# Container-Grown Plant Production

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# Nutrient and pH Management Programs for Nursery Production of *Helleborus* x *hybridus*

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**Index Words:** Lenten Rose, Nitrogen Rate,Lime Rate

**Nature of Work:** The use of herbaceous perennials in landscape plantings has increased tremendously over the last few years. As such, the production of herbaceous perennial plants by nurseries has also increased including sales of perennials that fit specialty gardening niches such as butterfly and shade gardening. The genus *Helleborus* includes many exciting species and selections that offer winter to early spring flowers for southeastern United States shade gardens (Rice and Strangman, 1993). In the landscape, *Helleborus* x *hybridus*, the lenten rose is quite easy to cultivate having few disease and insect problems and tolerating a wide range of soil. Such is not the case with nursery production of hellebores. In a container, hellebores suffer from phytophthora, botrytis, nutrient deficiencies, and slow growth rates. Growers complain of apparently healthy one year old seedlings suddenly dying and those that do survive taking 3-5 years to flower so that they can be sold by flower color.

Developing a nursery production program for any plant must begin with addressing the basics of fertility; furthermore, when a plant is not performing well in an existing program, fertility and pH need to be reassessed and modified for the production of this plant. A review of the literature turned up a confusing picture of recommendations for nutrient solution applications for the production of herbaceous perennials ranging from 100 to 200 mg/liter N applied with every irrigation to between 100 and 150 mg/liter N applied once weekly (Armitage, 1993; Nau, 1996). Dubois et al. (2000) found that 150 mg/liter N applied three times a week maximized growth of *Anemone* x *hybrida*. No actual nursery production information for the lenten rose could be found.

Development of a fertility program that addresses both the nutritional and pH requirements of helleborus would be a good first step in resolving some of the production issues associated with the lenten rose. Therefore, an experiment was designed to evaluate N rates in combination with lime additions for their effects on root and shoot dry weight and root to shoot ratio of *Helleborus* x *hybridus*.

The experiment was a 5 x 5 factorial in a split plot block design with N rates (10, 20, 40, 80, and 160 mg/liter) as the main plot and lime rate (0, 3, 6, 9, and 12 lbs. of dolomitic lime incorporated per cubic yard) as the subplot with four replications. One year old seedlings were potted into 4 quart containers with a pine bark substrate that was amended with the different lime rates. Nitrogen rates were applied every other day using pressure compensated spray stakes (Acu-Stick, Wade Mfg. Co., Fresno CA) at a rate of 200 ml/min (0.3 in/min.). As the N rate was increased in the nutrient solution from 10 mg/liter N through 160 mg/liter N, the P and K rates were also increased to maintain a 4:1:2 N:P:K ratio (Table 1). Ammonium nitrate, potassium phosphate, and potassium sulfate supplied the N, P, and K and a modified Hoagland's solution supplied the micronutrients in the nutrient solutions. Since our irrigation water contained adequate Ca and Mg, no additional Ca or Mg were applied other than that available from the lime additions.

At project termination, shoot and root dry weights were determined and used for growth comparisons and calculations of root : shoot ratios (root dry weight ÷ shoot dry weight). Data were tested for differences using analysis of variance and regression analyses (SAS Inst., Inc., 1985) and were considered significant at $P \leq 0.05$.

**Results and Discussion:** There was a significant interaction between N rate and lime rate for shoot dry weight while the N rate by lime rate interaction was nonsignificant for root dry weight and the root to shoot ratio (data not shown). Within each lime rate, helleborus shoot dry weight increased linearly with increasing N rate (Table 2). Lime rate alone affected root dry weight with the largest increase in root grow occurring between the 0 lime treatment (3.4 g) and the 3 lb/yd$^3$ (5.1g). The 3, 6, 9, and 12 lb lime per cubic yard treatments averaged 5.0 g root dry weight. Root to shoot ratio was affected by the N rate only (data not shown). Low N rates (10 and 20 mg/liter N) resulted in greater root to shoot ratios (1.6 and 1.3, respectively). As N rate increased, the root to shoot ratio decreased (0.6 and 0.3 for 80 and 160 mg/liter N, respectively) as the plants directed energy to shoot growth with little increase in root growth.

