall. With the exception of 'White Stardom', florist chrysanthemums, produced better hanging gardens than garden chrysanthemums, this agrees with previous results that also agreeded 'Allure' was unacceptable for hanging garden or basket production (7).

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Table 1. Weeks to flowering, growth habit, flower color and form of Fleurettes and garden chrysanthemums compared for hanging garden production.

| Cultivar | Weeks to flower[z] | Growth habit | Flower color and form | Comments |
|---|---|---|---|---|
| Fleurettes | | | | |
| Blondell | 7 | Medium vigor, somewhat upright. | Strong yellow colored daisy with slightly raised center, floriferious. | Heat tolerant. Prolific. |
| Chantal | 7 | Not as vigorous as Blondell. Short growing. | Pure white daisy with a raised yellow center. | Earliest flowering of fleurettes. Heat tolerant. |
| Desiree | 7 | Short, semi-upright. | Striking light lavender daisy with petals having a dark purple reverse. Slightly yellow center. | Did not cover the garden. Side plants grew poorly |

| | | | | |
|---|---|---|---|---|
| Florist chrysanthemums | | | | |
| Davis | 9 | Strong semi-spreading plant. | Clear pink daisy with green turning yellow center. | Needs more than 1 application of growth retardant. Foliage damaged by pesticides. |
| Pert | 8 | Compact, spreading growth habit. | Bright dark yellow daisy with dark green center. | |
| Solo | 8 | Free-branching, vigorous, strong, uniform, compact, growth. | Pure white daisy with a light green center. Flower 2 inch in diameter. | Prolific. |
| **Garden chrysanthemums** | | | | |
| Adorn | 7 | Spreading growth habit. | Medium pink daisy fading to a light pink, center yellow. | Pesticide sensitive (leaf damage). Flowers fade. Side plants late flowering (crown buds formed). Aphids a problem. |
| Allure | 6 | Mounded habit. | Bright medium yellow daisy with a green center. | Compact plant. Could be fuller. Tolerates high temperature. |
| White Stardom | 7 | Compact growth. | White daisy with a yellow center. | Reliable plant. |

[z]Weeks of short photoperiod treatment necessary for flowering.

Table 2. Plant height and canopy area, number of flowers per garden and quality rating of Fleurettes, florist and garden chrysanthemums.

| Cultivar | Height cm[z] | Plant area[y] ($cm^2$) | Number of flowers per garden[x] | Quality rating[w] |
|---|---|---|---|---|
| Blondell | 22.3abc | 2034bc | 131bc | 4.3ab |
| Chantal | 18.0de | 2125ab | 182a | 3.3bc |
| Desiree | 18.2de | 1765bc | 154b | 3.8ab |
| Davis | 22.8ab | 2443a | 113cd | 4.2ab |
| Pert | 24.3a | 2453a | 75e | 4.3ab |
| Solo | 21.0bcd | 2037abc | 113cd | 4.0ab |
| Adorn | 19.6cde | 1899bc | 65e | 2.2c |
| Allure | 17.Oe | 1640c | 71e | 3.7b |
| White Stardom | 17.6e | 1916bc | 86de | 5.0a |

[z]Mean height of plants growing on the top of the hanging garden 2.5 cm = 1 inch.

[y]Diameter of garden measured in 2 directions and multiplied. 6.5 cm2 = i nch2 .

[x]Total number of flowers growing on 8 plants (4 on top, 4 on sides of garden).

[w]Plant quality rating: O - dead; 1 = very poor, unsalable; 2 =poor, some salable; 3 = average, good, salable; 4 = above average, very good, salable; and 5 = excellent, all salable.

# Comparison of the Growth of Selected Garden and Florist- Chrysanthemum Cultivars Grown in 6-Inch Pots During the Spring

**Kenneth C. Sanderson and John A. McGuire**
**Alabama**

**Nature of Work:** Spring production of garden chrysanthemums Dendranthema grandiflora (Ramat.) Kitamura (Chrysanthemum x morifolium) offer consumers dual use and additional value and adds an additional product for sales. Consumer familiarity with the florist form of potted chrysanthemum emphasizes comparison. Florist chrysanthemums are available year-around and extensively bred for production, color, flower type, and keeping quality (1). Garden chrysanthemums are selected for plant habit, growth characteristic, and early flowering. Evaluation of garden chrysanthemums have primarily focused on landscape use (3), however recent research has focused on spring-produced garden chrysanthemums (6, 7). The present study compared growth of selected garden- and florist-chrysanthemum cultivars grown in 6-inch pots during the spring. Rooted cuttings (four per pot) of recently introduced garden- and florist-chrysanthemum cultivars (Table 1) were potted using 1 sphagnum peat moss:1 vermiculite:1 perlite (v/v/v) medium on 25 January 1991. Plants were grown in full sun at 62°F (17C) minimum night temperature in a glass house. Standard commercial culture for spring production of potted chrysanthemum was used (2, 9). Supplementary light was provided by incandescent lighting (10 PM to 2 AM) from 25 January until 8 February (medium treatment) or 15 February. Natural daylength followed the supplementary lighting period for initiation and flower bud development. Four pots per cultivar were arranged in a randomized complete block design. When half of the flowers per pot were open, plant height and canopy area (diameter of a canopy measured in two directions and multiplied), number of flowers per pot and a quality rating were recorded.

