SECTION 2

CONTAINER-GROWN PLANT PRODUCTION

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Section 1 and Section 13 may contain related titles.

Rice Hull Ash as a Potting Substrate for Bedding Plants

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Nature of Work: Greenhouse studies were conducted to determine the effects of rice hull ash as a media substrate on the growth and quality of *Petunia x hybrida* 'Pink Madness', *Tagetes erecta* 'Yellow' (Marigold) and Catharanthus roseus 'Bright Eye' (Vinca) . The plants were purchased as plugs and transplanted into 606 cell packs on April 5, 1996. Rice hull ash, obtained from a rice processing plant in Greenville, MS, was blended at 0, 10, 20, 30, 40, and 50 percent by volume with a commercial potting media, Metro 366 (blended with 5% kenaf), manufactured by Scotts, Corp., Foglesville, PA. Rice hull ash was also blended at 0, 10, 20, 30, 40, and 50 percent by volume with one year old composted cotton gin trash. The treatments were arranged in a completely randomized design. Normal fertilization practices were followed using 200 ppm of Peters 20-20-20, manufactured by Scotts Corp., Foglesville, PA, twice a week. At the conclusion of the study on May 8, 1996, soil was extracted from each cell, and a composite sample made from the four replications of each treatment. A soil analysis was conducted on each sample. Also, growth indices were calculated from measurements taken from each plant while flower quality, root quality and number of flowers per plant were made by visual observations.

Results and Discussion: As the amount of rice hull ash increased, so did the soil pH. When amounts of 40 percent by volume of rice hull ash was added to the commercial media, the soil pH rose above 7.0. The soil pH of the composted cotton gin trash rose from above 7.0 to above a pH of 8.0. Studies by Shumack and others have shown that composted gin trash has a pH near 7.0, so this was not surprising to see a reading in this range. However, no plants in this trial showed any visible sign of nutrient defficiency. The commercial media used in this study is marketed with a "minor element" charge, which could provide sufficient nutrients without being tied up by a high soil pH. Also, the Peters 20-20-20 used in this study could have supplied enough minor elements to mask any potential nutrient deficiency. There were no consistent differences between treatments regarding number of flowers, flower quality, root quality and growth index. The consistent difference was the increase in soil pH.

Significance to Industry: Many by- products have been used quite successfully as media substrates, however, a major concern to any grower is availability and consistency. This study shows that rice hull ash can be used as a potting substrate for the production of bedding plants if incorporated in small quantities, less than 50 percent. Management of soil pH must be closely monitored to insure there is not excessive tie up of nutrients. Rice hull ash would require drying before being shipped long distances, but would be an excellent by- product as a potting substrate for bedding plants that require an slightly alkaline soil pH. Rice hull ash may also be used in situations where acid irrigation water is persistent. This product appears to be an excellent buffering agent in potting media for short term crops. Further study using longer term crops will help define this product as a potting media substrate. Another benefit of rice hull ash is its high content of silica. It has been shown by Newman and others that rice hulls contain a high amount of silica (2%). This could be a benefit in obtaining a favorable bulk density and porosity of a potting substrate.

Literature Cited

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Effect of rice hull ash on soil pH.	Soil pH		
soil substrate	**Marigold**	**Petunia**	**Vinca**
Metro 366 (5%kenaf) + 0 %v/v of rice hull ash	5.6	5.9	5.4
Metro 366 (5%kenaf) + 10 %v/v of rice hull ash	6.1	6.1	5.9
Metro 366 (5%kenaf) +20 %v/v of rice hull ash	6.4	6.5	6.2
Metro 366 (5%kenaf) + 30 %v/v of rice hull ash	6.8	6.8	6.5
Metro 366 (5%kenaf) + 40 %v/v of rice hull ash	7.2	7.2	7.2
Metro 366 (5%kenaf) + 50 %v/v of rice hull ash	7.6	7.4	7.5
Cotton Gin Trash + 0 %v/v of rice hull ash	7.2	7.7	7.4
Cotton Gin Trash + 10 %vlv of rice hull ash	7.3	7.4	7.5
Cotton Gin Trash + 20 %v/v of rice hull ash	7.9	7.9	7.9
Cotton Gin Trash + 30 %v/v of rice hull ash	7.9	7.8	7.9
Cotton Gin Trash + 40 %v/v of rice hull ash	8.2	8.4	8.1
Cotton Gin Trash + 50 %v/v of rice hull ash	8.4	8.2	8.2

Recycled Waste Paper as a Non-chemical Alternative for Weed Control in Container Production

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Nature of Work: Typically granular herbicides are broadcast with a cyclone spreader over the top of container grown plants. This method of application results in significant non-target herbicide loss (herbicide falling between pots rather than in the pots). In an effort to reduce herbicide use, a number of non-chemical materials have been evaluated as a mulch material.

Two recently developed products with potential to reduce herbicide use in container nursery crop production are made from recycled waste paper. These products are pelletized recycled paper or crumbled recycled paper (Tascon, Inc. Houston, TX). Waste paper is ground with a hammer mill equipped with a series of three screens, then compressed using pelletizing equipment to form pellets about 3/16 x 1 inch. To develop the crumble product, pellets are put through a granulator with variable pressure plates.

The objectives of this study were to evaluate these new recycled waste paper products as a non-chemical weed control alternative for container production and to determine plant growth response to recycled waste paper.

Results and Discussion: Uniform liners of ‘Fashion’ and ‘Girard’s Rose’ azalea were potted in trade gallons on August 9, 1995. Medium used was a 3:1 (v:v) pine bark:peat with 15 lb Nutricote (18-6-8), 6 lb lime, and 1.5 lb Micromax added per yd^3. Plants were grown in full sun and received daily overhead irrigation as needed.

Two paper products, recycled paper crumble and recycled paper pellets were applied at one of 2 depths, 0.5 or 1 inch. Phosphorus was applied to the recycled waste paper products in pots as triple superphosphate, at either 0 or 7.5 ppm, based on the dry weight of the paper. Previous work had demonstrated sensitivity of some bedding plants to Al in the recycled paper. Other treatments included a fabric disk , and a fabric disk with Spinout, Rout 3G applied at 3 lb ai/a, and a non-treated control. With all mulch treatments 30 prostrate spurge seeds were placed either under the mulch or on top of the mulch. All other treatments had 30 prostrate spurge seed placed on the medium surface. Azaleas were re-potted into

3 gallon containers on May 7, 1996 using the same medium, mulched with the recycled waste paper treatments, and Rout 3G treatment was reapplied.

Data collected were spurge number per pot 30 and 75 days after treatment (DAT), and spurge fresh weight 75 DAT for ‘Fashion’ azalea pots only. In 1996 after repotting, spurge number was determined 30 and 60 DAT and spurge fresh weights were determined in pots of both azaleas. Growth indices were determined for both species 245 and 550 DAT. Medium solution electrical conductivity (soluble salts) and pH of ‘Fashion’ containers were taken 7, 30, 90, 210, and 240 DAT using the VTEM.

Weed data: Recycled waste paper pellets applied to a depth of 1 inch completely suppressed spurge germination through the 1995 growing season, regardless of whether spurge seed were sown on top of the mulch or under the mulch (Table 1). In contrast, recycled crumble provided poor spurge control at both depths and when spurge were sown on top of the mulch there was increased spurge growth compared to when the seed were sown under the crumble mulch. With recycled crumble there was greater spurge number per pot at 30 DAT with the 0.5 inch depth than with any other mulch depth.

Spurge control with the fabric disk was not consistent in this study. Spurge emerged around the container circumference and in the slit where the fabric disk fits around the plant.

Recycled pellets continued to provide excellent spurge control after the plants were re-potted in May of 1996. With ‘Girard’s Rose’ azalea at 60 DAT, recycled pellets provided greater spurge control (number per pot) than recycled crumble (1.0 vs 3.8). The 1 inch depth provided greater control of spurge number per pot at 60 DAT than the 0.5 inch depth (1.5 vs 3.3); data for ‘Fashion’ azalea followed a similar trend.

Growth indices: Azaleas grown with recycled waste paper mulch were generally similar in size to non-treated control plants and Rout treated plants at both 240 and 550 DAT.

Salts and pH: When P was added to recycled paper, leachate pH was lower than for no P treatments (all dates except 210). Initially, the crumble recycled paper leachate had higher pH levels than pelleted (7 DAT); however, by 30 DAT pellet leachate had higher pH levels than for crumble and maintained these higher levels throughout the study. Leachate pH gradually increased in acidity with all treatments over the course of the study; ranging from 5.6 to 6.6 at 7 DAT to 4.9 to 6.0 at 240 DAT. These levels are within acceptable pH ranges for container grown nursery crops.

Significance to the Industry: Controlling weed populations in container grown nursery crops is essential for production of quality, marketable plants. The recycled waste paper pellet product evaluated in this study has proven to be effective in controlling weeds in containers without the use of herbicides. Two environmental issues are addressed with this product; a reduction in chemical use and an alternative application for a post consumer by-product that would otherwise be disposed of in land-fills.

Table 1: Effects of mulch on prostrate spurge control in container grown plants.

Spurge	Spurge	w/pot		fresh weight g/pot
Treatment	Depth (mm)	30 DAT	75 DAT	75 DAT
Pellet/su[z]	12.5	1.0	3.4	2.6
Pellet/su	25	0.0	0.0	0 0
Crumble/su	12.5	10.1	18.9	22.7
Crumble/su	25	2.5	8.5	9.2
Pellet/st[Y]	25	0.0	0.4	0.0
Crumble/st	25	9.3	21.6	12.7
mulch		**	**	**
depth		**	**	**
seed		**	**	NS
mulch*depth		**	**	*
mulch*seed[X]		**	**	NS
LSD[W]		3.8	4.1	7.0
FD/su[V]		0.3	9.5	3.5
FD/st		5.8	8.3	25.3
FDS/su[U]		0.8	1.3	7.1
FDS/st		2.6	4.6	11.3
fabric		NS	* *	NS
seed		**	NS	**
fabric*seed		**	NS	**
LSD[T]		2.5	5.2	9.9
Rout[S]		0.0	3 5	0.0
Control[R]		12.0	20.5	26.8
LSD[Q]		3.1	6.0	11.4

[z]su = seed applied under the mulch.
[Y]st = seed applied on top of the mulch.
[X]Mulch*seed interaction based on 25 mm depth only.
[W]LSD for paper mulch treatments; 5% level.
[V]Fabric disk with seed applied under.
[U]Fabric disk with spinout and seed applied under.
[T]LSD for fabric disk treatments; 5% level.
[S]Rout 3G herbicide applied at 3 lb ai/a.
[R]Nonmulch control.
[Q]Overall experimental LSD; 5% level.

Influence of Pine Bark and Hardwood Bark Media On Cool Season Bedding Plant Growth

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Nature of Work: In Louisiana, hardwood bark sources are being utilized in container production of woody ornamentals and herbaceous perennials/annuals. The influence of hardwood bark on growth of acid-loving woody ornamentals is fairly well documented, however, the role of hardwood bark in bedding plant growth has not been as thoroughly defined.

The primary objective of a recent LSU Agricultural Center study was to determine the performance of three cool-season annual bedding plant species as influenced by hardwood bark and pine bark. 'Telstar Crimson' dianthus, 'Cyiodori Red' flowering kale, and 'Tahiti Rose' snapdragons growing in 4" pots were transplanted November 10, 1996 into trade gallon nursery containers containing one of the following eleven medium treatments: 100% pinebark, 90% pinebark/10% hardwood bark, 80% pinebark/20% hardwood bark, 70% pinebark/30% hardwood bark, 60% pinebark/40% hardwood bark, 50% pinebark/50% hardwood bark, 40% pinebark/60% hardwood bark, 30% pinebark/70% hardwood bark, 20% pinebark/80% hardwood bark, 10% pinebark/90% hardwood bark, and 100% hardwood bark. Each medium was blended based on volume. All growing medium were amended with incorporated applications of 1.5 lbs/ yd^3 Micromax and 8 lbs/yd3 dolomitic lime. Plants were fertilized with a top-dressing of StaGreen 12-6-6 at the rate of 1/2 teaspoon/pot at planting and at the rate of i/. teaspoon/pot four weeks later. Each treatment in the completely randomized experiment was replicated four times. Plants were grown outdoors in full sun under an overhead irrigation system. Cold or freeze protection was not provided.
Visual quality ratings based on a scale from 1 to 5 (1=worst, 5=best) were taken six weeks after initiation. Plant height of dianthus and snapdragon were taken on the same date and was measured from the growing medium level to the tallest plant part. Spread of flowering kale was taken also at six weeks after initiation and represented the widest linear extent across the plant.

Results and Discussion: Visual quality ratings of dianthus, kale, and snapdragon after six weeks varied according to the growing media in (Table 1). Hardwood bark, in most cases, did not adversely affect the visual quality of the plants. The growing medium was least significant for snapdragons. Kale growing in higher percentages of hardwood bark had significantly superior quality when compared to plants growing in pine bark. This trend was also apparent when spread (width) of kale was considered. Height of snapdragons six weeks after the experiment was not influenced by the growing medium treatment.

Significance to Industry: Plants are being commercially produced across the southeastern United States in media containing varying percentages of hardwood bark. This medium source needs to be evaluated for potential utilization in container production of annual bedding plants, herbaceous perennials, and woody ornamentals. Hardwood bark was demonstrated in the study to be an acceptable consideration in short term production of three cool-season bedding plants species.