**Significance to Industry:** Helleborus is best grown with at least 3 lbs of dolomitic limestone amended per cubic yard of pine bark substrate and high rates of nutrition. Higher rates of lime appeared to neither increase nor reduce growth. Nitrogen rates of 160 mg/liter N with P and K balanced in a 4:1:2 N:P:K ratio applied with each irrigation resulted in greatest shoot growth; while N rate had no effect on root growth.

**Literature Cited:**

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2. Dubois, J.-J.B., S.L. Warren, and F.A. Blazich. 2000. Nitrogen nutrition of containerized *Anemone* x *hybrida*. J. Environ. Hort. 18(3):145-148.

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5. SAS Inst., Inc. 1985. SAS User's Guide: Statistics. Version 5 ed. SAS Inst., Inc., Cary, N.C.

**Table 1.** Nutrient sources and concentrations of nutrient solutions.

| Nutrient<br>N rate (mg/liter) | mg/liter | mM |
|---|---|---|
| **10** | | |
| N ($NH_4NO_3$) | 10.0 | 0.71 |
| P ($KH_2PO_4$) | 2.5 | 0.08 |
| K ($KH_2PO_4$) | 3.2 | |
| K ($K_2SO_4$) | 1.8 | 0.05 |
| **20** | | |
| N ($NH_4NO_3$) | 20.0 | 1.43 |
| P ($KH_2PO_4$) | 5.0 | 0.16 |
| K ($KH_2PO_4$) | 6.3 | |
| K ($K_2SO_4$) | 3.7 | 0.09 |
| **40** | | |
| N ($NH_4NO_3$) | 40.0 | 2.86 |
| P ($KH_2PO_4$) | 10.0 | 0.32 |
| K ($KH_2PO_4$) | 12.5 | |
| K ($K_2SO_4$) | 7.5 | 0.19 |
| **80** | | |
| N ($NH_4NO_3$) | 80.0 | 5.71 |
| P ($KH_2PO_4$) | 20.0 | 0.65 |
| K ($KH_2PO_4$) | 25.0 | |
| K ($K_2SO_4$) | 15.0 | 0.38 |
| **160** | | |
| N ($NH_4NO_3$) | 160.0 | 11.42 |
| P ($KH_2PO_4$) | 40.0 | 1.29 |
| K ($KH_2PO_4$) | 50.0 | |
| K ($K_2SO_4$) | 30.0 | 0.77 |
| B ($H_3BO_3$) | 0.5 | 0.046 |
| Cu ($CuSO_4 \cdot H_2O$) | 0.02 | 0.0003 |
| Mn ($MnCl_2$) | 0.5 | 0.009 |
| Mo ($(NH_4)_6(Mo_7O_{24})$) | 0.1 | 0.001 |
| Zn ($ZnSO_4 \cdot 7H_2O$ | 0.05 | 0.0008 |
| Fe (chelated) | 5.0 | 0.09 |

**Table 2.** Effect of N rate on shoot dry weight. A significant N rate x lime rate interaction exists.

| N rate (mg/liter) | Lime rate (lbs dolomitic lime / $yd^3$) 0 | 3 | 6 | 9 | 12 |
|---|---|---|---|---|---|
| 10 | 2.3 | 3.0 | 2.6 | 3.3 | 2.7 |
| 20 | 3.7 | 4.2 | 3.3 | 3.3 | 3.6 |
| 40 | 4.4 | 6.5 | 5.7 | 5.6 | 5.6 |
| 80 | 6.4 | 8.4 | 8.2 | 9.3 | 9.1 |
| 160 | 6.6 | 15.6 | 15.9 | 13.9 | 15.7 |
| Linear | 0.001[z] | 0.001 | 0.001 | 0.001 | 0.001 |
| Quadratic | 0.002 | NS | NS | NS | NS |

[z]Regression analysis. Nonsignificant (NS) at P > 0.05, P value stated otherwise.