**Results and Discussion:** Cultivars differed in all growth indices measured (Table 2). All cultivars exceeded the height criterion of Sachs et al. (5), but were within the range established by the Produce Marketing Association (PMA) for acceptable potted chrysanthemums (4). ‘Charm’ produced the tallest plants (30 cm or 12 inches) but had support problems. Often visual appeal is determined by the relation of canopy area to height (5). ‘Frolic’ plants usually did not fill pots and the canopy may have been inadequate (Table 1). However, ‘Stardom’, ‘Target’, ‘Eureka’, ‘Pasadena’, ‘Pink Arola’, and ‘Rejoice’ plants were similar in canopy area. ‘Charm’ plants had the largest canopy (Table 2). Flower numbers produced by 'Surf' plants was below the PMA standard of 37, however flower size should also be considered in cultivar evaluation. 'Surf' flowers are relatively large compared to garden chrysanthemum flowers such as 'Debonair'. 'Solo' plants exceeded all cultivars in flowers per pot (Table 2). 'Debonair', a garden chrysanthemum, received the highest quality rating of any cultivar. While all the florist chrysanthemums were of equal quality, 'Target' was the only garden chrysanthemum similar to 'Debonair' in quality. 'Frolic' plants received the lowest rating (3.4) but were still salable. The florist chrysanthemums cv. 'Pert',' Surf', 'Tara' and 'Charm' are recommended as proven cultivars by Yoder for spring production (8). 'Debonair', 'Frolic', 'Stardom' and 'Target' are recommended garden cultivars for spring pot plants (9)

**Significance to Industry:** Florist chrysanthemums generally produced taller and larger plants than garden chrysanthemum when grown in the spring. Plant height and size could be a problem in marketing spring-produced garden chrysanthemums. Number of flowers per pot was acceptable and quite similar for both chrysanthemums types. 'Debonair', a garden chrysanthemum, received the highest quality rating of any chrysanthemum tested, however all florist chrysanthemums and 'Target' were equal in quality. The garden cvs. 'Stardom' and 'Frolic' were salable but of lower quality than some of the other cultivars. 'Stardom' and 'Frolic' are not recommended for spring production.

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**Acknowledgement.** The authors thank Yoder Brothers Inc., Barberton, OH for furnishing the material and Dr. William H. Campbell, Dean of the School of Pharmacy, Auburn University, AL for providing greenhouse facilities.

Table 1. Flower color, and growth habit of selected garden and florist chrysanthemums grown in 6-inch pots during the spring.

| Cultivar | Flower color and form | Growth habit |
|---|---|---|
| Garden chrysanthemums | | |
| Debonair | Intense, lavender, purple, decorative. | Uniform flowering, good spray formation. Upright plant. Small flower. Outstanding. Short height. |
| Frolic | Medium size, pure white, decorative. | Doesn't fill pot like other cultivars. Nice flower. Short height. |
| Stardom | Light lavender, daisy with a yellow center. | A "standard" as a garden mum. Compact plant. Dependable, short height. |
| Target | Dark yellow, decorative. | Small. Compact, plant. Dark green foliage. Early flowering. Short height. |

Florist chrysanthemums

| | | |
|---|---|---|
| Charm | Large, flat, pink decorative. | Sprawling plant needing support. Flowers easily damaged by sun and water and often shatter. Medium height. |
| Eureka | Brilliant yellow anemone with light green cushion. | Skinny plant. Nice color. Medium height. |
| Pasadena | Rich lavender, spoon-tipped quilled daisy with a solid green center. Medium to large flowers (2-2.25 inches). | Strong, wirey grower.Excep-tional flower, plant form and color retention. Very floriferous. |
| Pert | Dark yellow daisy with a dark green center. | Short height. Full plant. Grows well. |
| Pink Arola | Lavender decorative, Medium to small flowers. Similar to Surf. | Free branching, upright, vigorous plant. Medium height. |
| Rejoice | Medium yellow anemone with light green to dark yellow cushion. | Flowers fade with age. Not as bright a color as Pert. Short height. |
| Solo | Pure white daisy with a green center. | Compact, wirey. An excellent pot plant. Very flori-ferous. Medium height. |
| Surf | Pure white medium sized decorative. | Excellent depend-able grower. Loses attractiveness with age. Full plant. Medium height. |

| | | |
|---|---|---|
| Tara | White anemone with large, 2-3 inch flower with a light yellow cushion. Strong peduncles. | A very nice pot mum. Floriferous. Medium height. |