Table 1. Influence of varying volumetric proportions of pine bark and hardwood bark media on growth of dianthus, snapdragon, and flowering kale.

Media %' (by volume)		Telstar Crimson Dianthus		"Cyiodori Red' Kale		'Tahiti Rose' Snapdragon	
Pine bark	Hard-wood bark	Height	Visual Quality	Spread	Visual Quality	Height	Visual Quality
100	0	7.78 ab	3.25 bc	9.35 abed	3.25 d	7.19 a	2.63 b
90	10	7.87 ab	3.38 abc	7.97 e	2.63 e	6.89 a	3.00 ab
80	20	7.09 b	3.13 bc	8.46 de	3.13 de	7.48 a	3.13 ab
70	30	8.37 ab	3.13 bc	8.86 cd	3.25 d	7.28 a	3.00 ab
60	40	8.56 a	3.38 abc	10.04 a	3.25 d	7.19 a	2.75 ab
50	50	7.68 ab	3.00 c	9.74 abc	4.13 ab	7.28 a	3.13 ab
40	60	7.48 ab	3.00 c	9.65 abc	4.25 a	7.38 a	3.13 ab
30	70	8.56a	3.75 a	9.35 abed	3.50cd	7.09a	3.25 a
20	80	7.48 ab	3.63 ab	9.84 ab	3.88 abc	6.99 a	2.75 a
10	90	8.27 ab	3.13 bc	8.96 bcd	3.63 bcd	7.28 a	2.75ab
100	100	8.46a	3.00c	9.74abc	3.63bcd	7.09a	3.13ab

Note: Plant height, plant spread, and visual quality ratings made six weeks after experiment initiation. Visual quality ratings based on a scale from 1 to 5 (1=worst, 5=best). Height measured from medium line to highest plant part. Spread measured at widest linear extent across the plant. means separated by Duncan's multiple range test at level = 0.05 (means followed by the same letter are not significantly different).

Container Production of Petunia Utilizing Shredded Waste Tires as a Growing Medium

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Nature of Work: Shredded waste tires are currently being investigated in several states as an ornamental horticulture growing medium amendment. In Louisiana, studies funded by the Louisiana Department of Environmental Quality have been initiated to evaluate shredded waste tires as a container growing amendment and landscape mulch material.

The primary objective of a recent LSU Agricultural Center Study was to determine the performance of shredded waste tires as a container medium in production of 'Dream Pink' petunias. Petunias growing in 4" pots containing a commercially available pine bark based medium were transplanted March 14, 1997 into trade gallon containers containing one of the following median (by volume): 100% pine bark, 90% pinebark/10% shredded waste tires, 80% pinebark/20% shredded waste tires, 70% pinebark/30% shredded waste tires, 60% pinebark/40% shredded waste tires and 50% pinebark/50% shredded waste tires. All growing medium were amended with incorporated applications of 1.5 lbs/yd^3 Micromax, 4 lbs/yd^3 dolomitic lime, 12 lbs/yd^3 StaGreen Nursery Special 12-6-6 and treatments were replicated five times and placed in a completely randomized design in full sun under overhead irrigation.

Visual quality ratings based on a scale from 1 to 5 (1=worst, 5=best) were taken March 28 and April 12. This corresponded to 2 and 4 weeks after initiation. Plant height was determined on March 28 and April 12 and was measured from the growing medium level to the tallest plant part. Shoot dry weight was determined at experiment termination (April 12) by drying all plant parts (shoots and flowers) above the growing medium level for 72 hours at 70° Celsius.

Result and Discussion: Visual quality ratings of petunia as influenced by growing medium treatments were non-significant two weeks after initiation and significant four weeks after initiation (Table 1). Petunias growing in 100% pine bark and 90% pine bark/10% shredded waste tires had superior quality when compared to treatments containing 30% or greater shredded waste tires. Some of the petunias growing in media containing these higher percentages of shredded waste tires exhibited visual symptoms of nutritional deficiencies and toxicities (primarily zinc toxicity and magnesium deficiency).

Height of petunias was only slightly influenced by the percentage of shredded waste tires in the medium. This occurred by four weeks after treatment initiation. Plants growing in 20-30% shredded waste tires were shorter than plants growing in 100% pine bark. Shoot dry weight was significantly reduced for plants growing in 60% pine bark/40% shredded waste tires when compared to 100% pine bark.

Significance to Industry: The use of shredded waste tires in ornamental horticultural settings is currently being investigated at several land grant universities in the southeastern United States. These studies are evaluating shredded waste tires as a constituent of container medium, as an amendment in landscape bed preparation, and as a mulch material. Shredded waste tires have some application in these cases but addition research efforts are needed to develop final conclusions and practicality of these uses.

Table 1. Visual quality ratings, plant height, and shoot dry weight of 'Dream Pink' petunias as influenced by growing medium containing varying volumetric proportions of shredded rubber tires.

Growing Medium		Visual Quality (%Volume)		Height Ratings		
Pine Bark	Rubber Tires	Week 2	Week 4	Week 2	Week 4	Shoot DryWeight
100	0	3.4 a	4.7 a	15.2 a	22.8 a	13.3 a
90	10	3.4 a	4.3 ab	14.8 a	22.0 ab	12.3 ab
80	20	3.1 a	4.0bc	15.2a	20.8 b	11.4ab
70	30	3.2 a	3.7 cd	15.0 a	20.6 b	10.8 ab
60	40	3.2 a	3.5 d	15.6 a	21.2 ab	10.5 b
50	50	3.1 a	3.3 d	15.2 a	21.6 ab	11.1 ab

Note: Visual quality ratings based on a scale from 1 to 5 (1=worst, 5=best). Plant height expressed in centimeters and measured from growing medium level to tallest plant part, and shoot dry weight expressed in grams. Means separated by Duncan's multiple range test at level = 0.05 (means followed by the same letter are not significantly different).

Container Production of Sixteen Lantana Cultivars

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Nature of Work: Lantanas continue to be one of the leading flowering perennials in Louisiana and the southeastern United States. Landscape trials and container production evaluations are being conducted in response to high interest in this plant by center managers, and consumers.

The primary objective of a recent study at the LSU Agricultural Center was to evaluate sixteen lantana cultivars under typical container production methods. Cultivars evaluated were Patriot Sunburst, Confetti, Tangerine, Dallas Red, Silver Mound, Patriot Cherry, Samantha, Patriot Dovewings, Lady Olivia, Weeping Lavender, New Gold, Patriot Firewagon, Patriot Desert Sunset, Patriot Honeylove, Cream, and Patriot Rainbow.

Lantanas growing in 1206 cell packs were transplanted into trade gallon containers on March 7, 1997. The growing medium used was pine bark amended with incorporated applications of 1.5 lbs/yd^3 Micromax, 8 lbs/yd^3 dolomitic lime, and 12 lbs/yd^3 Osmocote 18-6-12. Plants were arranged in a completely randomized design and each cultivar treatment was replicated three times. The experiment was maintained in full sun under sprinkler irrigation. No pinching was conducted. Visual quality ratings based on a scale from 1 to 5 (1=worst, 5=best) were taken May 15, June 1, and June 15. This corresponded to approximately 9, 11 and 13 weeks after initiation. Plant height was determined on June 15 and was measured from the growing medium level to the tallest plant part.

Results and Discussion: By May 15 (plants had reached salable condition) visual quality ratings of lantanas ranged from 2.5 to 3.7. The higher visual quality ratings were obtained for New Gold, Weeping Lavender, Patriot Sunburst, Tangerine, Confetti, Dallas Red, Lady Olivia, Patriot Firewagon, and Patriot Desert Sunset. Acceptable visual quality ratings were obtained for Cream and Patriot Dovewings. Patriot Cherry and Patriot Rainbow had the lowest visual quality ratings on May 15.

Weeping Lavender, New Gold, and Cream had the highest visual quality ratings on June 15. These cultivars were followed by Confetti, Tangerine, Samantha, and Patriot Dovewings. Most of the other cultivars also had very acceptable visual quality ratings on June 15.

The shortest growing lantana in terms of height on June 15 were Patriot Sunburst, Tangerine, Samantha, Patriot Rainbow, and Patriot Honeylove. The most upright growing lantanas at this time were Silver Mound, Dallas Red, Confetti, Cream, Weeping Lavender, and Lady Olivia. New Gold appeared in the intermediate size class.

Significance to Industry: Lantanas are very much increasing in popularity and sales in the southeastern United States. Landscape trials and container production evaluations are necessary to determine performance of the numerous cultivars now available. The LSU Agricultural Center is trialing 33 lantana cultivars in landscape settings in 1997 and will be evaluating over 40 in 1998.

Table 1. Visual quality ratings and plant height of sixteen cultivars of container-grown lantana.

	Visual Quality Ratings			
Cultivar	May 15	June 1	June 15	Plant Height
Patriot Sunburst	3.2	3.7	3.7	23.7
Confetti	3.2	4.5	4.2	26.6
Tangerine	3.2	4.2	4.2	21.0
Dallas Red	3.2	4.0	3.8	27.3
Silver Mound	2.7	3.7	3.8	33.3
Patriot Cherry	2.5	3.7	3.7	26.3
Samantha	2.8	4.3	4.2	21.0
Patriot Dovewings	3.0	3.5	4.2	26.0
Lady Olivia	3.3	3.7	3.8	27.7
Weeping Lavender	3.5	5.0	4.7	30.0
New Gold	3.7	4.3	4.3	24.0
Patriot Firewagon	3.2	3.7	3.5	24.7
Patriot Desert Sunset	3.2	3.5	3.7	25.3
Patriot Honeylove	2.7	3.7	3.7	20.3
Cream	3.0	4.2	4.3	27.7
Patriot Rainbow	2.7	4.0	3.8	19.0
LSD (alpha = 0.05)	0.3	0.3	0.4	3.9

Note: Visual quality ratings based on a scale from 1 to 5 (1=worst, 5=best). Plant height expressed in centimeters and measured from growing medium level to tallest plant part.
Means separated by Least Significant Difference at level = 0.05.

Enhancing Blue Flowering in Hydrangea with Alum (Aluminum Sulfate, Hydrate)

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Nature of Work: A preliminary study was conducted to investigate the effect of alum (aluminum sulfate, hydrate) on flower color of *Hydrangea macrophylla* var. 'Nikko Blue' applied late in the production cycle. Budded liners of H. *Macrophylla* var 'Nikko Blue' were potted in 1.6 gallon containers using a 3:1 vol:vol pine bark:peat moss media amended with 1.5 lb micromax, 2 lb gypsum, and 1 lb magnesium sulfate per cubic yard. Nitrogen was supplied at the rate of 3 lb N per cubic yard with either a controlled release urea formaldehyde formulation (39-0-0) or a controlled release sulfur-coated urea formulation (35-0-0). An alum drench was applied at 15 lb per 100 gallons water (approximately 0.5 ounces of alum per pot). Drenches were applied once a week, once every 2 weeks, once every 4 weeks, or no drench applied. Flowers were rated for color using the Royal Horticulture Color Chart and then described as light pink, medium pink dark pink, light blue, medium blue, or dark blue.

Results and Discussion: Alum applications had a noticeable effect on flower color. All treatments which received at least one alum drench were visibly more blue than the treatments which were not drenched with alum. There was not a detectable difference in flower color among the treatments that were drenched one to 4 times with aluminum sulfate, hydrate..

Significance to the Industry: Although preliminary, this study indicates that alum applied as a drench may enhance blue flower color in *H. Macrophylla*. In this study, blue flower color was enhanced by applying the alum drenches as late as one month prior to blooming. More work is needed to determine the optimum timing of alum drenches and the benefits of multiple applications or different fertilizer sources.

Table 1. The effect of alum drenches on flower color of *H. macrophylla*

Fertilizer Treatment	Drench Number	VTEM pH	Average Flower Color
Urea formaldehyde	0	6.9	Light Pink
	4	3.8	Medium Blue
	2	4.3	Medium Blue
	1	5.5	Medium Blue
Sulfur-Coated Urea	0	6.3	Light Pink
	4	3.3	Medium Blue
	2	3.4	Medium Blue
	1	3.6	Medium Blue

VTEM: Virginia Tech. Extraction Method.

Influence of Dolomitic Limestone Form and Rate on `Fashion' Azalea and `Soft Touch' Holly

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Nature of Work: Amending media with finely ground dolomitic limestone is a common cultural practice in container nurseries. The influence of limestone on growth of container-grown woody ornamentals has been the focus of a number of studies (1, 2, 3, 4). Little work has been done evaluating the influence of limestone product formulation on growth of woody ornamentals. The objective of this study was to compare pelletized dolomitic limestone (Easy Lime, Pursell Industries, Sylacauga, AL) with finely ground dolomitic limestone (Dolitco) (not less than 90% passing a 10 mesh screen, not less than 50% passing a 60 mesh screen) as a media amendment for container grown landscape crops. Uniform liners of Soft Touch Holly (*Ilex crenata* `Soft Touch') and Fashion azalea (*Rhododendron* `Fashion') were containerized into trade gallon containers in April, 1996, in a 3:1 (vol:vol) pinebark:peat moss substrate amended with 14 lbs. of 17-7-12 Osmocote and 1.5 lbs. of Micromax per cubic yard (O.M.Scotts Co., Maryville, Ohio). Treatments considered in this study were form and rate of incorporation of dolomitic limestone. The five treatments were: Finely ground or pelletized dolomitic limestone at two rates each; 5 or 10 lb./cubic yard; and a control with no limestone in the substrate. Plants were grown at the Ornamental Horticulture Substation, Mobile, Alabama in full sun under standard nursery practices with overhead irrigation. Canopy growth index and foliar color ratings were made monthly, and container leachates were collected every 2 weeks, for 330 days following initiation of the study.