# Fertilization of Bedding Plants: Constant Fertilizer Concentrations Versus Constant Growing Medium EC

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**Index Words:** Petunia, *Petunia xhybrida*, Begonia, *Begonia xsemperflorens*, Fertilizer, Electrical conductivity, EC

**Nature of Work:** In recent years, there has been a change in the approach to fertilization of bedding plants. Traditionally, recommendations for fertilization of bedding plants have focused on which concentration of fertilizer to apply. Recently, the focus of fertilization guidelines has shifted from applying optimal fertilizer concentrations to maintaining the electrical conductivity (EC) of the growing medium within an optimal range. The optimal EC of the growing medium is likely to be much less sensitive to environmental conditions than the optimal fertilizer concentration (Kang and van Iersel, 2001). The disadvantages of trying to maintain a constant growing medium EC are that it requires regular measurements of growing medium EC, which can be time-consuming, and that fertilizer concentrations may have to be changed periodically to maintain the EC within the required range.

Surprisingly, there has been no research comparing the effects of these two fertilization strategies (constant fertilizer concentration and constant growing medium EC) on the growth of greenhouse crops. Therefore, the objective of this experiment was to determine whether maintaining a constant growing medium EC results in better growth than constant fertilizer concentrations.

Plug seedlings of wax begonia ‘Cocktail mix’ and petunia ‘Gnome white’ were received from Speedling Greenhouses on April 4, 2002, and transplanted into 4" pots filled MetroMix 300 growing medium. The seedlings were placed on 4' x 8' ebb-and-flow benches, where they were subirrigated daily with a solution of water-soluble fertilizer. Fertilizer solutions were made with Peters 20-10-20 Peat-lite special water-soluble fertilizer with an EC of 0.5, 1.5, 2.5, 3.5, 4.5, or 5.5 mS/cm (corresponding to approximately 50, 200, 350, 500, 650, and 800 ppm N). The EC of the fertilizer solutions was measured weekly and adjusted as needed.

Plants were either subirrigated with the same fertilizer solution throughout the growing period or we tried to keep the EC of the growing medium constant at 0.5, 1.5, 2.5, 3.5, 4.5, or 5.5 mS/cm. To do this, leachate EC of two (begonia) or three (petunia) plants per experimental unit was measured twice weekly, using the pour-through method. Plants were moved to another bench with higher or lower fertilizer EC, if necessary to keep the leachate EC within the desired range.

Dry weight of the plants was measured at regular intervals throughout the growing period. The experimental design was a randomized complete block with a split-plot (constant fertilizer of growing medium EC), six treatments (EC levels) and two replications. The data were analyzed by regression analysis. To determine the effect of fertilizer or growing medium EC and plant age on the dry weight (DW) of the plants, a polynomial model, including an interaction term, was used:
$DW = \beta_0 + \beta_1 xEC + \beta_2 xDAT + \beta_3 xEC^2 + \beta_4 xDAT^2 + \beta_5 xEC^3 + \beta_6 xECxDAT$,
where: $\beta_0$, ...., $\beta_6$ are regression parameters, EC is either the EC of the fertilizer solution, or the target EC of the growing medium, and DAT is days after transplanting. This regression equation was used to estimate the EC resulting in maximum growth.

**Results and Discussion:** The EC of the growing medium of petunias fertilized with constant concentrations of fertilizer increased throughout the experiment, if the fertilizer EC was 2.5 mS/cm or higher, was stable in the 1.5 mS/cm treatment, and decreased in 0.5 mS/cm treatment (Fig. 1). An increase in EC indicates that more fertilizer was added to the growing medium than was taken up by the plants, while a decrease in EC indicates either that the plants were taking up more nutrients than were applied, and/or that the nutrients in the growing medium accumulated in the top layer of the growing medium. Stratification of salts in subirrigated plants is common, because salts accumulate in the top layer of the medium, as water evaporates from the medium surface. In treatments where we tried to keep the growing medium EC constant, the EC generally was close to the target EC, and averaged over the experimental period, was within 0.2 mS/cm of the target value. Treatment effects on the growing medium EC of begonias were similar (not shown).