Table 2. Potted plant height, area, flowers per pot, and rating of select garden- and florist-chrysanthemum grown in 6-inch pots during the spring

| Cultivar | Height cm[z] | Area cm$^{2}$[z] | Number of flowers per pot[y] | Quality rating[x] |
|---|---|---|---|---|
| Debonair | 22d | 1412bc | 47bc | 5.0a |
| Frolic | 21de | 1054d | 42cd | 3.4c |
| Stardom | 21de | 1158cd | 39cd | 4.0bc |
| Target | l9e | 1292bcd | 42cd | 4.6ab |
| Charm | 30a | 1751a | 55b | 4.4ab |
| Eureka | 27bc | 1283bcd | 36d | 4.2abc |
| Pasadena | 28b | 1256bcd | 37cd | 4.3ab |
| Pert | 25c | 1568ab | 48bc | 4.4ab |
| Pink Arola | 25bc | 1135cd | 43cd | 4.8ab |
| Rejoice | 21de | 1282bcd | 47bc | 4.8ab |
| Solo | 20de | 1422bc | 68a | 4.4ab |
| Surf | 26bc | 1407bc | 34d | 4.6ab |
| Tara | 26bc | 1430bc | 41dc | 4.4ab |

[z]Height measured from medium surface. 2.5 cm = 1 inch. Plant diameter measured in 2 directions and multiplied. 1 square inch = 6.25 square cm.
[y]Pots contained 4 plants per pot.
[x]Quality rating: 0 = dead; 1 = very poor, totally unsalable; 2 = poor, some pots salable; 3 = average, good salable; 4 = above average, very good, salable; and 5 = excellent, salable.

# Spin Out™ Enhances Subsequent Growth of Tomato, but not Pepper, Transplants

**Joyce G. Latimer and Sherrod A. Baden**
**Georgia**

**Nature of Work:** Copper products have been used to control root growth of container-grown woody ornamentals for several years. Nursery plants grown in copper-treated containers were observed to establish in the landscape more quickly than traditionally-grown container plants (Arnold and Struve, 1989). More rapid establishment and resumption of growth of transplants would also be of benefit in vegetable and bedding plant production. Therefore, the following preliminary study was undertaken to evaluate the effect of chemical root pruning of tomato or pepper transplants with a cupric hydroxide compound on subsequent root and shoot growth.

'Sunny' tomato (Lycopersicon esculentum) and 'Jupiter' pepper (Capsicum annuum) seeds were sown in TODD 100A flats left untreated or treated with a latex-based carrier of 7% (100 g/liter) cupric hydroxide (Spin Out™, Griffin Corp., Valdosta, GA). At 33 or 45 days after seeding (DAS) for tomato or pepper, respectively, six plants were randomly selected for growth measurement. Stem length and shoot dry weight were measured. Root systems were divided into basal (including adventitious) roots and tap plus lateral roots. Individual roots were removed and counted from each section and pooled for the dry weight of the section.

The remaining plants were transplanted into 32-oz pots of sand in the greenhouse. Plants were watered daily with 50 ppm N (Peters 20N-20P-20K, Grace-Sierrra). At 3, 6, 9, and 12 days after transplanting (DAT), three plants from each treatment were harvested for determination of rate of shoot dry weight gain. At 14 DAT, six plants were harvested for shoot and root growth measurements as described above. All data were subjected to analysis of variance using SAS GLM and regression models. The natural logarithm of shoot dry weight was plotted against time after transplanting.

**Results and Discussion:** Neither stem length nor shoot dry weight of 33-day-old tomato plants was affected by the Spin Out™ treatment (data not presented). Total root numbers were not affected by Spin Out™ but initial root dry weight of 33-day-old tomato plants was reduced 30% by the treatment (Table 1). Two weeks after transplanting to sand-culture in the greenhouse, total root dry weight of treated transplants was 4% greater than that of untreated tomato transplants. The rate of shoot dry weight gain of treated transplants (0.134 mg/day) over 12 days of sand culture was slightly greater than that of untreated transplants (0.122 mg/day, $P<0.05$).

However, roots of 45-day-old pepper transplants were slower to recover from the copper damage. Initial root dry weight of treated plants was reduced 32% relative to controls (Table 1). After two weeks of sand culture, root dry weight of treated plants was still 22% less than controls. Shoot growth of pepper transplants was unaffected. Root development inside the plug was particularly lacking indicating reductions in lateral root branching.

Preliminary studies indicate that treatment of flats with Spin Out™ enhances the subsequent growth of tomato, but not that of pepper transplants. Growth response of treated transplants under stress conditions and actual field conditions must be examined before recommending its use in vegetable production. Preliminary results with other Spin Out™ treatment concentrations suggest improvements in pepper transplant growth can also be achieved with flat treatments.

**Significance to Industry:** Further work with Spin Out™ will provide growers with the ability to control root growth and development of herbaceous plants in order to enhance subsequent performance under field conditions.