Results and Discussion: Medium solution pH increased with increasing rate of dolomitic limestone. Finely ground dolomitic limestone had a greater impact on medium solution pH than pelletized dolomitic limestone when incorporated at the same rate, and differences increased as limestone rate increased. Leachate data (Table 1) gives an indication of different dolomitic limestone formulations impact on maintaining medium solution pH in containers over a 330 day period. Addition of ground dolomitic limestone at 10 lbs/cubic yard reduced foliar color and growth of azalea. Amending with dolomitic limestone had little or no effect on holly foliar color or growth, regardless of product formulation or rate.

Significance to Industry: Previous studies have shown that excessive limestone in container media may reduce growth in woody ornamentals (2, 3, 4). The results of this study indicate that growth of `Fashion' azalea is not improved by incorporating dolomitic limestone into a pinebark:peat container media. Furthermore, excessive liming, leading to decreased growth, is more likely from a finely ground dolomitic limestone formulation than a pelletized formulation of dolomitic limestone in production of `Fashion' azalea. However, incorporation of dolomitic limestone increased growth of `Soft Touch' holly compared to plants grown in an unamended substrate. Differences in growth of `Soft Touch' holly were not affected by rate and formulation of dolomitic limestone, indicating that either finely ground or pelletized products would be suitable for container producers.

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Table 1. Influence of dolomitic limestone formulation and rate on media pH[z]

Treatment formulation	Rate per yd^3	7 DAT	42 DAT	60 DAT	120 DAT	180 DAT	240 DAT	270 DAT	330 DAT
Control	0	3.97	4.49	4.12	4.37	4.29	4.39	4.04	3.82
Pelletized	5 lbs	5.45	5.58	4.99	4.87	4.91	4.94	4.44	3.96
Pelletized	10 lbs	5.84	6.18	5.72	5.48	5.53	5.57	S.49	4.88
Finely Ground	5 lbs	5.99	6.06	5.46	4.90	4.82	4.86	4.48	3.94
Finely Ground	10 lbs	6.44	6.71	6.47	6.44	6.33	6.05	6.25	6.06

[z] Data collected from 7/17/95 through 6/11/96 by VA. Tech. Pour Thru Method.

Growth Responses of Annuals in Five Potting Media

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Nature of Work: Cost, availability, and quality of peat moss for use as a component of potting media have lead to the evaluation of alternative products as a peat substitute. Coconut coir pith has previously been evaluated as a medium component for ornamentals (1,3). Coconut coir pith is the material left when long fiber has been separated from coconut husks (1). Successful production of both woody (1) and subtropical ornamentals (2,3) has lead to the availability of several commercial media that substitute coir pith for peat moss. The objective of this experiment was to evaluate coconut coir-based media as a growing substrate for annual production in trade gallon containers.

Uniform jumbo cell pack liners (10 in3/cell) of discovery orange marigold (*Tagetes erecta* 'Discovery orange'), accent orange impatiens (*Impatiens wallerana* 'Accent orange'), showstar melampodium (*Melampodium paludosum* 'Showstar'), and new wonder scaevola (*Scaevola aemula* 'New wonder') were transplanted into 3-quart containers on April 4, 1997. Media included Metro-Mix 366 coir, Metro-Mix 366 growing media, Metro-Mix 700 coir, Metro-mix 700 growing media (The Scotts Company, Marysville, OH), and pine bark:sand (4:1 v:v, amended with 2 lbs dolomitic limestone/yd^3). All containers were top-dressed with 9 g Osmocote Plus 15- 11-13 (The Scotts Company, Marysville, OH). Impatiens were grown under 33% shade from black cloth, and all other species were grown under full sun conditions.

Electrical conductivity, pH, and foliar color were measured at 0, 15, 30, 45, 60, and 90 days after treatment (DAT). Electrical conductivity was measured for two replications of marigold at each sampling. The study was terminated 90 DAT, and root ratings and shoot dry masses were recorded. Each species was analyzed as an individual experiment. Experimental design was a randomized complete block consisting of six 2-plant replicates of five treatments.

Results and Discussion: There were no differences in pH measurements for any media 90 DAT (data not shown). Electrical conductivity was highest for the pine bark:sand medium (0.10) and lowest for the Metro-Mix 700 peat medium, which registered no conductivity (data not shown). Electrical conductivity measurements were similar for Metro-Mix 366 coir, Metro-Mix 366 peat, and Metro-Mix 700 coir media compared to the Metro-Mix 700 peat and the pine bark:sand media.

African marigold-There were no differences in foliar color for any treatment 90 DAT. Root ratings were highest for plants grown in the Metro-Mix media and lowest for plants grown in the pine bark:sand medium (Table 1). Shoot dry masses were highest for plants grown in Metro-Mix 366 peat and Metro-Mix 700 coir media and lowest for plants grown in pine bark:sand medium. Shoot dry masses for plants grown in Metro-Mix 366 coir and Metro-Mix 700 peat media were similar to those of Metro-Mix 366 peat, Metro-Mix 700 coir, and pine bark:sand media.

Impatiens-Foliar color ratings were highest for plants grown in pine bark:sand medium and lowest for plants grown in Metro-Mix media. Root ratings were higher for plants grown in Metro-Mix 366 media than plants grown in pine bark:sand medium. Root ratings were similar for the Metro-Mix 700 media compared to all other media. Shoot dry masses were highest for Metro-Mix 366 peat media and lowest for the pine bark:sand medium.

Melampodium-There were no differences in foliar color ratings 90 DAT, regardless of media . Root ratings were highest for Metro-Mix 366 peat medium and lowest for the pine bark:sand medium. Shoot dry masses were higher for the Metro-Mix media than for the pine bark: sand medium.

Scaevola-There were no differences in foliar color 90 DAT. The root ratings of plants grown in Metro-Mix 700 coir medium was similar to both Metro-Mix 366 media and the Metro-Mix 700 peat medium while the Metro-Mix 700 peat medium was similar to the pine bark:sand medium. Shoot dry masses were highest for plants grown in the Metro-Mix media and lowest for plants grown in pine bark:sand medium.

There were no differences in any parameter measured between plants grown in Metro-Mix 700 coir compared to those grown in Metro-Mix 700 peat. Likewise, there were no differences between plants grown in Metro-Mix 366 coir and those grown in Metro-Mix 366 peat except for root ratings of melampodium and scaevola and shoot dry masses of impatiens.

Significance to Industry: The results of this research demonstrate that coir may be successfully substituted for peat in commercial potting media used for annual production without sacrificing plant growth in most cases. A viable peat moss substitute results in more alternatives for growers when availability and quality of peat moss declines and cost rises.

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Table 1. Influence of growing media on foliar color, root ratings, and shoot dry masses for African mangold, impatiens, melampodium, ann scaevola[z].

Medium	Foliar color rating[y]	Root rating[x]	Shoot dry mass
African marigold			
Metro-Mix 366 Coir	5.0a[w]	4.2a	30.7ab
Metro-Mix 366 Peat	5.0a	4.4a	32.3a
Metro-Mix 700 Coir	5.0a	4.4a	33.4a
Metro-Mix 700 Peat	5.0a	4.2a	30.3ab
Pine bark:sand	5.0a	3.7b	26.7b
Impatiens			
Metro-Mix 366 Coir	4.0b	4.8a	38.2c
Metro-Mix 366 Peat	4.0b	4.7a	47.6a
Metro-Mix 700 Coir	4.1b	4.5ab	41.9bc
Metro-Mix 700 Peat	4.0b	4.5ab	42.8b
Pine bark:sand	4.3a	4.3b	28.3d
Melampodium			
Metro-Mix 366 Coir	4.0a	4.6b	64.3a
Metro-Mix 366 Peat	4.0a	5.0a	73.0a
Metro-Mix 700 Coir	4.0a	4.6b	65.3a
Metro-Mix 700 Peat	4.0a	4.7b	70.9a
Pine bark:sand	4.0a	4.3c	45.8b
Scaevola			
Metro-Mix 366 Coir	4.5a	4.6b	56.7a
Metro-Mix 366 Peat	4.5a	5.0a	61.3a
Metro-Mix 700 Coir	4.5a	4.9ab	56.7a
Metro-Mix 700 Peat	4.5a	4.5bc	59.6a
Pine bark:sand	4.5a	4.3c	44.6b

[z] Data collected 717197, 90 DAT.

[y] Foliar color rating where 5=dark green, 4-medium green, 3=light green, 2=slightly chlorotic, 1=severely chlorotic, and 0=dead.

[x] Root rating where 5=100% root ball coverage, 4=75% root ball coverage, 3=50% root ball coverage, 2=25% root ball coverage, and 1=0% root ball coverage.

[w] Means within a column followed by the same letter for a species are not different according to Fisher's Protected Least Significant Difference ($p<0.05$).

Does Method of Fertilizer Application (Surface or Incorporation) Affect Nutrient Losses of Controlled Release Fertilizers?

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Nature of Work: Many studies have been conducted to decide whether surface application or incorporating fertilizer into container medium produces larger plants. Results have varied with species, location, and medium. However, to our knowledge, there are no studies that have examined which method of application is the most efficient. Major factors affecting nutrient release from controlled-release fertilizers (CRFs) are temperature and moisture. As a result, placement in the container medium may influence efficiency of fertilization. Therefore, the objective of this study was to evaluate the impact of method of fertilizer application (surface or incorporation) of two commercial CRFs on nutrient losses in the irrigation effluent.

The experiment, a randomized complete block design with four replications and treatments arranged in factorial combinations of two CRFs and two methods of fertilizer application (surface or incorporation), was conducted for 100 days at the North Carolina State University Horticulture Field Laboratory, Raleigh from June to September. Rooted cuttings of *Cotoneaster dammeri* 'Skogholm' were potted into 3.8 liter (4 qt) containers in an 8 pine bark : 1 sand (by vol) substrate amended per m^3 (yd^3) with 1.8 kg (4 lb) dolomitic limestone. Each plant was fertilized at potting with 5.0 g N from Nutricote 18N-2.6P-6.6K (18-6-8, Florikan ESA Corp., Sarasota, Fla.) composed of polymer-coated ammonium nitrate, ammonium phosphate, calcium phosphate, and potassium nitrate; or Meister 18N-2.6P-9.7K (18-6-12, Helena Chemical Co., Tampa, Fla.) containing polymer-coated urea, calcium phosphate, potassium sulfate, and potassium-magnesium sulfate. Both fertilizers contained micronutrients. Plants were placed on a container-grown plant production area subdivided into 16 separate plots that allowed collection of all effluent leaving each plot. Plots were 7.6 x 1.8 m (25 x 6 ft) with a 2% slope and were lined with black plastic. Twenty containers were placed in each plot (80 containers per treatment). A daily irrigation volume of 800 ml (1 in) was applied in two equal applications with a two hr interval between irrigation allotments via pressure compensated spray stakes (Acu-Spray Stick, Wade Mfg. Co., Fresno, Calif.) at a rate of 200 ml/min (0.3 in/min).

At 9:00 AM daily, volume of effluent from each plot (four per treatment) was measured and a sub-sample of effluent was collected, filtered, and analyzed for NO_3-N (1), NH_4-N (2), and P (4) using a spectrophotometer (Spectronic 1001 Plus, Milton Roy Co., Rochester, N.Y.). Urea in effluent was hydrolyzed to NH_4 with urease (Sigma Chemical Company, St. Louis, MO.) prior to analysis. Data were subjected to analysis of variance procedure (ANOVA) (5). Treatments means were separated by least significant difference (LSD), P = 0.05.

Results and Discussion: CRF and method of application affected nutrient losses in irrigation effluent. Both fertilizers lost greater quantities of NO_3 and P when incorporated compared to surface application (Table 1). Nitrate losses increased 90% or 253% when Nutricote or Meister was incorporated compared to surface application, respectively. Similarly, Meister when incorporated lost greater quantities of NH_4 compared to surface application (Table 1). Nutricote had similar NH_4 losses regardless of method of application. Yeager et. al (1989) and Eakes et. al (1990) reported higher leachate concentrations when fertilizer was incorporated compared to surface application. This suggests that incorporated fertilizer might have a faster release rate compared to surface applied fertilizer due to differences in container temperature and water content. A faster nutrient release rate, if not subsequently absorbed by the plant could result in higher nutrient losses in the effluent. Another possibility would be that nutrients released from incorporated fertilizer are more easily leached since they are dispersed uniformly throughout the medium in contrast to surface application.

Significance to the Nursery Industry: Concerns over water quality have placed pressure on growers to adopt practices that reduce or eliminate nutrient contamination in irrigation effluent. Therefore, any production technique that improves efficiency and reduces nutrient losses could be advantageous. Our data illustrates that method of fertilizer application does affect nutrient losses in irrigation effluent. Under these specified conditions, incorporating CRFs increased NO_3 and P losses in irrigation effluent an average of 171% and 58%, respectively compared to surface application. A single study does not necessarily mandate changes in the choice of fertilizer application. However, growers should be aware that choice of fertilizer application may increase nutrient losses in the irrigation effluent depending on fertilizer, medium, and irrigation management. Therefore, if growers incorporate CRFs, irrigation practices such as cycled irrigation or monitoring irrigation volume to decrease leaching could be critical.

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Table 1. Effect of method of fertilizer application and controlled-released fertilizer on total nutrient content in effluent, 100 days after treatment initiation.