Dry weight of the plants increased rapidly during the experiment, and was greatly affected by the EC of the fertilizer solution or growing medium. When plants were fertilized with constant concentrations, a fertilizer solution EC of 0.52 and 1.24 mS/cm were estimated to be optimal for begonia and petunia, respectively. When the growing medium was maintained at a constant EC, 1.0 and 1.7 mS/cm were estimated to be optimal for begonia and petunia, respectively. One clear difference between using a constant fertilizer concentration and maintaining the growing medium EC at a constant level occurred at higher than optimal EC. Growth was reduced much more by high EC of the fertilizer solution than by high growing medium EC. This difference probably occurred because higher than optimal fertilizer concentrations resulted in very high growing medium EC (up to 10.5 mS/cm for petunia and 12.5 mS/cm for begonia), which in turn inhibited growth.

**Significance to Industry:** High quality bedding plants can be grown successfully either with constant fertilizer concentrations, or by maintaining the growing medium EC at a constant level. However, growth of both begonia and petunia is greatly inhibited when high fertilizer concentrations cause accumulation of soluble salts in the growing medium. Periodic measurements of growing medium EC will help prevent this accumulation, and are therefore a valuable tool in fertilizer management. The optimal growing medium EC is approximately 0.8-1.2 mS/cm for begonia and 1.5-2.0 mS/cm for petunia.

**Literature Cited:**

1. Kang J.G. and M.W. van Iersel. 2001. Interactions between temperature and fertilizer concentration affect growth of subirrigated petunias. J. Plant Nutr. 24:753-765.

**Days after transplanting**

**Figure 1.** The effect of constant fertilizer concentration (top) or management of the growing medium EC on leachate EC. Data shown are for petunia. Trends were similar for begonias.

**Days after transplanting**

**Figure 2.** The effect of constant fertilizer EC (left) or management of the growing medium EC (right) on the dry weight of begonia (top) and petunia (bottom) throughout their development.

# Effect of Nutri-mist on Growth of Begonias and Impatiens

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**Index Words:** Nutri-mist, Impatiens, Begonias, Organic, Fertilizer

**Nature of Work:** Nutri-mist (Agxplore International, Cape Girardeau, Missouri) is a certified organic water-soluble fertilizer comparable to currently available water-soluble fertilizers. Limited amount of production data is available for Nutri-mist. Nutri-mist is a potential fertilizer source for organic production of bedding plants.

The objective of the study was to determine the effect of different rates of Nutri-mist foliar fertilizer on begonia and impatiens production. Variables measured included flower number, bud number, and shoot fresh weight. The study was conducted in the biology greenhouse at Southeast Missouri State University, Cape Girardeau, Missouri. All plants were grown from transplants in 6-inch pots using a commercially available growing media (Pro-Mix BX, Premier Horticulture, Quebec, Canada). Trials consisted of two separate experiments with ‘Super Olympic Light Pink’ begonias and ‘Super EIF Coral’ impatiens. Begonia treatments consisted of transplanting four week old begonias in 6-inch pots replicated 5 times. Begonias received Nutri-mist 20-20-20 at the following rates: 0 ppm N, 100 ppm N, 200 ppm N, and 300 ppm twice weekly with a bottle sprayer. Impatiens were fertilized using Nutri-mist 20-20-20 at 0, 75, 150, and 225 ppm N with a bottle sprayer. Experimental plots were irrigated thoroughly before watering prior to spraying and irrigated as needed on all other days. Experiments were terminated on June 7 and 8, 2001. Experimental design was completely randomized. Data were analyzed using PROC GLM (SAS Institute, Cary, NC) and means separated using Duncan’s multiple range test.

**Results and Discussion:** Begonia responded similarly at all treatment levels, with no significant differences found in either flower number or shoot fresh weight. Begonias fertilized at 100 and 300 ppm N had greater flower buds than the control (Table 1). Growth of impatiens did not differ significantly from the control at any treatment level (Table 2).

Our results were not significant which may have been due to the loss of nitrogen due to overhead irrigation of our study. Nitrogen is required in large quantities by plants and is easily leached during irrigation, making it the most difficult nutrient to manage in a container production system (1).