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Table 1. Root growth measurements of ‘Sunny’ tomato or ‘Jupiter’ pepper transplants grown in TODD 100A flats left untreated or treated with 7% Spin Out™. Day 0 measurements were made 33 or 45 days after seeding, for tomato or pepper, respectively, at which time plants were transplanted to pots of sand and subsequent growth was measured 14 days later (Day 14).

| | Tap + lateral roots | | Basal roots | | Total | Total |
|---|---|---|---|---|---|---|
| Dry wt | | | | Dry wt | number | root dry wt |
| Treatment | Number | (mg) | Number | (mg) | of roots | (mg) |
| Tomato | | | | | | |
| Day 0 | | | | | | |
| Untreated | 27 | 7.9 | 20 | 10.3 | 48 | 18.2 |
| Spin Out™ | 24 | 5.4 | 25 | 7.2 | 50 | 12.6 |
| Main effect | NS | ** | NS | NS | NS | ** |
| Day 14 | | | | | | |
| Untreated | 39 | 91 | 36 | 140 | 76 | 231 |
| Spin Out™ | 37 | 105 | 41 | 135 | 78 | 240 |
| Main effect | NS | * | * | NS | NS | NS |
| Pepper | | | | | | |
| Day 0 | | | | | | |
| Untreated | 24 | 9.2 | 31 | 12.6 | 55 | 21.8 |
| Spin Out™ | 21 | 6.5 | 34 | 8.3 | 54 | 14.9 |
| Main effect | NS | * | NS | * | NS | * |
| Day 14 | | | | | | |
| Untreated | 37 | 30.9 | 54 | 93 | 91 | 124 |
| Spin Out™ | 34 | 26.0 | 54 | 70 | 88 | 96 |
| Main effect | NS | NS | NS | NS | NS | * |

NS, *, **,  Not significant or significant at $P < 0.05$ or 0.01, respectively.

# How to Build Container Media from the Characteristics of Their Components

**Silvia Bures, F. A. Pokorny, and M. G. Dunavent**
**Georgia**

**Nature of Work:** Commercial container media consist of mixtures of different components (pine bark, peat, perlite, sand, and others) mixed in various proportions. Physical and chemical characteristics of the final mixture are determined by the nature and proportion of each component used in preparing the mixture. Selection and blending of medium components is often done empirically and testing the resulting medium by trial and error is time consuming and costly.

In 1983, Pokorny (7) proposed the idea of computer models in an integrated management program that would include the selection of container media on the basis of physical/chemical properties of the components. One of the problems in mixing components of different particle size is shrinkage of the mixture volume as small particles fill the pores between large particles. Available computer programs do not account for shrinkage (1, 3). Characterization and modeling of shrinkage can be useful in establishing a system of equations to estimate container media mixture characteristics. Once corrected for shrinkage, several characteristics can be estimated on a linear basis.

**Results and Discussion:** The estimating equations that have been developed in recent years can be introduced in a general system. Knowing the analytical characteristics of components, several characteristics of the final mixture can be estimated, such as bulk density (8), water retention (6), cation exchange capacity (4), and hydrogen-ion activity (5). For three-component mixtures the system is:

$$(X_1\ BD_1 + X_2\ BD_2 + X_3\ BD_3) / (I\text{-}S/100) = BD$$
$$(X_1\ WR_{t1} + X_2\ WR_{t2} + X_3\ WR_{t3}) / (I\text{-}S/100) = WR_t$$
$$(X_1\ CEC_1 + X_2\ CEC_2 + X_3\ CEC_3) / (I\text{-}S/100) = CEC$$
$$X_1\ HA_{satl} + X_2\ HA_{sat2} + X_3\ HA_{sat3} = HA_{sat}$$

BD is bulk density of the mixture, WRt is water retained at a given tension t, CEC is cation exchange capacity, and $HA_{sat}$ is the hydrogen-ion activity of the mixture. S is the percent shrinkage of the resulting mixture and $x_i$ is the proportion for a given component i=1,2,...,n. Note that saturated hydrogen-ion activity does not require a shrinkage value for its estimation.

Knowing $x_i$ and $BD_i$, $WR_{ti}$, $CEC_i$, and $HA_{sati}$, one can estimate BD, $WR_t$, CEC and $HA_{sat}$ of the mixture if the value S is also known.