Controlled-release fertilizer		
Fertilizer application	Meister 18-6-12	Nutricote 18-6-8
	— — NH_4-N (mg) — —	
Incorporated	20.5 a[z]	6.8 c
Surface	17.2 b	5.9 c
	— — NO_3-N (mg) — —	
Incorporated	45.2 b	56.9 a
Surface	12.8 d	30.0 c
	— — P (mg) — —	
Incorporated	6.4 a	1.6 c
Surface	3.5 b	1.2 d

[z]Means followed by the same letter or letters are not significantly different as determined by LSD, P = 0.05.

Composted Dairy Cow Manure as an Amendment for Nursery Potting Substrates

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Nature of Work: The nursery industry continues to explore the advantages of using alternative amendments for production of ornamentals in containers. One product that may have potential as a growing substrate is a products formulated from composted cow manure and marketed as Daddy Pete's Plant Pleaser Composts. This study was initiated on May 20, 1996 to determine the physical and chemical characteristics and growth response of three nursery crops to five different container substrates. Research was conducted using two holly cultivars, *Ilex cornuta* 'Burfordi' and *Ilex X* 'Nellie R. Stevens', and *Nandina domestica* 'Harbor Dwarf'. Test substrates included: (a) Setzer's Greenhouse & Nursery standard mix of pine bark:sand (95:5 by volume) amended with 1.8Kg (4 lbs.) each of lime and gypsum (b) standard mix amended with Daddy Pete's Composted Cow Manure (80:20 by volume), (c) Daddy Pete's Potting Mix consisting of composted cow manure, perlite, vermiculite and pine bark fines (75:10:10:5 by volume), (d) Daddy Pete's Pro C mix (Same as substrate (c) but screened one additional time though 0.5mm (3/16 in.) screen.), (e) Daddy Pete's Nursery Blend consisting of pine bark fines, composted cow manure, perlite and vermiculite (80:15:2.5:2.5 by volume). All plants were top dressed after potting with 13 g (0.5 oz.) Scotts 15-9-11 + minors Controlled Release Fertilizer. Plants were grown under sunny conditions on black weed barrier cloth. All cultural practices, including irrigation, fertilizer and weed control, were those of Setzer's Greenhouse & Nursery, Claremont, NC.

Results and Discussion: Physical Properties - Total porosity and air space fell within guidelines for substrates amended with composted cow manure. Container capacity and available water exceeded normal ranges with Daddy Pete's Potting Mix and Pro C Mix. This maybe related to these substrates retaining more moisture due to a higher volume of composted material and less pine bark when compared to other substrates. In regard to physical properties, all five substrates could be used to produce plants in containers if irrigation management was tailored to the substrate. Observations and data indicate that substrates with higher volumes of composted cow manure would need less watering due to these having a higher water holding capacity. Electrical conductivity (EC) and initial pH readings were significantly higher and above the optimum growing range (5.2- 6.5) for Daddy Pete's Potting Mix (6.7) and Pro C Mix (6.7). However, over the course of the growing season all substrate pH's fell within the optimum range with no significant differences between substrates. Conductivity levels started out within optimum levels of 0.5 to 2.0 dS/m for all but Daddy Pete's Potting Mix. With this mix the EC level (4.9 dS/m) was significantly higher. After the 15th week, EC fell below optimum levels for all substrates except Daddy Pete's Potting Mix and Pro C Mix. This may be attributed to above average rains leaching soluble salts more readily from substrates containing higher volumes of pine bark. Container leachate NO_3N and NH_4N concentrations were not significant after 15 weeks. Container leachates for nitrate nitrogen were below optimal levels (50 to 100 ppm) for producing rapid growth at 15 weeks. Nitrate and ammonium nitrogen levels were lowest in mixes with higher volumes of pine bark. Phosphorous concentrations after 5 weeks were significantly higher for Daddy Pete's Potting Mix and Pro C Mix, and above the optimum growing levels of 10-15 ppm for Virginia Tech extraction method for leachates. Because phosphorous is not fixed by organic potting amendments, phosphorous leachate readings were highest in mixes with high volumes of composted cow manure. After 15 weeks levels of phosphorous were below the optimum levels, with the lowest readings from mixes with high volumes of pine bark. In general, substrates with higher pH levels had higher phosphorous levels in the leachate. Foliar tissue samples after 15 weeks indicated that N, P, K, Mg and Fe levels were all within the acceptable range for sufficient growth. Phosphorous tissue levels were within guidelines but low for all substrates. Foliar phosphorous levels were significantly higher in those mixes with higher volumes of composted cow manure. Tissue calcium levels of substrates with high foliar phosphorous readings were significantly lower than other mixes. All foliar calcium levels were below the levels appropriate for optimal growth. Plant growth indexes were not different (PGI=(plant growth at 15 weeks - plant growth at 0 weeks) /plant growth at 0 weeks) for any of the three plant species grown in the different potting substrates. However, all three of the plant species had higher plant growth indexes when compared to Setzer's standard mix.

Significance to Industry: Daddy Pete's potting mixes amended with composted cow manure can be used to grow the same high quality plants that Setzer's Greenhouse & Nursery is accustomed to growing with their standard mix. The test substrates used contained the nutritive and physical properties needed to grow a quality container plant. Because some of the test substrates had a higher water holding capacity, benefits to the grower include reduced irrigation and savings on valuable water resources. By utilizing a compost based substrate, the grower will be able to save on freight and substrate costs and will have the convenience of delivery within 24 hours.

The Use of Bioconverted Swine Biosolids as an Amendment for Potting Media for Commercial Nursery Production

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Nature of Work: North Carolina's hog farmers, who currently produce 9.5 million hogs are at odds with many of the state's 7.2 million residents and legislators, over current waste-handling practices. Hog waste is typically retained in large, clay-lined lagoons and can create strong odors detectable from several miles away. An even greater concern is nutrient contamination of the state's living waters if a lagoon fails. Several companies have emerged with different treatment technologies designed to control the odor and reduce the nutrient load in the liquid fraction of the wastewater. One of those companies, Bion Technologies, Inc., is presently attempting to develop a soil amendment product from the solid fraction. Currently, the only documented economic return available from swine waste is through the sale of coastal bermuda hay produced from land-application of the lagoon's liquid fraction. And this is successful only if the nitrate levels in the hay can be managed at levels that are not toxic to livestock. Therefore our objective was to determine the suitability of bioconverted swine biosolids as an amendment to potting media under commercial nursery conditions. The plant growth characteristics of bioconverted hog biosolids were tested on gardenia, thorny elaeagnus, 'Blue Pacific' juniper and 'Crimson Pygmy' barberry. Plants of each cultivar were potted into 3.8 l (#1) containers with the following substrates: a) the grower's standard mix which was pine bark and sand (8:1 by volume) amended with 3.6 Kg (8 lbs.) 18-6-4 Coor's fertilizer, 3.6 Kg (8 lbs.) dolomitic limestone, 0.7 Kg (1.5 lbs.) C-Trel minor elements package and 0.7 Kg (1.5 lbs.) chelated iron per cubic yard; b) hog biosolids and the grower's standard mix (9:1 by volume); c) hog biosolids and the grower's standard mix (8:2 by volume); d) hog biosolids, pine bark and sand (1:9:1 by volume) without additional amendments. All substrates were treated equally. Plants were grown on gravel beds under sunny conditions. Cultural practices including irrigation, fertilizer and minor element supplement were those of the cooperating nursery. Physical signs of nutritional deficiencies were apparent on plant growth in all four substrates by mid-season. The plants, which were skipped by the nursery crew during the scheduled mid-season fertilizer application, responded when it was applied one month after the scheduled date.

Results and Discussion: The dried biosolids had a slight musty smell, but no "hog" or "manure" odor. After incorporation into test substrates, even the slight odor dissipated.

Electrical conductivity (EC) and pH - EC levels were initially above the optimum range (0.5 to 2.0 dS/m) for nearly all treatments which is expected in unleached containers immediately after potting. The one exception, the biosolids substrate without commercial fertilizer or lime, had an EC of 1.97 dS/m on the first collection date. By the sixth week, EC levels for all treatments had fallen below 0.5 mmhos/cm. Initial pH varied among test substrates for the first three to four weeks. The highest pH, which occurred on the first sampling date, was recorded for the 20% biosolids treatment with a pH of 6.3. Otherwise all test substrates, including the biosolids substrate without lime, maintained pH within the optimum growing range (5.2-6.5).

Container leachate - initially, leachate concentrations of total nitrogen and nitrate in the standard media were twice as high as those associated with the 10% biosolid substrate without commericial fertilizer or lime. By the fourth week, treatment differences were not significant.

Dry weights - in nearly all species, shoot dry weights were greater for the 10% biosolid treatment (without additional amendments) when compared to the standard media. Plants in general were significantly larger when biosolids were incorporated into the pine bark:sand substrates.

Pine bark/sand amended only with swine biosolids outperformed the standard media. Differences might be attributed to changes in the media's physical properties or perhaps biosolids provided additional cation exchange sites that held on to more nutrients than the standard media, thereby providing nutrients at a critical time in the plant's seasonal development.

Significance to the Industry: From the data presented, all four plant species grew best in substrates that contained biosolids. In all plants, the greatest plant growth occurred in the substrate which biosolids were the only source of nutrients. Although nutrient levels fell below the optimum level, as evidenced by foliar symptoms of deficiency, something about the biosolids, especially in the substrate without commercial fertilizers or lime, gave all plant species a growth advantage. Swine biosolids, with further research to develop specific guidelines for use, appear to have potential as an amendment for container substrates.

Effects of Mycorrhizal Fungi and Phosphorus on Growth, Development and Gas Exchange of Containerized Neem Trees (Azadirachfa indica)

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Nature of Work: The neem tree (*Azadirachfa indica*) is of ornamental, reforestation, medicinal and biomass value in India, Myanmar, Southeast Asia, and Africa. The compound azadirachtin is extracted from neem seeds and is commercially used as an insecticide for controlling insect pests (National Research Council, 1992). Oil extracted from the neems seeds can control plant fungal diseases, such as powdery mildew and rust (Becker, 1994).

The survival of neem trees under low fertility conditions, particularly low phosphorus (P) availability—which is a common characteristic of many soils where it is planted, may depend on vesicular-mycorrhizal fungi (VAM). Little information is known about naturally occurring VAM associations in neems. The benefits of VAM on growth enhancement, improvement of nutrient uptake, and diminishing abiotic stresses have been reported in a wide range of host plants from annual crops to woody perennials (Smith and Gianinazzi, 1988). Neem is commonly propagated by seed and grown in nurseries for 3-5 months before it is transplanted to productions sites (Benge, 1989). Preinouculation of neem seedlings with efficient VAM fungi would potentially enhance growth, reduce transplants shock and increase rate of survival and growth after transplanting, as reported in the production of other woody plant species (Strong and Davies, 1982: Graham, 1986; Davies and Call, 1990).

The objectives of this research were to determine: 1) the effect of VAM on growth and development, and gas exchange of neem trees at different soil P levels, and 2) the effect of soil P on VAM colonization and extraradical hyphae development. The relationship between growth, P uptake, and gas exchange with the VAM colonization level and extraradical hyphae development were also determined.

Results and Discussion: Rooted cuttings of the neem tree (*Azadirachta indica* A. Juss) were grown for 65 days at 4 levels of soil phosphorus (P) supply: 0, 15, 30, and 60 mg $P.kg^{-1}$ soil (0, .00024, .00048, .00096 $oz.lb^{-1}$). Half of the plants were inoculated with the vesicular arbuscular mycorrhizal (VAM) fungus *Glomus intraradices* at transplanting. VAM enhanced growth and photosynthetic rate (*A*) at the two lowest soil P levels. Increased A was attributed to increased stomata! conductance (g_s) and greater leaf P concentrations. Nonstomatal inhibition of *A* due to P-deficiency was also observed in Non-VAM plants at lower soil P levels. At higher soil P levels, VAM and Non-VAM had comparable growth, A, g_s and tissue concentration of P and other elements. VAM plants at 0 P. kg^{-1} soil had similar growth and leaf P concentration, when compared to Non-VAM plants at 15 mg P.kg^{-1}, yet had a 11% higher A, indicating a direct effect of VAM on gas exchange. As soil P supply increased, VAM colonization decreased, while the amount of extraradical hyphae increased. Decreased VAM colonization was in part due to reduction of fungal entry points and vesicle formation. Relatively high arbuscular and extraradical formation at the soil P levels where VAM sign)ficantly enhanced growth and gas exchange, suggest the important roles of arbuscules and hyphae on the symbiosis.

Significance to Industry: The nursery industry stands to benefit from naturally occurring mycorrhizal symbionts that potentially help reduce fertility and irrigation needs and reduce pesticide usage during production. VAM enhanced growth and photosynthetic rate (*A*) at the two lowest soil P levels. Increased *A* was attributed to increased stomata! conductance (g_s) and greater leaf P concentrations. At higher soil P levels, VAM and Non-YAM had comparable growth, *A*, g_s, and tissue concentration of P. VAM plants at 0 P. kg^{-1} soil had similar growth and leaf P concentration, when compared to Non-VAM plants at 15 mg P.kg^{-1}, yet had a 11% higher *A*, indicating a direct effect of VAM on gas exchange. As soil P supply increased, VAM colonization decreased, while the amount of extraradical hyphae increased. Relatively high arbuscular and extraradical hyphae formation at the soil P levels where VAM significantly enhanced growth and gas exchange, suggest the important roles of arbuscules and hyphae on the symbiosis.