**Significance to Industry:** In our study, fertilization with Nutri-mist had no significant effect on the growth of begonias or impatiens. Further work is necessary to determine the efficacy of this fertilizer on other bedding plants.

**Literature Cited:**

1. Green, J.L. 1989. Practice to minimize contamination of groundwater and runoff water in greenhouse and nursery production of container-grown plants. Ornamentals Northwest Newsletter 13(3): 9-16.

**Table 1.** Effect of fertilizer level on flower number, flower bud number, and shoot fresh weight of begonia.

| Fertilizer Level (ppm N) | Flower Number | Flower Bud Number | Shoot Fresh Weight (g) |
|---|---|---|---|
| 0 | 23.3 a | 11.0 c | 46.4 a |
| 100 | 23.2 a | 18.6 ab | 60.8 a |
| 200 | 20.2 a | 14.2 bc | 43.7 a |
| 300 | 21.8 a | 20.8 a | 50.9 a |

*means separated using Duncan's multiple range test ($P \leq 0.05$)

**Table 2.** Effect of fertilizer level on flower number, flower bud number, and shoot fresh weight of impatiens.

| Fertilizer Level (ppm N) | Flower Number | Flower Bud Number | Shoot Fresh Weight (g) |
|---|---|---|---|
| 0 | 53.8 a | 9.4 a | 45.3 a |
| 75 | 46.2 a | 13.0 a | 46.7 a |
| 150 | 63.6 a | 14.2 a | 51.1 a |
| 225 | 55.0 a | 27.0 a | 52.3 a |

*means separated using Duncan's multiple range test ($P \leq 0.05$)

# Comparison of Slow-Release and Water-Soluble Fertilizers for Pansy Production

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**Index Words:** Pansy, *Viola x wittrockiana*, Osmocote, Fertilizer

**Nature of Work:** Bedding plant producers must use efficient fertilization programs to maximize the size and quality of their crops. Fertilization using water-soluble fertilizers with injection systems can be effective, though contributes to increased inputs of labor, equipment, and time. Water-soluble fertilizers are also easily leached and often lost to run-off, becoming a potential pollution source. Slow-release fertilizers may provide a more efficient fertilization program.

Research was conducted to compare the size and quality of pansies (*Viola x wittrockiana*) under slow-release and water-soluble fertilization programs in a greenhouse at Southeast Missouri State University in Cape Girardeau, Missouri. Delta Blotch Pansy seeds were planted into 4" pots using Pro-Mix BX soilless potting media (Premier Horticulture, Quebec, Canada) and grown with the following treatment regimens: 1) No fertilizer (control), 2) slow-release fertilizer only (Scotts Osmocote 15-9-12, 7 to 9 month at 6.0 lbs/yd$^3$(5900 g/M$^3$)), 3) water-soluble fertilizer only (Peters 20-20-20 General Purpose at 200 ppm N), and 4) water-soluble (100 ppm N) and slow-release (3.0 lbs/yd$^3$ (2950 g/M$^3$)) fertilizers. Water-soluble fertilizers were premixed and applied using a Hozon (16:1) siphon following emergence of the first true leaves. Slow-release fertilizers were incorporated into the media prior to planting. Treatments consisted of 5 reps of 15 plants each in a randomized complete block design. Plant measurements included germination percentages, mortality rates, plant height, plant width, and root and shoot fresh weights. Electrical conductivity and pH were monitored and maintained within recommended ranges (1,2). Data were analyzed using PROC GLM (SAS Institute, Cary, NC). Treatment effects were separated using orthogonal contrasts. Quality assessments were made by visual examination and rated on a scale of 1 to 10, with 1 being poor and 10 being ideal. Evaluations were based on appearance and likelihood of purchase. Quality assessments were analyzed using PROC FREQ (SAS Institute, Cary, NC) and the CMH option, which requests the Cochran-Mantel-Haenszel statistic.