While $x_i$, $BD_i$, $WR_{ti}$, $CEC_i$, and $HA_{sati}$ are known for all the components, S is different for each mixture proportion. To avoid having to determine shrinkage for all mixtures, S can be estimated for up to three components by using the following model (2) that uses as inputs maximum shrinkage ($S_{max}$) of the binary combinations 1-2, 1-3, and 2-3, that we assume is obtained when they are mixed in a 50% - 50% proportion:

if $x_1 > 0.5$, $S = 2\ x2\ Smax_{12} + 2\ x_3\ Smax_{13}$
if $x_2 > 0.5$, $S = 2\ x_l\ Smax_{12} + 2\ x_3\ Smax_{23}$
if $x_3 > 0.5$, $S = 2\ x_l\ Smax_{l3} + 2\ x_2\ Smax_{23}$
if $x_l$, $x_2$, and $x_3 < 0.5$, $S = (1 - 2\ x_l)\ Smax_{23} + (1 - 2\ x_2)\ Smax_{l3}$
$+ (1 - 2\ x_3)\ Smax_{l2}$

The proposed system of equations is capable of estimating bulk density, water retention, cation exchange capacity and hydrogen-ion activity for up to three-component mixtures. Incorporation of these equations into a computer program may facilitate selection of container media based on estimated physical and chemical properties.

**Significance to Industry:** The application of this system of equations can be useful in providing an estimation of which components should be mixed to obtain desired characteristics. By knowing only the chemical and physical characteristics of the components, one can obtain mixtures with pre-established chemical and physical characteristics.

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## Soil Temperature and Root Regeneration in Large Black Plastic and White Aluminum Containers

**R. C. Beeson, Jr. and E. F. Gilman**
**Florida**

**Nature of Work.** In the mid-1980s, many citrus groves destroyed by previous freezes were replanted with shade trees predominately using fabric containers (Root Control Bag, Root Control, Inc., Stillwater, Okla.). When fabric container-grown trees became unmarketable, most producers containerized these trees into commercial 45 to 200 gal containers. Containerization consisted of removing the fabric container from a harvested tree and transplanting into a container of pine bark-based media. Trees were then allowed 4 to 12 months for root regeneration to fill the container before marketing.

Several types of containers were tried during the early years. Wooden boxes were sometimes used for + 100 gal containers, but their weight significantly increased shipping cost. Black plastic containers dominated the market due to availability, but were expensive for many cash-strapped, small tree farms. Besides expense, many growers were concerned with impeded root regeneration caused by excessive soil temperatures, similar to that which occurs in small black plastic containers (Ingram, 1981). One entrepreneur marketed white aluminum rings as an alternative to black plastic pots. These rings were purported to increase uniform root regeneration by lowering medium temperatures and lower capital cost by remaining at a tree farm and reused. During the summer/fall of 1990 we compared container substrate temperatures and root regeneration of *Quercus virginiana* Mill. (live oak) in 65 gal black plastic pots and equivalent volume white aluminum rings.

On 18 June 1990, 4-inch caliper live oaks, produced in 24-inch fabric containers and previously hardened-off (Beeson and Gilman, 1992), were transplanted into 8 aluminum rings and 8 black plastic 65 gal containers (Lerio Corp, Kissimmee, Fla.) in a randomized design. Growing substrate consisted of 3 milled pine bark: 1 Florida peat moss: 1 sand (v/v/v) amended with 1.5 lb of micronutrients per $yd^3$ (Micromax, Grace-Serra, Calif.). Trees were irrigated 6 times daily for 15 min using 2 micro-emitters per container (12 gal/hr each; Roberts Irrigation, Calif). Irrigation frequency was reduced to 4 times per day on 5 July and to 3 times per day on 2 August. On 14 July, thermocouples were installed at half the depth of a container approximately 1.5 inches in from the container wall at the four cardinal directions in three aluminum and plastic containers. Temperatures were measured every 10 min and hourly average recorded. On 5 October, thermocouples were removed and each tree lifted from its container for root collection. At the four cardinal directions on each of the 16 trees, a volume 4 inches wide by 10 inches long to the depth of original root ball was removed from the upper and outer portion of a container root ball. Collected roots were divided into different diameter classes and dry weights determined. Root dry weights were analyzed as a split block with each tree serving as a replicate. Container type was the main plot with direction as the subplot. Maximum, minimum, and average substrate temperatures were extracted for each day and analyzed as repeated measurements using a split plot design for each direction. Container type was the main plot and day the subplot. Temperatures measurements were also analyzed by regression using global solar radiation (GSR) as the independent variable.

**Results and Discussion.** The interaction of container type and day was significant for maximum, minimum, and average substrate temperatures for all directions. Substrate temperature was correlated with daily fluctuations in GSR. On cloudy days, differences in substrate temperature between aluminum and plastic containers were not significant. However, on sunny days, substrate temperatures in black plastic containers were significantly higher than in aluminum containers at all four directions. Differences in average temperature between container types were more prevalent on the east side, as were differences in maximum temperatures. Average temperatures on the east side generally ranged from 88° to 91° F (31° to 33° C) for plastic and 81° to 84° F (27° to 29° C) for aluminum containers. Maximum temperatures on the east side generally ranged from 104 to 109 F (40° to 43° C) for plastic containers and 86° to 90° F (30° to 32° C) for aluminum rings. Higher temperatures on the east than other sides may have been due to the clear mornings and usual afternoon development of clouds that normally occurs in central Florida through September. Differences in minimum substrate temperature were more predominant on the western side with plastic containers generally ranging from 78 to 81° F (25.5° to 27° C) and being 5° F (3° C) warmer than aluminum rings. Despite significant differences in substrate temperatures, there were no differences in roots regenerated by early October between container types or cardinal directions. The amount of roots at the substrate-container wall interface also were visually similar.