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Cycle Irrigation and Grassed Waterways Reduced Isoxaben and Trifluralin (Snapshot TG) Movement in Runoff Water

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Nature of Work: Production of containerized plant material involves the use of herbicides several times per year for weed control. They are often applied as broadcast or spray applications where a majority of the material may land on non-target surfaces (1) where it is transported in runoff water into containment ponds (2,4). Snapshot TG, containing isoxaben and trifluralin, commonly used in nurseries, was transported from its application site in runoff water (6). Management practices can affect herbicide movement in runoff water. Pesticide runoff has been reduced by channeling water through vegetated strips or grassed waterways (3). Pulse or cycled irrigation usage also reduced NH_4-N losses (5) Our objective was to determine the effect of combining cycle irrigation and grassed waterways on levels of isoxaben and trifluralin in runoff water.

The study was conducted at a containerized plant production facility in northwestern South Carolina. The nursery has a 1.5 ha growing area which is isolated from the remainder of the operation and which slopes uniformly and unidirectionally. The site contains eight growing beds each 18 x 90 m divided by gravel roadways. A hybrid Bermuda grass (*Cynodon daclylon* x C. *transvaalensis*) waterway (1.8 x 90 m) on a 5% slope was installed at the down slope of four of the growing beds in the summer of 1994. Runoff from the other four beds was directed into an existing clay and gravel roadway (1.8 x 90 m). Weirs were placed at the ends of waterways to determine runoff volumes and facilitate sample collection.

Trifluralin (4 kg ai ha^{-1}) and isoxaben (1 kg ai ha^{-1}), preemergence herbicides, were broadcast applied with hand-held spreaders (Snapshot TG, 200 kg ai ha^{-1}). The growing area where runoff was directed into the clay/gravel waterway was irrigated for 1.5 hours (1.9 cm). The section bordered by the grassed waterway was irrigated in three 30 minute pulse cycles, with a 90 minute interval between cycles. Runoff samples were collected on the day of application and 1, 2, 4 and 8 days after application. Samples were taken at the beginning of runoff and at 20, 40, 60, 80, and 100 minutes of runoff flow from the clay and gravel waterway. Samples from the grassed waterway were taken at the beginning of runoff and after 20 minutes of flow for each of the pulse cycles. Samples were collected in silanized glass jars, transported on ice and stored at 4 C until analysis. Pesticide applications were made in August, 1996 and

October, 1996. The pH of water samples was adjusted to 2.2, and duplicate 150 ml aliquots were filtered through Whatman #5 qualitative paper, and extracted onto C_{18} solid phase extraction columns, and eluted with 2 ml acetone (4). Analysis was by high pressure liquid chromatography using a C_{18} reverse phase column, an acetonitrile:water solvent gradient, and the diode array detector was set at 206 nm. Percent recoveries and limits of detection for isoxaben and trifluralin were 121 and 78, and 36 and 51 ug/L, respectively.

Results and Discussion: Runoff volume from the pulse irrigation treatment averaged 7900 gallons, approximately 60% of the water applied as irrigation. Volumes were lowest from the first pulse cycle which was approximately 2/3 of the intermediate cycle which was slightly higher than the last cycle. Runoff volumes from the continuous irrigation treatment averaged 9300 gallons, approximately 71 % of the applied amount. Total volume of runoff water from the pulse irrigation treatment was 15% less than for the continuous irrigation treatment.

Highest concentration of herbicides was found in the first sample from pulse irrigation and in the first 80 minutes of runoff from continuous irrigation (Figure 1). Highest concentrations detected in samples were 1.2 ug/ml for isoxaben and <0.06 ug/ml for trifluralin. Trifluralin was detected on the day of application in runoff samples through 80 minutes from the continuous irrigation treatment and in only the initial pulse irrigation sample. Residues of trifluralin were not detected on later sampling days or pulse irrigation samples. Isoxaben was detected through 9 days after application in all runoff samples with amounts decreasing on each subsequent sampling day and approaching the limit of detection in the final samples.

Isoxaben concentration was higher in early samples from the pulsed/grassed waterway treatment (when runoff volumes were less) on the day of application, but lower for the last sample of the second pulse cycle and for samples of the third cycle (Figure 1). Concentration of isoxaben was consistently reduced on other sampling days by the pulsed/grass waterway treatment. These concentrations do not take into account the differences in total runoff between treatments. Total amount of herbicide detected in runoff water was calculated by multiplying runoff volume by concentration for specific sampling time. Total isoxaben amounts which moved in runoff water were reduced 30% by the pulse/grassed treatment (Table 1). The greatest reduction was on the day of application when isoxaben amounts from the pulsed/grassed treatment were 66% of the amount from the continuous irrigation treatment. The total amount of isoxaben detected in runoff water from the continuous irrigation treatment was 9% compared to a 6% loss of isoxaben from the pulse irrigation/

grassed waterway treatment. A 33% reduction in isoxaben losses was obtained through the utilization of pulse irrigation in combination with grassed waterways.

Significance to Industry: Grassed waterways and pulsed irrigation appear to be an effective means of reducing herbicide movement in runoff water. Pulse irrigation also reduces water loss. Increases in the time interval between pulse cycles could further reduce water/herbicide losses and lead to more economical utilization of water and herbicides.

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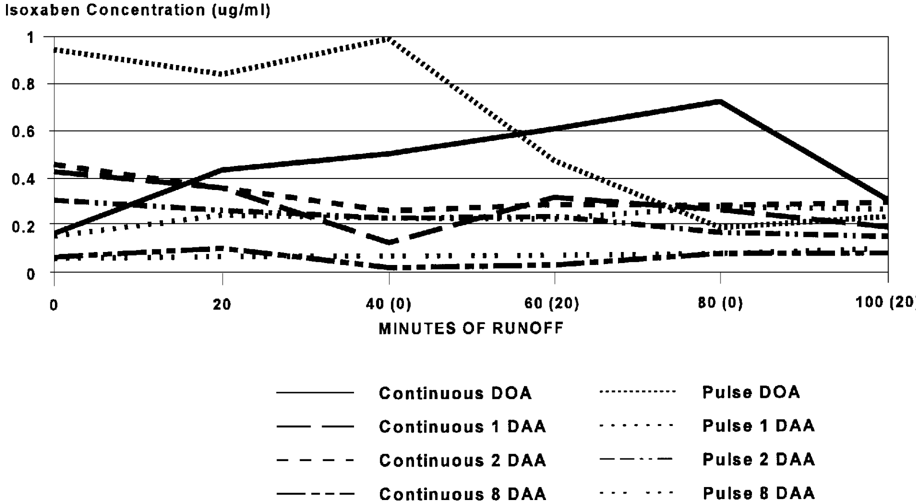

Figure 1. Isoxaben concentration in runoff water on day of application (DOA), 1,2 and 8 days after application (DAA), for minutes of runoff duration with continuous irrigation and three pulse irrigation events of 30 minutes with 90 minute intervals between pulse irrigation events. Sampling for pulse irrigation events was at time of inital runoff and 20 minutes after runoff began (Indicated by 0 and 20 in parenthiesis for second and third pulse irrigation cycles). Results are averages of two experiments.

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Table 1. Isoxaben detected in runoff water on day of application (DOA) and 1,2, 4, and 8 days after application (DM), and total detected during study period. Results are averages of two experiments.

Sample Day	Continuous Irrigation	Pulsed Irrigation/ Grassed Waterway	LSD(P=0.05)
DOA	18.9	12.5	5.9
1 DM	9.6	6.6	13.7
2 DM	10.4	6.7	5.5
4 DM	4.2	3.3	2.9
8 DM	2.1	2.3	4.5
TOTAL	45.3	31.5	9.8

Pruning and Overwintering Container Grown Herbaceous Perennials

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Nature of Work: Overwintering unsold container grown herbaceous perennials is a concern. Late pruning to rejuvenate the plants for late fall sales is one possible solution to this problem, although this may reduce the cold hardiness of the plant material. The goals of this study were to determine if the late pruning of several species of herbaceous perennials would rejuvenate the plant material, or cause it to be too "soft" to tolerate winter temperatures. Another aspect of this study was to determine if the plant material could survive the winter without being spaced pot to pot. Moving plants pot to pot for winter protection and then re-spacing them when regrowth begins in the spring is common practice. This is labor intensive and very costly. If this practice could be avoided, it would be very economical to the nursery industry.

This study was started in the fall of 1995. All research was done at Carolina Nurseries, Inc., Monck's Corner, SC. On October 2, 1995, twenty-two species of one-gallon herbaceous perennials (Table 1) were pruned back. The perennials were cut back to the pot rim, and at different heights above the rim. These plants were observed until an early freeze, on November 15, killed them back. At this time a decision was made to leave the pots spaced out and not put them pot to pot. Notes were made on their recovery in the spring. This study was repeated in the fall of 1996, using different plant material and different pruning times (Table 2). These plants were cut at three heights: low (at pot rim), medium (half height of vegetation), and high (removal of flower heads). The pots were not moved pot to pot to determine if these species could withstand winter temperatures.

Results and Discussion: After the first study, there appeared to be no differences between plants, as a result of the cutting heights, for all but five of the species (*Iris, Ratibida, Perovskia, Rosmarinus*, and *Agastache*). The plant height of Iris, *Ratibida*, and *Perovskia* was directly correlated to the cutting height from the previous fall. The lowest cut gave the shortest plants and the uncut control gave the tallest. The spring growth of the *Agastache* was inversely correlated to pruning height. Plants with the lowest cut (0) were the tallest and the uncut controls were the shortest. *Rosmarinus* did not flower the following spring due to the removal of the flowering wood in the fall. Pruning should be done on R*osmarinus* in the spring.

All plants overwintered well with the exception of *Ceratostigma plumbaginoides*. The plants grew out through the drain plugs. Apparently the warmer ground temperature allowed the plant to survive close to the ground. The only plant that benefited from the fall prune was *Gaura lindheimeri*. The high cut reflowered within two weeks of pruning. Pruning appeared to delay the spring flowering of *Penstemon, Gaura,* and *Rudbeckia maxima* approximately two weeks between the uncut control and the low cut (0). The biggest benefit of the low and medium cut was that they removed the unsightly stems that can be difficult to remove in the spring. The low cut in *Dianthus* appeared to have opened it up for invasion by weeds and disease. There was no overwintering damage to any of these species. The winter of 1996-1997 was very mild in Monck's Corner. This study needs to be repeated again to be sure of the ability of these plants to withstand winter temperatures without being pot to pot.

Significance to Industry: Pruning should be done depending on the desired result. All plants respond to pruning in different ways. Pruning improved the appearance of many of the perennials by removing the old flower stems. Many species can survive overwintering without being placed pot to pot. Ceratostigma plumbaginoides should be overwintered pot to pot to allow survival throughout the winter.

Table 1. These species were evaluated Fall 1995-Spring 1996. There was no difference between treatments with the exception of those mentioned in the Results and Discussion Section.

Agastache sp.	*Iris siberica* 'Blue Emperor'
Artemisia lactifolia 'Guihzo'	*Kniphofia uvaria* 'Pfitzeri'
Aster dumosus 'Nesthakshen'	*Perovskia* 'Filagran'
Baptisia lactea	*Phlox paniculata* 'Eva Cullum'
Bergenia cordifolia 'Silberlicht'	*Platycodon* 'Sentimental Blue'
Boltonia asteroides 'Snowbank'	*Ratibida* columnifera
Ceratostigma plumbaginoides	*Rosmarinus officinalis*
Dianmus sp. 'Mountain Mist'	*Salvia x superba* 'Blue Queen'
Gypsophila p. 'Viettes Dwarf'	*Solidago rugosa* 'Fireworks'
Hemerocallis sp. 'Bitsy'	*Stokesia laevis* 'Blue Danube'
Hibiscus moschentos 'Disco Belle Rose'	*Veronica spicata* 'Rosenrot'

Table 2. Species Evaluted Fall 1996-Spring 1997

Species	Pruning Date	Observations April-May 1997
Chrysanthemum x superbum 'Rocky'	8/14/96	More weed growth in low cut
Dianthus gratianopolitanus 'Bath Pink'	8/14/96	More weed growth in low cut; high cut and control were thatchy and and unsightly. Medium cut had best overall appearance.
Dianthus 'Mountain Mist'	8/14/96	Several of the cut treaments died; pruning may have predisposed plants to disease
Gaura lindheimeri	8/14/96	All treatments showed visible bud;low cut slightly later; stems on medium and high cut unsightly
Helianthus angustifolius	8/14/96	A lot of variability in growth in all treatments; Old stems unsightly in medium and high cut
Penstemon sp. 'Husker Red'	9/26/96	Low and medium cut best;flowering delayed two weeks in low and medium cut
Pardancanda norisi	8/14/96	Lots of variability in size in all treatments
Rudbeckia fulgida 'Goldsturm'	8/14/96	High cut and control were fuller in size; More severe cut caused weaker growth
Rudbeckia maxima	9/20/96	All similiar in appearance
Sedum x 'Autumn Joy'	8/14/96	Low cut not as full; Old stems unsightly
Tradescantia andersoniana	9/27/96	All treatments overwintered well and flowering. All were similar in appearance
Veronica latifolia 'Alba'	8/14/96	Low cut were not as full; Unsightly stems in medium and high cut

Movement of Prodiamine and Oryzalin in Container Plant Media

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Nature of Work: Chemical weed control is an important management practice in the production of containerized plant material. Prodiamine and oryzalin are preemergent dinitroaniline herbicides which have provided effective control in container-grown nursery stock of many weed species including Florida betony, yerba-de-tago, large crabgrass, bermudagrass, purslane and red sorrel (1, 2, 4, 7). However, a prodiamine application of 1.1 kg ai/ha decreased shoot and root weights in bedding plants (3), and reduced clipping weights and verdure of Kentucky bluegrass (5). Restricted growth and root development of azaleas was noted at prodiamine rates of 9.0 kg ai/ha (1, 6). Oryzalin was phytotoxic to Chinese holly at recommended rates for weed control (6).