**Results and Discussion:** Germination percentage was significantly affected by the incorporation of slow-release fertilizer. In the 2 groups without slow-release fertilizer, germination percentages were 100% and 98.6% (Table 1). Germination dropped to 64% and 73% in the groups with slow-release fertilizer (Table 1). Many slow-release seedlings also died shortly after germination, decreasing survival to 57% and 72% of planted seeds. This is most likely due to the elevated fertilizer concentration. Electrical conductivity readings in the slow-release groups were 3.35 and 3.69 mmhos/cm, well above the recommended level of .50 mmhos/cm (1).

Plant size was also significantly different among treatments. Fertilization with water-soluble fertilizers produced the tallest plants, with the highest fresh root and shoot weights (Table 2). Slow-release fertilization produced the next largest group, and the control plants were the smallest (Table 2).

The water-soluble plants received the highest quality ratings as well (Table 3). This is due in great part to the high mortality and poor germination in the slow-release groups. The water-soluble plants did begin to have micronutrient deficiencies toward the end of the study. It should be noted that the slow-release plants that survived were growing larger and had fewer nutrient deficiency symptoms at the termination of the study than did the water-soluble plants.

**Significance to Industry:** These data suggest that the use of water-soluble fertilizers remains the most efficient means of producing pansies, seed to sale. The elevated mortality rates and poor germination of seedlings makes it infeasible to incorporate slow-release fertilizers prior to seeding. However, the improved response of slow-release plants in the later stages of production may make this technique a viable option when using transplants.

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2. Healy, W. 1998. Viola x wittrockiana (Pansy). In: Ball Redbook, V. Ball, ed. p. 777-782.

**Table 1.** Seed germination percentages of pansies under 4 fertilization treatments.

| Treatment | Germination Percentage | Mortality | Electrical Conductivity (mmhos/cm) |
|---|---|---|---|
| Control (0 ppm N) | 100* | 0% | 1.99 |
| Water-soluble and slow-release[z] | 64 | 7%* | 3.35 |
| Slow-release[y] | 73 | 1% | 3.69 |
| Water-soluble[x] | 98.6* | 0% | 1.89 |

*significant ($P \leq 0.05$)
[z]Peters 20-10-20, 100 ppm N; Osmocote Plus 15-9-12, 3.0 lbs/yd$^3$
[y]Osmocote Plus 15-9-12, 6.0 lbs/yd$^3$
[x]Peters 20-10-20, 200 ppm N

**Table 2.** Plant size measurements of pansies under 4 fertilization treatments.

| Treatment | Plant height (cm) | Plant width (cm) | Fresh shoot weight (g) | Fresh root weight (g) |
|---|---|---|---|---|
| Control (0 ppm N) | 9.7 | 9.2 | 5.3 | 1.7 |
| Water-soluble & slow-release[z] | 12.3* | 13.3* | 11.9* | 1.8 |
| Slow-release[y] | 11.7 | 11.6 | 8.1 | 2.3 |
| Water-soluble[x] | 16.1* | 14.2* | 14.8* | 3.2* |

*significant ($P \leq 0.05$)
[z]Peters 20-10-20, 100 ppm N; Osmocote Plus 15-9-12, 3.0 lbs/yd$^3$
[y]Osmocote Plus 15-9-12, 6.0 lbs/yd$^3$
[x]Peters 20-10-20, 200 ppm N

**Table 3.** Quality assessments of pansies grown under 4 fertilization regimens. Quality was assessed visually and scored on a scale of 1 to 10, with 1 being poor and 10 ideal. Evaluations were based on appearance and likelihood of purchase.

| Treatment | Rating |
|---|---|
| Control (0 ppm N) | 4.75 |
| Water-soluble and slow-release[z] | 4.75 |
| Slow-release[y] | 5.75 |
| Water-soluble[x] | 8.0* |

*significant ($P \leq 0.05$)
[z]Peters 20-10-20, 100 ppm N; Osmocote Plus 15-9-12, 3.0 lbs/yd$^3$
[y]Osmocote Plus 15-9-12, 6.0 lbs/yd$^3$
[x]Peters 20-10-20, 200 ppm N

# Incorporated Granular Sulfur Influences Growth of Two Tree Species

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**Index Words:** Red maple, *Acer rubrum*, Willow Oak, *Quercus phellos*, sulfur, pH, soluble salts