**Significance to Industry:** Replacement of large black plastic containers with white aluminum rings will significantly reduce media temperatures during the summer and early fall months. However, this reduction in substrate temperature did not affect quantity or quality of regenerated roots, or root system development of live oak at the substrate-container wall interface. Live oaks are tolerant of dry sand soils and the maximum temperatures obtained may have been within their soil tolerance range. Limited root development due to high media temperature similar to that found in small containers may still occur in large black plastic container with other tree species.

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Florida Agricultural Experiment Stations Journal Series No. N-00794.

# Efficacy of a Cupric Hydroxide/Latex Paint Formulation for Root Pruning 41 Species of Containerized Nursery Stock

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**Tennessee**

**Nature of Work:** Mixtures of cupric sulfate, cupric carbonate or cupric hydroxide in latex paint applied to interiors of containers have been effective in preventing deflected roots (1,2,3,4). When lateral roots contact copper-treated container walls, root elongation is inhibited (3). Second and third-order roots develop behind these root tips, creating a dense fibrous root system oriented in a natural position (3). This root branching effect enhances the quality of containerized plants. Plants grown in copper-treated containers do not require root pruning before transplanting. Copper-treated plants establish quickly after transplanting (l) perhaps because the horizontal orientation of the roots allows for efficient interception of water and nutrients (3). Copper toxicity is localized at the root tip with root elongation resuming 3-6 days after transplanting (1,4). Foliar copper toxicity has not been observed (2,3). Also, plants are easily removed from pots facilitating potting up procedures.

In non-treated containers, deflected and coiled roots that typically develop should be removed before transplanting. This can induce transplant shock and increase the time necessary for establishment. When growth was compared between plants grown in copper-treated and non treated containers, generally economically significant differences were not found (2,3,4,5,6,). To date, relatively few species have been tested for their response to copper compounds. This study surveyed the effect of cupric hydroxide on 41 species of woody ornamental trees, shrubs, perennials and grasses.

Thirty-two uniform rooted cuttings or seedlings were selected from each taxa (Table 1). Containers were 3 5/8 x 3 5/8 x 6 inch plastic bands (Anderson Die and Manufacturing Co. Portland, OR.). Half the containers were painted on the interior surface with a formulation of cupric hydroxide in latex paint (Spin Out™ Griffin Corp. Valdosta, GA). Control containers were unpainted. Pine bark media was used and amended with 7 lb. dolomitic limestone, 2 lb. treble phosphate, 2 lb. 10-10-10 granular fertilizer, 2.25 lb. gypsum, 1.5 lb. Micromax (Grace-Sierra) per yard3. Containers were randomly distributed on a greenhouse bench on 7-inch centers within a species. Standard greenhouse conditions and cultural practices were maintained. Starting dates varied with species ranging, from June to August 1992. Data were collected from 15 October to 10 November 1992.

Root development was rated subjectively by a panel of 4 judges. Each plant was removed from the band and an 8 sec. color video tape recording made of one randomly selected face of the root ball. The judges collectively viewed the tape and scored each root ball on a scale of 1 to 5 with 1 indicating zero root deflection (excellent control) and 5 indicated severe root deflection (no control). Color photographs demonstrating each point on the scale were provided. Data were analyzed with a GLM procedure using Statistical Analysis Software (SAS) and means were separated using LSD at the 5% level of significance.

**Results and Discussion:** Spin Out™ was effective in controlling deflection in all species tested. No foliar symptoms of copper toxicity were observed. With some slower growing species, e.g. Buxus sempervirens 'VARDAR VALLEY', root systems in control container were not well developed prior to collecting data, thus the level of control was unclear. Cupric hydroxide did not inhibit or restrict the growth of stem structures such as rhizomes, stolons or basal suckers.

**Significance to Industry:** This study extends the list of species whose roots can be controlled by cupric hydroxide. While 100% control of root deflection was not always achieved in treated containers, root deflection was consistently reduced compared to untreated containers. With the use of cupric hydroxide paint, nursery growers can produce a higher quality containerized plant that should establish quickly in the landscape. It may also allow growers more time between potting up procedures because root-bound conditions are greatly reduced.