Oxadiazon losses and desorption were found to be enhanced in a soilless media (8). However, the herbicide was not detected below the surface 4 cm of media, and mobility was minimal. In a preliminary study by our research group, prodiamine applied to newly potted liners of dwarf Burfordi holly and azalea spp. in pine bark media at 2x and 4x recommended rates caused serious root system injury. Postulated was that despite very low solubility in water (0.03 mg/l at 25C), prodiamine leached downward in the media and affected the lower root system. The purpose of this study was to investigate the movement of prodiamine as compared to oryzalin in container media.

In a greenhouse study, uniform liners of *Azalea kurume* var.Hino Crimson were placed in 1 gallon containers (4:1 pine bark:sand), and after 24 hrs treated with Factor 65WG (prodiamine) at a rate of 1.65 kg ai/ha, Surflan (oryzalin) at a rate of 4.4 kg ai/ha, or left untreated. Irrigation (510 ml) was applied on a daily basis. On the day of application and at 1, 7, 14, 30, and 60 days after application, the azaleas were removed and containers were split in half vertically. The pots were laid on side, divided into four quadrants (each 2 cm wide), seeded with bentgrass (*Agrostis palustris* var. Penncross), and placed under continuous mist as a bioassay to detect herbicide presence. Shoot height of numerous seedlings throughout the quadrant was measured after 7 days. Root weights of azaleas were determined by subtracting ashed weights (8 hr at 500C) from dry weights (24 hr at 100C). There were four replications of treatments and the study was repeated once.

Results and Discussion: The bentgrass bioassay indicated that prodiamine accumulated in the top 2.0 cm horizon (A) of the media through 30 days of the study as daily irrigations allowed desorption from the surface layer of the media (Chart 1). Differences were noted between prodiamine effects on shoot height in the top horizon and lower two horizons on all sampling days. At 14 days, effects in the B and C-D horizons were different, as the herbicide accumulated in the second quadrant. However, at 30 and 60 days after treatment, the two middle horizons were similar. Shoot height effects were 3x greater in the lowest quadrant (D) at 30 and 60 days than at 7 days. Effects decreased in zone A by 25% between 30 and 60 days after application. Prodiamine appears to be mobile in the pinebark media, moving downward over time as a result of daily irrigation.

Oryzalin accumulated in the A horizon through 14 days (Chart 2). Differences were found between horizon A and D at 7 days, and between A-B and C and D at 14 days. At 30 days after treatment the effects on shoot height in the lower two quadrants were similar and at 60 days the lower three quadrants were not different. Oryzalin effects on shoot height generally declined in the uppermost quadrants after 14 days. Effects of oryzalin noted in the lower media zone were greatest at 30 days with a decline noted at 60 days, as the herbicide was apparently leached from the container. Oryzalin has a solubility of 2.5 mg/l in water (25C), much greater than that of prodiamine. Oryzalin would therefore be expected to be more mobile in a pinebark media.

Differences in root weights were not found among treatments at 30 and 60 days after application.

The azalea variety used in this study may not have been sensitive to the herbicides, or sufficient time may have not been allowed for differences to manifest.

Significance to Industry: This study indicates that prodiamine and oryzalin will move downward in a pinebark media under normal irrigation conditions used for containerized plant material. Weed control may be affected and the herbicides may have an effect on the root growth of sensitive species.

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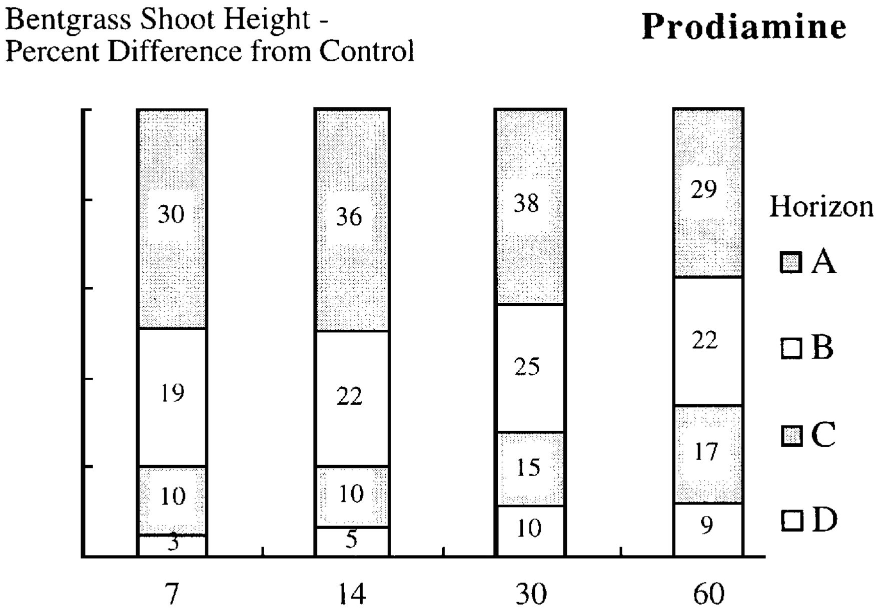

Chart 1. Percent difference between control and prodiamine treatment of shoot height of bentgrass for container horizons by days after treatment. LSD = 11.7 at P=0.05.

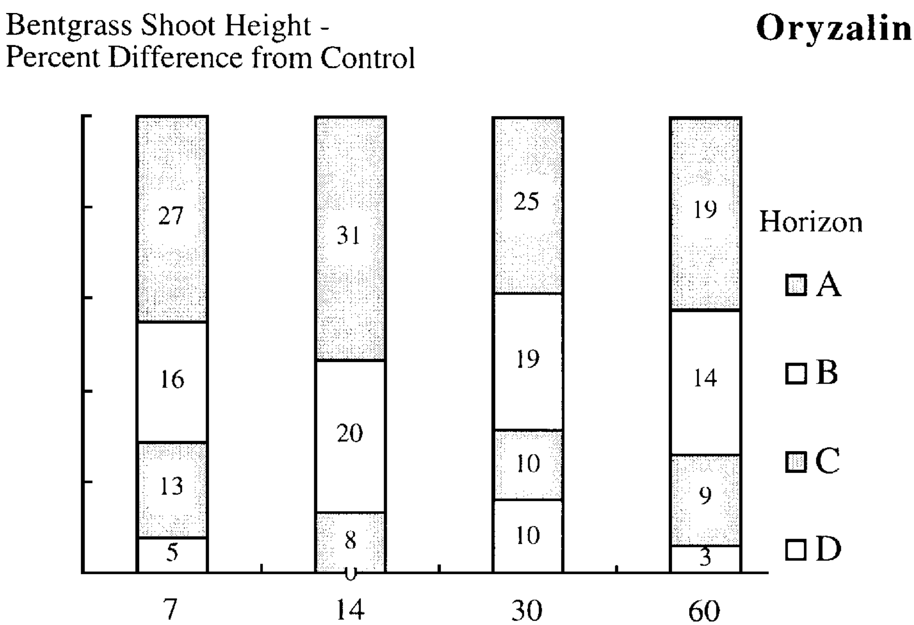

Chart 2. Percent difference of shoot height between control and oryzalin treatment of bentgrass for container horizons by days after treatment. LSD = 11.7 at P=0.05.

Evaluation of Tex-R Agroliners for Bag-in-Pot Production

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Nature of Work: Rooting-out is a well documented problem for producers of pot-in-pot plants (2,3). Copper hydroxide (Spin Out, Griffin Corporation, Valdosta, GA) has been useful for reducing rooting-out problems but does not eliminate the problem (2,3). Several landscape fabrics have been evaluated for controlling rooting-out with varying degrees of success (2,3). Treating field-grow bag material with Spin Out complicated removal of the fabric due to the extensive root branching which occurred (2). Difficulty in removing field-grow bags from the root system is considered to be one of the limitations of the grow bag system.

Tex-R Agroliners (Texel USA Inc., Henderson, NC) are needlepunched, nonwoven polypropylene bags treated on one side with a latex coating of Spin Out to control root circling and rooting-out when used in a modified pot-in-pot system called bag-in-pot. Previous work in Canada indicated that experimental Agroliners worked well on controlling root growth of *Acer saccharinum* and *Fraxinus pennsylvanica* (1). The purpose of this study was to evaluate the effects of two experimental Agroliner bags on the growth and rooting-out of two species produced bag-in-pot compared to pot-in-pot.

The experiment was conducted outdoors under full sun at the University of Georgia Coastal Plain Experiment Station in Tifton, GA. Uniform liners in 2.8 l (#1) containers of *Lagerstroemia indica x fauriei* 'Muskogee' (crapemyrtle) and *Liriodendron chinense* (Chinese tulip poplar) were potted into 26 l (#7) containers on 12, October 1994 and the following planted container treatments were used: 1) Spin Out in a #7 container (SO), 2) lightweight Agroliner (120 g/m^2) (LW), and 3) heavyweight Agroliner (175 g/m^2) (HW). Holder pots (#7, The Lerio Corporation, Mobile, AL) were placed in the ground with 1 in. at the top of the container remaining above grade. Treatments were placed in the holder pots until the termination of the experiment (September, 1995). Potting substrate consisted of milled pine bark and sand (8:1 by vol) amended with 5.0 lbs. of dolomitic limestone and 1.5 lbs. of Micromax (Grace-Sierra, Milpitas, CA). Plants were topdressed with High-N 22-4-7 (Grace-Sierra) at 1 oz. per container in October, 1994 and with Graco 21-3-12 (Graco Fertilizer Company, Cairo, GA) at 4.5 oz. per container in March, 1995. Plants were irrigated as needed using low volume spray stakes (Roberts Irrigation, San Marcos, CA) at the rate of 1.0 gal per container per day.

At the termination of the study in September, 1995, height, growth index [(height + width 1 + width 2 (perpendicular to width 1))/3] (crapemyrtle), stem diameter (Chinese tulip poplar), shoot dry weight, root dry weight inside the planted container, and root dry weight outside the planted container determinations were made. Root coverage (a visual estimation of the amount of root area at the container:growing medium interface) was rated using the scale of 1 = less than 20% of the rootball covered with white root tips, no root circling; 3 = about 50% of the rootball covered with white root tips, moderate root circling; and 5 = greater than 80% of the rootball covered with white root tips, extensive root circling. Data was analyzed using analysis of variance with mean separation by Waller-Duncan K-ratio t-test. Root rating data was analyzed using chi-square analysis.

Results and Discussion: For crapemyrtle, plants grown in the HW Agroliner had reduced growth indices compared to the SO container. Shoot dry weight of plants grown in the HW Agroliners were reduced by 67% compared to plants in the SO container. Root dry weight inside the planted container was not influenced by treatment. Root dry weight outside the planted container was greatest for SO (90 g) compared to 42 g for the LW treatment. Percent root dry weight outside the planted container ranged from 4.2% (SO) to 2.2% (LW). There was no difference in rooting dry weight outside the planted container between the LW and HW treatments, although the HW treatment was not different from SO. The root:shoot ratio was greater for the HW treatment (3.0) compared with the SO (1.9) and LW (1.8) treatments. Two of the six replicates for the SO and LW treatments were sufficiently rooted-out such that they had to be harvested with the aid of a tractor-mounted boom, whereas all HW plants could be manually harvested. Treatment had no effect on root ratings for crape myrtle (range 3.7 to 4.3).

Height, stem diameter, and shoot and root dry weight of Chinese tulip poplar were not influenced by treatment. Root dry weight outside the planted container was 58 g, 6 g, and 0 g for SO, LW, and HW; respectively. Percent root dry weight outside the planted container was 4.9% for SO, 0.5% for LW, and zero for HW. Treatment had no effect on the root:shoot ratio of Chinese tulip poplar. Root ratings were lowest for the HW treatment (2.0) compared to the SO (3.5) and LW (3.7) treatments.

Significance to Industry: Crapemyrtle is a vigorous-rooted tree species which poses problems when trying to control rooting-out in pot-in-pot production systems. Use of a heavyweight Agroliner did not eliminate rooting-out but did prevent anchoring into the surrounding soil. As a trade off, crape myrtle plants in this study were 22% smaller in terms of growth indices due to limiting the rooting-out process. Many fine roots were found penetrating the HW bag whereas fewer but larger diameter roots penetrated the LW bag. Rooting through the bags occurred primarily where potting medium became lodged between the holder pot and the Agroliner.

Chinese tulip poplar, being a coarse-rooted species, did not penetrate the Agroliners to the extent of the crapemyrtles. For both species, removal of the Agroliners was easy since there were not large quantities of roots growing through the fabric. It therefore appears that Agroliners offer the possibility of a new production system, bag-in-pot, and may also be useful for in-ground field production similar to the existing field-grow bag system of production. Texel is currently marketing an Agroliner bag which is intermediate in weight (150 g/m^2) to the bags used in this study.