**Nature of Work:** Deep well water in south Georgia used for irrigation of nursery stock typically has a pH greater than 7.0 and an alkalinity of greater than 2.0 meq/liter. While initial pH values in freshly potted pine bark substrates are typically between 5.0 to 5.5, it is not uncommon to see pH values in the 7.3 to 7.8 range by mid-summer when well water is used. Growth is decreased and iron deficiency is a common problem on several tree species produced in southwest Georgia, particularly maples and oaks, when water with moderate to high alkalinity is used for irrigation. Growers using water from collection basins which trap rainfall generally have fewer problems with increasing substrate pH due to the acidic nature of rain water (<5.0). Due to lack of rainfall during the growing season in 1998 through 2000, growers needed to supplement irrigation basins with deep well water to meet water demands. The well water increased the pH of the water being used for irrigation and iron chlorosis became a common problem for growers. Sulfur is recommended for reducing the pH of soilless substrates on long-term crops where precise control of pH is not critical and a gradual change is acceptable (2). Elemental sulfur is oxidized to sulfuric acid in the substrate by the bacterium *Thiobacillus.* The oxidation process can take several weeks (3). For floricultural mixes a rate of 0.75 lbs. per cubic yard of substrate will reduce the pH 0.5 to 1.0 units (1). Little information is available on the use of sulfur in pine bark substrates. A rate of 0.25 lbs. per cubic yard has been suggested (Jim Knauss, personal communication). The purpose of this study was to evaluate the influence of incorporated granular sulfur on the growth of two common ornamental tree species.

This study was conducted outdoors under full sun conditions on black polypropylene-covered beds at Gainous Shade Trees, Inc. in Cairo, GA. On 26 February, 2001, uniform bare-root liners of *Acer rubrum* (red maple) and *Quercus phellos* (willow oak) were potted into #5 containers using a substrate consisting of 7 pine bark: 2 peat moss: 1 sand (by vol) amended with the following in lbs. per cubic yard: 3.0 James River dolomitic limestone, 1.5 Micromax , and 3.0 Osmocote 17N-2.6P-10.0K. Granular (split-pea) sulfur (International Sulphur, Inc., Mt. Pleasant, TX) was incorporated at the rate of 0 (control), 0.33, 0.66, 1.00, and 2.00 lbs. per cubic yard of substrate. All plants were topdressed with 110 grams of Nutricote Total 17N-2.6P-6.6K (T-360, Florikan, Sarasota, FL). Leachate pH and EC were determined monthly using a Myron-L AG-6 pH/conductivity meter on all willow oaks. Plant height and stem diameter were measured on 1 November, 2001. Final shoot dry mass was determined at the termination of the study after drying plant tissue in a forced-air drying oven at 150F for 72 hrs. Plants were arranged by species. A completely randomized design with five treatments and six replications was utilized. Treatments were analyzed using SAS and Dunnett's t Test for mean separations.

**Results and Discussion:** Percent changes relative to the control for final plant height, stem diameter, and shoot dry mass are presented in Table 1. For red maple, sulfur incorporated at the two lowest rates had no influence on plant growth. Red maples grown with the 1.0 lb. sulfur treatment had similar height and stem diameter compared to the control, but shoot dry mass decreased 33%. The 2.0 lb. sulfur rate reduced plant height, stem diameter, and shoot dry mass 37%, 62%, and 370%, respectively compared to the non-treated control.

Growth of willow oak was not influenced by the lowest rate of sulfur application (Table 1). Final height of willow oak seedlings was reduced 40% and 59%, respectively, as sulfur rate increased to 0.66 and 1.00 lbs. per cubic yard. Stem diameter decreased 18% and 35% when plants were grown with the 0.66 and 1.00 lb. treatments. Shoot dry mass decreased 115% at the 1.00 lb. sulfur treatment. All willow oak trees were dead five months into the study when grown at the 2.00 lb. rate of sulfur.