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Table 1. Mean scores of root deflection in containerized plants. Interior of treated pots were sprayed with cupric hydroxide/latex paint formulation (Spin Out™) and controls were not painted.

| | Mean Score | |
|---|---|---|
| | Control | Treatment |
| Acorus gramineus 'VARIEGATUS' | 2.6 | 1.0 |
| Artemisia ludoviciana 'SILVER KING' | 4.0 | 1.0 |
| Betula nigra | 3.4 | 1.3 |
| Buxus sempervirens 'VARDAR VALLEY' | 2.9 | 2.1 |
| Buxus microphylla | 2.8 | 1.0 |
| Calluna vulgaris | 4.6 | 1.0 |
| Carex morrowi variegata | 3.3 | 1.0 |
| Ceratostigma plumbaginoides | 3.1 | 1.0 |
| Cercis canadensis | 3.3 | 1.0 |
| Chionanthus retusus | 1.9 | 1.0 |
| Cortaderia selloana | 4.6 | 1.5 |
| Euonymus fortunei 'COLORATUS' | 3.8 | 1.0 |
| Euonymus fortunei 'VARIEGATUS' | 2.4 | 1.1 |
| Festuca cinerea 'SOLLING' | 2.8 | 1.0 |
| Hibiscus syriacus 'APHRODITE' | 4.7 | 1.5 |
| Hydrangea paniculata 'GRANDIFLORA' | 3.6 | 1.1 |
| Hypericum x 'HIDCOTE' | 2.8 | 1.0 |
| Iberis sempervirens | 4.4 | 1.1 |
| Ilex x 'NELLIE R. STEVENS' | 2.1 | 1.0 |
| Kerria japonica 'PLENIFLORA' | 4.8 | 1.0 |
| Ligustrum japonicum | 2.5 | 1.1 |
| Lythrum 'MORDEN'S PINK' | 4.8 | 1.0 |
| Magnolia liliiflora 'ANN' | 3.6 | 1.8 |
| Magnolia liliiflora 'JANE' | 3.3 | 1.5 |
| Nandina domestica | 2.6 | 1.0 |
| Nyssa sylvatica | 2.8 | 1.0 |
| Pennisetum alopecuroides | 4.9 | 1.4 |
| Photinia x fraseri | 3.1 | 1.0 |
| Pinus thunbergiana | 2.2 | 1.0 |
| Prunus subhirtella 'AUTUMNALIS' | 3.1 | 1.1 |
| Salix melanostachys | 2.4 | 1.0 |
| Spirea japonica 'LITTLE PRINCESS' | 4.7 | 1.0 |
| Spirea nipponica 'SNOWMOUND' | 3.3 | 1.0 |
| Syringa vulgaris 'MICHAEL BUCHNER' | 3.3 | 1.0 |
| Taxus x media 'DENSIFORMIS' | 2.8 | 1.2 |
| Taxus x media 'HICKSII' | 2.0 | 1.7 |
| Thuja occidentalis 'PYRAMIDALIS' | 3.4 | 1.1 |
| Thuja occidentalis 'TECHNY' | 4.3 | 1.4 |
| Viburnum plicatum tomentosum 'MARIESII' | 3.1 | 1.1 |
| Viburnum x rhytidophylloides 'ALLEGHANY' | 2.7 | 1.0 |
| Vitex agnus-castus | 4.6 | 1.0 |

* Comparisons within all species were significantly different (Alpha = 0.05).

# Root Distribution of Carpentaria Palm Grown in Copper Hydroxide-Treated Containers

**Sven E. Svenson and Timothy K. Broschat**
**Florida**

**Nature of Work:** Matted and kinked roots of container-grown stock have been associated with increased mortality, poor mechanical stability, and susceptibility to drought after transplanting (7). Root pruning before transplanting container-grown plants may eliminate root system deformation, but may also reduce survival and growth (5). Application of copper compounds to interior container surfaces prevents or reduces root growth at the container-medium interface (l, 2, 3, 4, 8), and may increase root growth after transplanting (I, 8). Response to copper-treated containers differs among various ornamental species (2, 3).

Carpentaria acuminata is a popular palm used in tropical and subtropical landscapes. When grown in containers, the vigorous palm root system grows in a dense circular pattern at the base of the pot, producing a pot-bound appearance. This pattern of root growth also makes the palm difficult to remove from the pot. The objectives of this study were: 1) to determine if copper hydroxide [$Cu(OH)_2$] application to interior container surfaces would reduce the pot-bound appearance of carpentaria palm by reducing root growth at the container-media interface; and 2) to determined if $Cu(OH)_2$ application to interior container surfaces would reduce the difficulting in removing the rootball from the container.

Carpentaria palm seeds were collected in southwestern Broward County, FL and sown in germination flats. After five months, germinated seedlings of uniform size were transplanted into 0.5 liter (approximately one pint) pots filled with a pine bark:Florida sedge peat:sand (5:4:1 by volume) medium. A dibble application of 6 g of Osmocote 17N-3P-9.9K (Grace/Sierra, Milpitas, CA) was applied at transplanting, and a top-dress application of the same amount was applied after six months growth. Before planting, interior container surfaces were treated as follows: I) untreated; 2) sprayed with white exterior acrylic latex paint; 3) sprayed with a 3% solution of NuFilm-17™ surfactant per (96% di-I-p-Menthene; Miller Chemical and Fertilizer Corporation, Hanover, PA); 4) sprayed with a commercial formulation of 100 grams $Cu(OH)_2$ per liter of latex carrier- (Spin Out™; Griffin Corp., Valdosta, GA); and 5) sprayed with a solution containing 3% NuFilm-17 and 100 g of $Cu(OH)_2$ per liter of solution. Seedlings were grown under 63% black-poly shade cloth using daily overhead irrip,ation. A completely randomized experimental design was used.