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A Method of Monitoring the Nutritional Status of Pine Bark Substrate in Large Containers

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Nature of Work: The pot in pot (PIP) system of growing trees in large (15 gallon or greater) production containers within in-ground socket containers is gaining wide acceptance within the nursery industry. Another widely accepted nursery practice is substrate solution extraction via the pour-through (PT) method (2). Water added to the surface of a substrate at container capacity results in leachate that is collected from the container drainage holes for nutrient analysis. Use of the PT method with the PIP system, however, necessitates removal of the production container from the socket container. Not only are these large containers heavy but removal from the socket pot exposes the previously shaded sidewall of the production container to solar radiation, which may result in root injury due to heat stress.

Suction-cup lysimeters (SCL) have been used to monitor pesticide movement through soils by extracting soil solution at various depths in the soil profile (1). This device consists of a tube with a ceramic tip (similar to a tensiometer) that is inserted into the soil at the desired sampling depth. Soil solution is drawn in through the porous tip in response to suction created by removing air from the sealed tube. Such an in place method for sampling the substrate solution in large containers would facilitate determination of the nutrient status of the substrate when growing trees in an in-ground system. We have modified this methodology to extract solution from a pine bark substrate. The objective of this study was to compare SCL and PT extract N and pH levels in a pine bark substrate.

A SCL consisted of an 18 inch long (0.5 inch diameter) clear acrylic tube with a one inch long (0.375 inch diameter) ceramic-cup tip. An additional 18 inches of flexible vacuum tubing was attached to the acrylic tube. The terminal end of this tubing was equipped with a check valve and coupling for connection to a hand-held vacuum pump. Tubes were placed into a hole vertically augered into the container substrate so that the ceramic tip rested on the container bottom.

Experiment 1 compared SCL and PT extract N levels. Fifty 15-gallon containers were filled with 100% pine bark substrate amended with 5 lbs dolomitic limestone per cubic yard. Containers received eight one-inch irrigations at approximate five day intervals with fertilizer solution containing 56, 112, 164, 224, or 280 ppm N. N was supplied as a 21-7-14 fertilizer consisting of 11.9% NH_4-N and 9.1% NO_3-N. Extract treatment methods were conducted following the last irrigation after a two-hour drainage period. The PT treatment consisted of an 800 ml application of distilled water to the substrate surface and collection of the initial 100 ml leachate. For the SCL treatment, 30 ml of extract was drawn into each of two tubes per container following an 800 ml application of distilled water. This extraction was achieved by imposing a vacuum in the tube equal to 28 inches of mercury. The experimental design was a RCB with five replications of each extract method x N rate treatment combination. Extracts were analyzed for NO_3-N and NH_4-N by specific ion electrodes.

Experiment 2 compared SCL and PT extract pH levels. Thirty-two 15-gallon containers were filled with 100% pine bark substrate amended with 0, 1.7, 3.4, or 5.1 lbs hydrated lime per cubic yard and received daily 1-inch irrigations with plain tap water for five days. Extract treatments were imposed as described for Experiment 1 with the exception that SCL tubes were in place and allowed to equilibrate overnight prior to the last irrigation. This modification was employed because preliminary experiments with smaller containers had indicated that extract pH was influenced by the pH of the preceding solution extracted into the tube when extract volumes were less than 40 ml. This effect may be due to adsorptive properties of the ceramic tip. The experimental design was a RCB with four replications of each extract method x lime rate treatment combination. Extract pH was determined with a pH electrode.

Results and Discussion: Quadratic relationships between the level of applied and extracted N for both extraction methods had R^2 values close to unity (Fig. 1A), indicating that the SCL method is comparable to the PT method for extracting total N. The level of total N in SCL extracts was slightly lower than that in the PT extracts (P=0.02) due to lower levels of NO_3-N (P=0.03), but not NH_4-N (data not shown). This result may be due to dilution of the NO_3-N in the perched water at the bottom of the container during the SCL extraction. Added displacement solution continues to drain from containers well after the time required to collect the initially displaced 100 ml for the PT extract. At present, the time required to extract a 30 ml volume via SCL varies from 1-3 hours. This may be due to variability in the composition of ceramic tips or the hydraulic conductivity of the substrate between micro sites surrounding each tip. Extract pH was highly correlated with lime amendment (r^2=0.96) and did not differ between extraction methods (Fig. 1B)

Significance to Industry: Periodic extraction of the substrate solution of container-grown plants and subsequent nutrient analysis allows growers to adjust fertilizer regimes so that plants can be supplied with an adequate but not excessive amount of fertilizer. The inconvenience of moving large containers may deter some growers from adequately monitoring the nutritional status of the substrate in PIP production. This research demonstrates a simple in place method for extracting substrate solution from large containers that is comparable to the PT method for total N and pH determination. Further research is needed to accelerate the time required for the SCL extraction. The longer extraction time required for this method, however, may be offset by the ease of initial set up in comparison to the PT method, since extraction tubes could be left in place in containers during the growing season.

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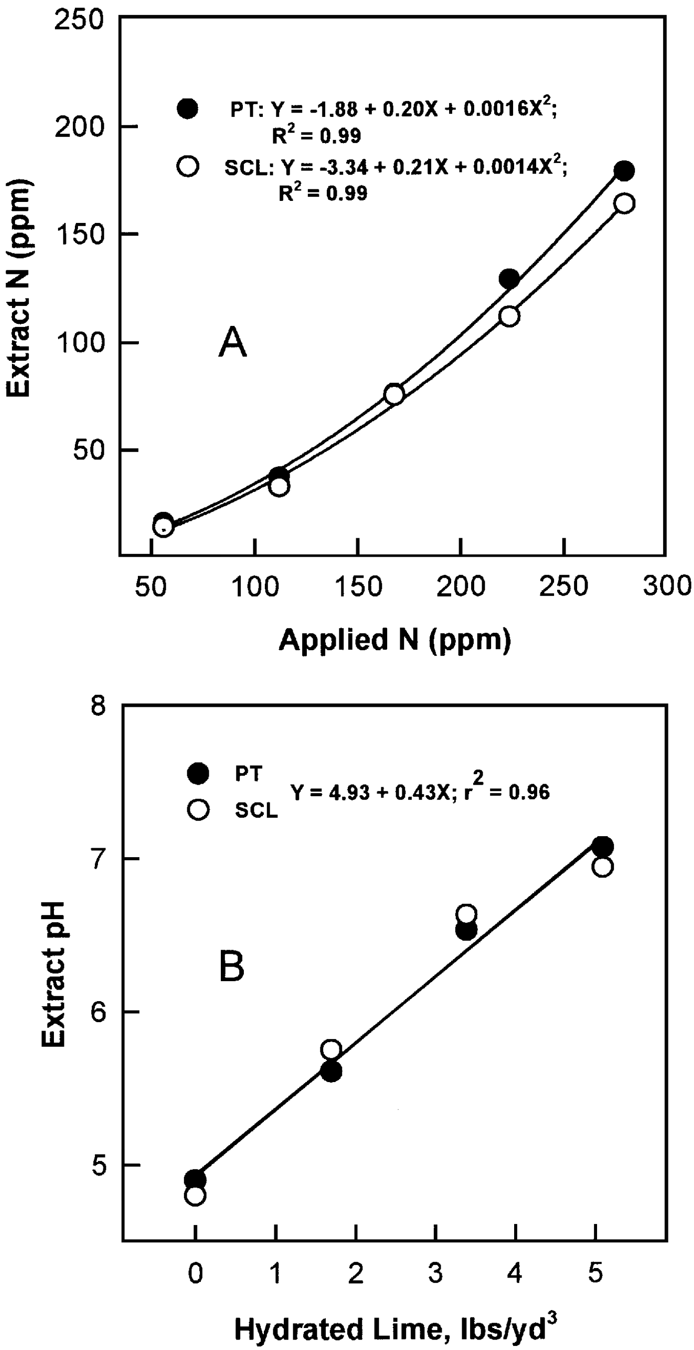

Figure 1. Substrate extract evels of total N (A) and pH (B) for purt-through (PT) and suction-cup lysimeter (SCL) methods.

The Interaction of Air-Filled Porosity and Irrigation Regime on the Growth of Three Woody Perennial (Citrus) Species in Pine Bark Substrates

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Nature of Work: A number of factors determine the particle size distribution (and hence physical characteristics) of a pine bark substrate. It is well documented (Handreck and Black, 1991; Bunt, 1988) that the fine fraction (<0.5mm diameter) controls Air-Filled Porosity (AFP) and Water-Holding Capacity (WHC). Determining the percentage 'fines' by particle size analysis enables one to predict the approximate AFP of a particular substrate (Handreck and Black, 1991). Progressive pine bark producers are able to supply a substrate with a known AFP by sieving and proportionately reconstituting various fractions.

The AFP and WHC of a substrate not only have an effect on water and nutrient availability, but also the spread and longevity of soil-borne pathogen propagules in the nursery, particularly *Phythium, Phytophthora, Rhizoctonia* and *Fusarium* species. Increasing the porosity of a substrate may help suppress pathogenic infestations, but a reduction in water-holding capacity may induce a greater prevalence of water stress in plants. This may be especially true when the rooting volume is reduced relative to the shoot volume in containerized production, or when the irrigation scheduling is insufficient to maintain the wetness of the substrate. This experiment was set up to determine the interactive effects of substrate porosity and irrigation regime on the growth of three woody perennial *Citrus* rootstock species in a pine bark substrate. The three species used were chosen for their differing growth rates, i.e. Carrizo citrange [*Poncirus trifoliata* (L.) x *Citrus sinensis* (L.) Osbeck], a slow-growing trifoliate species, Cleopatra mandarin [*Citrus reshni* Hort. ex Tan.] , an intermediate and Rough Lemon [*Citrus jambhiri* (Lush.)], a fast-growing species.

A pine bark substrate derived from *Pinus patula, P. elliottii* and *P. taeda* was obtained from a local supplier in Natal, South Africa. The mixture was sieved into five particle sizes (Table 1), using an automatic shaker after air-drying under cover. These fractions were then re-wetted to field capacity with water and a wetting agent on a concrete floor and left to drain. Twenty-four hours later, six mixes were made up (on a volume basis), using the proportions shown in Table 1. The combined fractions were mixed in a concrete mixer for 30 minutes to ensure a complete

Table 1. Particle size distribution (percentages) for the six substrate mixes used in the experiment.

Actual AFP (%)	Particle Size				
	< 0.5 mm	0.5 - 1.0 mm	1 - 2 mm	2 - 3.2 mm	3.2 - 8 mm
6.0	100	0	0	0	0
6.8	70	30	0	0	0
7.6	60	20	20	0	0
10.1	40	20	20	20	0
12.5	20	20	20	20	20
24.9	0	0	33	33	33

redistribution of particle size. A preplant fertilization regime was added to all six mixes on an equivalent basis at the start of mixing, consisting of single superphosphate, ferrous sulfate, FRIT 504, dolomitic lime and calcitic lime. The various substrates were then potted up into 3.5L black polyethylene pots and 12 week-old seedlings, selected from polystyrene liners, were transplanted into each treatment. The experiment was laid out as a 6 x 3 x 2 factorial (AFP x species x irrigation frequency), with three seedlings per plot and two replications of each treatment. Seedlings were irrigated using pressure-regulated drippers, which plugged into central irrigation pipe running down the center of a raised bench. The seedlings received a standard N:P:K:S solution at 100:20:100:8 mg L^{-1} of each element (respectively) once every two days. The 'optimal' irrigation treatment provided an additional five irrigations in that time period (i.e. 3 irrigations per day to leaching) . The 'suboptimal' irrigation treatment only provided the single fertigation every two days; however, care was taken to ensure that this irrigation leached all substrates, so that growth was not affected by the excessive buildup of salts within each substrate.

The experiment was located on a raised bench in a double-layered polyethylene greenhouse, which was cooled by a fan-wetwall system. Daytime air-temperatures were regulated to a minimum of 8°C and a maximum of 30°C. Relative humidity was controlled to <80% by a dehumidifying fan at the top end of the tunnel. Photosynthetic photon flux averaged between 420 and 610 moles μm^{-2} s^{-1} in the greenhouse during the eight months of the experiment.

Results and Discussion: Substrate Analysis: The actual AFP of each substrate (Table 1) was determined according to the method of Bunt (1988), similar to the procedure of Handreck and Black (1991). The AFP (Fig. 1) decreased logarithmically from 25% with no fine particles (<0.5mm) in the mix to 7.5% AFP with 60% fine particles. There was a strong correlation between increasing proportions of fines in the mix and decreasing AFP. A significant negative correlation was also found between increasing AFP and WHC, which varied from 585 to 740 cm^3 dm^{-3}.

Seedling growth measurements: Stem diameter and seedling height were highly correlated, and therefore only seedling diameter will be discussed. AFP had a significant effect on stem diameter in all three rootstocks at various stages of growth. Since the results of Carizzo citrange (CC) were very similar to those of Cleopatra mandarin (CM), only those for CM (Fig 2) and RL (Fig. 3) are presented. Since the growth rate of CC and CM was slower than that of RL, there were no significant differences between the two irrigation regimes (Fig. 2), except at the highest AFP rate (25%) after 225 days with CM. Since RL had a greater growth rate and leaf area (data not shown), there were significant reductions in growth with the sub-optimal irrigation regime at 25% AFP, even after only 147 days (Fig. 3). There were few significant differences in mean stem diameter between other substrate mixes, whatever the rootstock species.