After 8 months growth, palms were harvested by separating plants into shoot, root, and circling root sections, with dry weights recorded after drying at 65° C (150° F) for two days. Data were analyzed using analysis of variance and Duncan's Multiple Range Test.

**Results and Discussion:** When applied in Spin Out™ or NuFilm-17, $Cu(OH)_2$ reduced root growth at the container-medium interface, controlling the circular growth pattern commonly observed in container-grown plants. Dry weights of whole plants (data not shown) and whole root systems of carpentaria palm were not influenced by any interior container surface treatments (Table 1). Circling roots comprised over 50% of palm root dry weight without $Cu(OH)_2$, and there was no response to the paint or NuFilm-17 applications. $Cu(OH)_2$ applied with SpinOut™ or NuFilm-17 reduced circling root dry weight to less than 15% of the root system. Seedling roots were more easily removed from $Cu(OH)_2$-treated pots. There were no symptoms of copper toxicity in the shoots.

Copper-containing compounds mixed with white acrylic latex paint and applied to interior container surfaces control root growth at the container-medium interface, and increase root density (1, 4). The reduction of circling root dry weight for carpentaria palm when either Spin Out™ or NuFilm-17 were the carriers for $Cu(OH)_2$ shows that a latex carrier is not required. Application of paint produced an unsightly container while applications of Spin Out™ or $Cu(OH)_2$ in NuFilm-17 were not readily noticeable.

Application of $Cu(OH)_2$ to interior container surfaces reduced circling root growth without reducing growth of the whole root system or shoot, similar to results for windmill palm (Trachycarpus fortunei; 2). Carpentaria palm roots grew within the growing medium rather than along the container-medium interface. Such root growth within the growing medium could provide increased root surface contact with water and mineral elements stored in the medium, possibly supporting faster growth. Use of $Cu(OH)_2$-treated containers often eliminates needed root pruning of container-grown stock before transplanting, and may support faster growth and establishment with less mortality after transplanting (l, 2, 7).

After transplanting, palms quickily extend adventitious roots originating from the root initiation zone at the base of the trunk (9). Unlike dicotyledonous species, reduced circling of the adventitious root system of the monocotyledonous carpentaria palm produced in $Cu(OH)_2$-treated containers may be less important to improved establishment and growth after transplanting (6, 9).

**Significance to Industry:** Application of $Cu(OH)_2$ to interior container surfaces restricted root circling of Carpentaria palms. Palms had more roots distributed within the growing medium when grown in treated containers. Palms were more easily removed from $Cu(OH)_2$-treated pots. There were no symptoms of copper toxicitiy in the shoots of palms grown in Cu(OH)2-treated pots. Use of Cu(OH)2-treated pots to produce palms could provide a more appealing product to consumers by reducing the root-bound appearance, and by making it easier to remove the plants from the container at transplanting.

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The authors thank Griffin Corporation for supplying Spin Out™. Assistance of Bonnie Coy, Diane Johnston, Tony Mixon and Susan Thor is acknowledged.

Table 1. Dry weight of roots in the growing medium, dry weight of circling roots, total root dry weight, and percentage of circling roots of Carpentaria acurninata grown in 0.5 liter containers for 8-months after transplanting from germination flats. Containers were treated with cupric hydroxide [$Cu(OH)_2$] in Spin Out™ or NuFilm-17, with paint or NuFilm-17 only, or were untreated.

| Container Treatment | Media root dry wt. (grams) | Circling root dry wt. (grams) | Total root dry wt. (grams) | Percentage of circling roots[z] (% dry wt.) |
|---|---|---|---|---|
| Untreated (Control) | 0.65 b[y] | 0.85 a | 1.50 a | 56.4 a |
| Paint only | 0.78 b | 0.73 a | 1.51 a | 48.3 a |
| NuFilm-17 only | 0.71 b | 0.81 a | 1.52 a | 53.2 a |
| 100g $Cu(OH)_2$ in SpinOut™ | 1.24 a | 0.15 b | 1.39 a | 10.5 b |
| 100g $Cu(OH)_2$ in NuFilm-17 | 1.30 a | 0.19 b | 1.49 a | 12.6 b |

[z] Analysis performed on arcsine transformed data.

[y] Means within columns followed by the same letter are not different ($P<0.05$) according to Duncan's New Multiple Range Test; n = 10.