Seedling dry mass: Similar effects were seen in the total dry mass of the seedlings (Fig. 4), taken at the end of the experiment. The growth of RL was significantly reduced with the sub-optimal irrigation regime. More importantly, this reduction in growth was not substantially ameliorated by increasing the WHC of the substrate (i.e. by increasing the proportion of fine particles). This was curious, and made us suspect that a high salt load, measured by electrical conductivity (EC) might be the cause of this growth reduction, especially since RL is a salt-sensitive rootstock. However, when we plotted the EC measurements of the final substrate mix, we found that only the two most porous substrates (12.5% and 25%) had EC's that might be considered detrimental to the long-term growth of RL (Fig.5). Our conclusion from this data is therefore that the higher EC's were more likely an indicator of reduced nutrient (water) availability (i.e. the increase in EC was a consequence of irrigation regime and AFP, but not necessarily the reason for reduced growth under the sub-optimal irrigation regime). There was just not enough available water for RL to grow optimally, irrespective of the proportions of fine particles. With CC and CM, on the other hand, there was adequate water at both irrigation regimes, such that it negated any effect that altering the substrate physical properties might have had.

Significance to the Industry: It is therefore important to recognize that different crop species have substantially different requirements for water and nutrients, and that any one particular substrate formulation is unlikely to be adequate for the optimal growth of these different species. Substrates with very high porosities are likely to restrict the lateral movement of water and nutrients, whereas substrates with AFP's below 10% are likely to result in reduced root densities, due to a lack of aeration and perhaps encourage the incidence of soil-borne pathogens.

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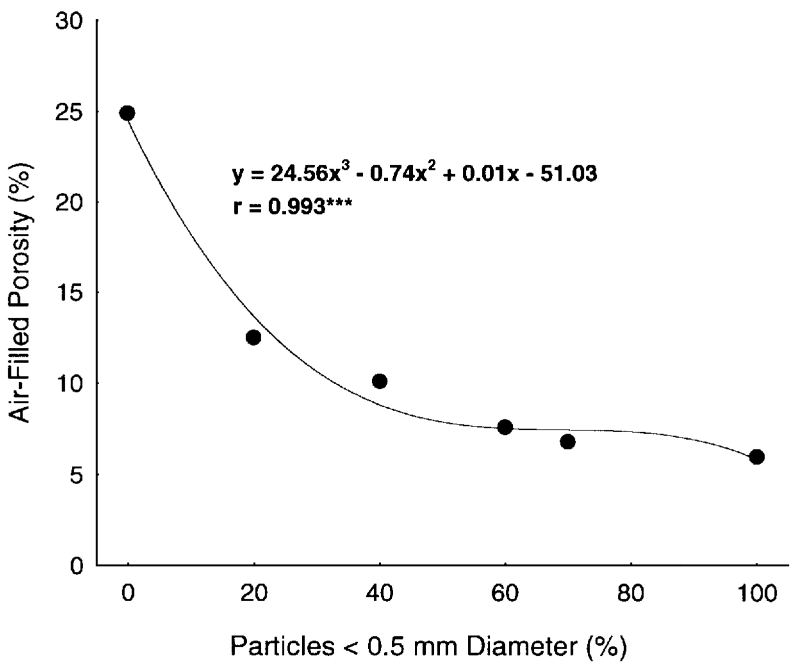

Figure 1. Mean percentage air-filled porosity of six reconstituted pine bark mixtures with increasing proportions of fine (<0.5mm diameter) particles.

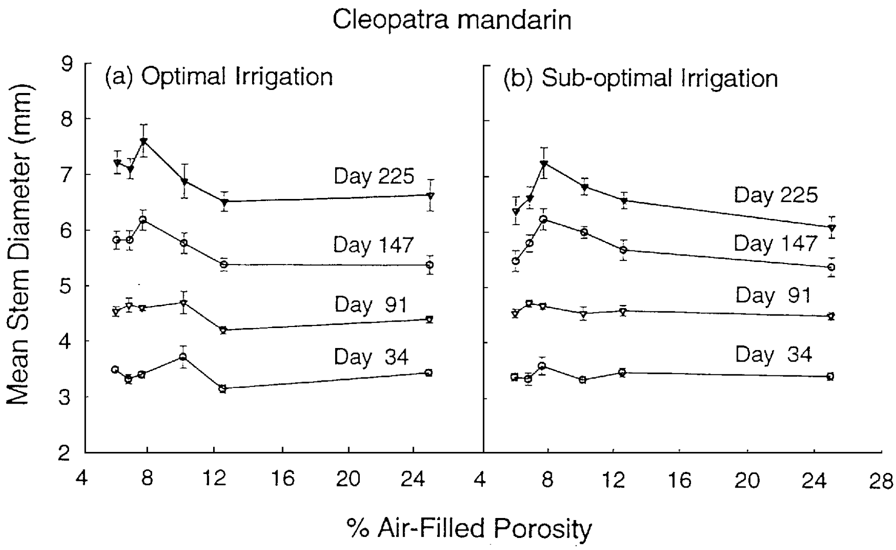

Figure 2. Mean stem diameter (n=6), at two-monthly intervals, of Cleopatra mandarin seedlings grown in the six pine bark mixes with varying air-filledporosities and at two watering regimes; (a) optimal (=3 irrigations per day) and (b) sub-optimal (=1 irrigation per day). Error bars represent one standard error (S.E.) about the mean.

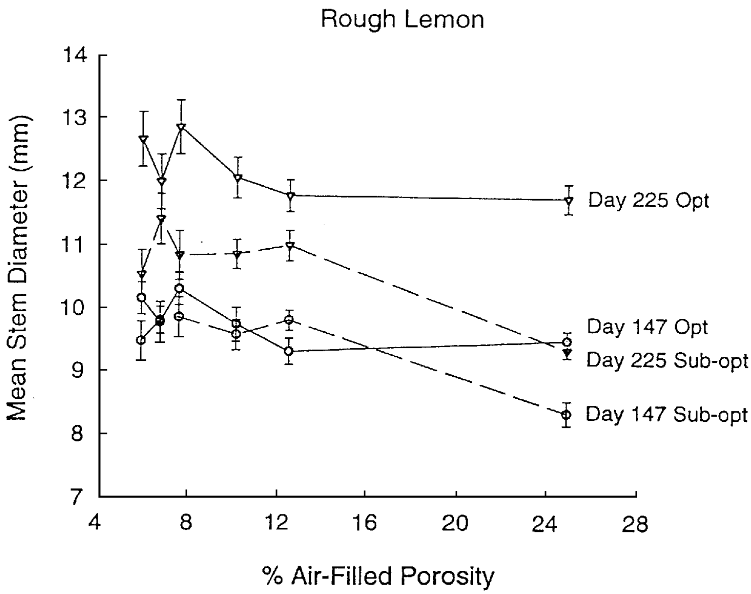

Figure 3. Mean stem diameter (n=6) at days 147 and 225 of Routh lemon seedlings grown in the six pine bark mixes with varying air-filled porosities and at two watering regimes (optimal = 3 and sub-optimal = 1 irrigations per day). Error bars represent one S.E. about the mean.

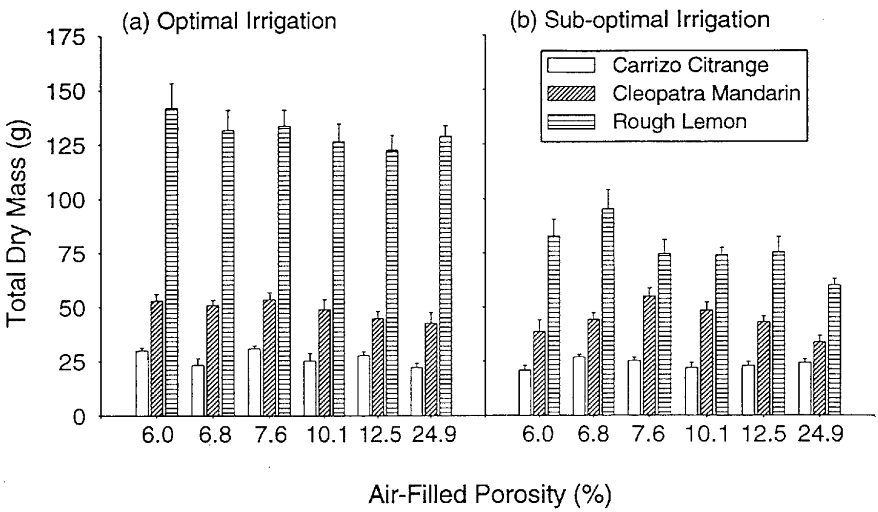

Figure 4. Total dry mass (n=6) of Rough lemon, Cleopatra mandarin and Carizzo citrange seedlings grown in the six pine bark mixes with varying air-filled porosities and at two watering regimes, (a) optimal (= 3 irrigations per day) and (b) sub-optimal (= 1 irrigation per day). Error bars represent one S.E. from the mean.

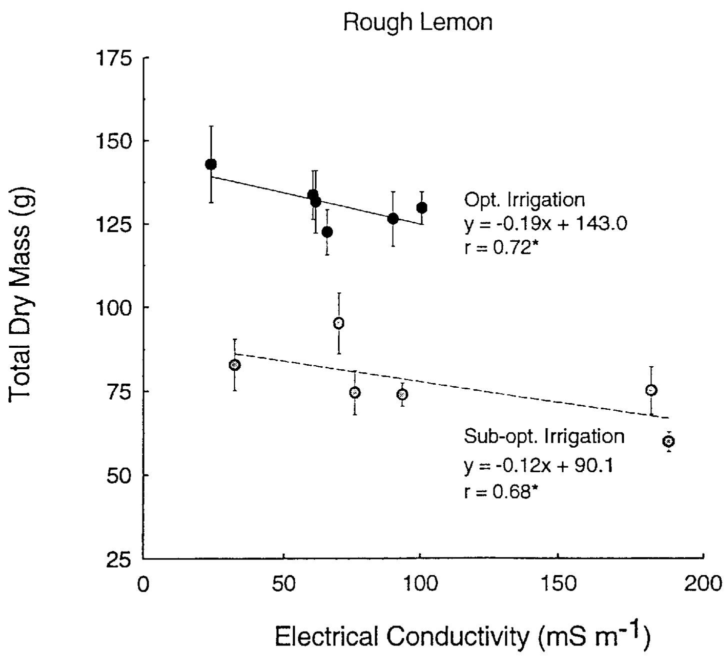

Figure 5. Regression of Rough lemon seedling total dry mass (n=6) versus the electrical conductivity of the six pine bark mixes at two watering regimes (optimal = 3 and sub-optimal = 1 irrigations per day). Error bars represent one S.E. from the mean.

Yard Waste Compost as a Container Substrate Component

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Nature of Work: Yard waste and the ensuing composted products provide alternative substrate components for container production systems. Excellent growth of *Rhododendron indicum* 'Duc du Rohan' and *Pittosporum tobira variegata* was reported in a pine bark based medium with up to 40% by volume composted yard waste in central Florida (1). Our study was initiated in July, 1995, in Lexington, KY to evaluate several sources of leaf and yard waste composts as container substrate components in combination with pine bark and across two irrigation volume treatments.

Composts from Kentucky State University, Frankfort, KY; Numus (bulk and bagged) Ag- Renew, Middletown, OH; Nea's Mushroom Compost, Dayton, OH; and Nature's Own, Dayton, OH were blended with pine bark at different ratios. Treatments (% by volume) were: 100% pine bark, 75% pine bark:25% KSU compost, 75% pine bark:25% Nea's Compost, 75% pine bark:25% Numus (bag), 75% pine bark:25% Numus (bulk), 75% pine bark:25% Nature's Own, 50% pine bark:50% Numus(bulk), and 100% Numus (bulk).

Ilex verticulata 'Winter Red' and *Ilex crenata* 'Glory' were transplanted into 2-gallon nursery containers on 19 July 1995, using the blended media. Micronutrients (Perk, Vigoro Industries, Chicago, IL) and dolomitic limestone were incorporated at 1.5 and 4 lbs per cubic yard (0.9 and 2.4 kg/m3), respectively. Woodace 20-4-11 fertilizer (Vigoro Industries, Chicago, IL) was surface-applied at 0.8 oz (23 g) per container at transplanting and on 15 April 1996. Two daily irrigation volume treatments were initiated as 250 or 500 ml per container split into two applications per day and increased to 300 or 600 ml on 17 August 1995 for the remainder of the study. Plants were moved to a unheated, plastic-covered greenhouse for winter protection. The nine media and two irrigation regimens were factorially combined and replicated eight times in a split block design for each species.

Chlorosis ratings were recorded in October 1995. Shoot and root dry weights were determined at termination of the experiment in October 1996.

Results and Discussion: The 100% pine bark and the treatments with 75% pine bark and 25% of either compost produced larger and higher quality plants than the other media. Neither plant species grew well in the two 100% compost treatments. There was an intermediate response to 50% compost. The 50% or 100% compost treatments significantly suppressed root growth in both species compared to treatments. There were no significant substrate by irrigation volume treatment interactions. The greater irrigation volume treatment resulted in increased shoot and root dry weight in *I. verticulata* 'Winter Red' but not in *I. crenata* 'Glory'. Although all substrates exhibited some shrinkage, the 100% Numus (bag and bulk) exhibited the greatest shrinkage. The 100% Numus caused leaf chlorosis in both test species, which was probably a reflection of inadequate aeration and a higher pH when not blended with pine bark.

Significance to the Industry: This study demonstrated that at least 25% of yard waste compost can be blended with pine bark to yield a container substrate with acceptable physical and chemical properties for outdoor production in central Kentucky. The aeration porosity should be 22 to 28% and the initial pH should be adjusted to meet plant requirements.

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