One month into the study the substrate pH was lower for the 2.00 lb sulfur treatment compared with the control (data not shown). The EC of the leachate ranged from 1.67 dS/m at the low rate of sulfur to a high of 4.71 dS/m at the highest rate of application 90 days into the study, while pH ranged from a high of 5.5 for the control to a low of 2.4 at the high rate of sulfur. At 120 days, the EC of all sulfur treatments was >2.35 dS/m and the pH of the 2.0 lb. sulfur treatment was less than the lower limit (2.0) of the Myron-L meter used. After 120 days the pH for all treatments remained near or below 4.0. The drop in pH for all treatments corresponded with an increase in rainfall during the month of June, 2001 (8.46 in).

**Significance to Industry:** During the growing season of 2001, above average rainfall occurred during the months of March, June, and September. Additional rainfall during these periods kept the irrigation basin replenished and limited the quantity of alkaline ground water needed for irrigation purposes. Incorporation of granular sulfur in 2001 decreased the growth of red maple at the 1.00 or 2.00 lb rate of application while diminishing return was seen at the 0.66 lb. rate for willow oak. The reaction of sulfur based on decreased pH and increased EC occurred between 60 and 90 days into the study. Limited growth and/or mortality may have occurred due to excessive salts or hydrogen-ion toxicity. Based on the species used in this study incorporation of sulfur was not required for optimal growth during the 2001 growing season. No more than 0.66 lb per cubic yard of granular sulfur should be incorporated into the substrate for pH modification.

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**Table 1.** Influence of incorporated granular sulfur on the final growth of red maple and willow oak in #5 containers. Values presented are percent increase or decrease relative to the non-treated control.

**Percent Change Relative to Non-treated Control**

| Taxa | Sulfur (lbs/yd$^3$) | Final Height | Stem Diameter | Shoot Dry Mass |
|---|---|---|---|---|
| Red Maple | 0.33 | 3 | 0 | 3 |
| | 0.66 | 0 | 5 | -6 |
| | 1.00 | -13 | -5 | -33 |
| | 2.00 | -37 | -62 | -370 |
| Dunnett's $_{0.05}$ | | | | |
| | 0-0.33 | NS | NS | NS |
| | 0-0.66 | NS | NS | NS |
| | 0-1.00 | NS | NS | * |
| | 0-2.00 | * | * | * |
| Willow Oak | 0.33 | -18 | -11 | -17 |
| | 0.66 | -40 | -18 | -55 |
| | 1.00 | -59 | -33 | -115 |
| Dunnett's $_{0.05}$ | | | | |
| | 0-0.33 | NS | NS | NS |
| | 0-0.66 | * | * | NS |
| | 0-1.00 | * | * | * |

# Topdressing with Hosta

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**Index Words**: electrical conductivity, leachate, controlled release fertilizer, *Hosta undulata* 'albo-marginata,' *Hosta fortunei* 'patriot', Extension

**Nature of Work:** During the winter of 2001, Mike Duckwall of Hickory Mountain Plant Farm expressed a desire to determine how long a fertilizer was lasting in containers in an effort to better manage his Hosta crop. An experienced Hosta grower, Mike felt his observations were not consistent with his expectations. Numerous SNA publications have reported use of the VTEM method to monitor container crop fertility. Both authors have used and are familiar with the process of leaching containers and measuring electrical conductivity (EC) and pH of the leachate. The tool is one that growers can use with a little instruction and experience.

On March 13, 2001 a study was initiated to compare four fertilizers by collecting weekly leachate to be analyzed for electrical conductivity (EC) and pH. Plants used were *Hosta undulata* 'albo-marginata,' and *Hosta fortunei* 'patriot'. The plants were in one-gallon containers and just breaking dormancy. The study consisted of randomized complete blocks with four fertilizer treatments. Each container received 2 grams nitrogen as follows:

15 g Coors 14-14-14
15 g Wilbro/Polyon 14-12-14 (6-7 months @ 70 F)
11 g Wilbro/Polyon 19-5-12 (4-5 months @ 70 F)
12 g Meister 17-6-10 (5-6 months)

Leachate was collected weekly and analyzed at the nursery for EC and pH. After 23 weeks on August 21 the plants were qualitatively evaluated on a scale of 1 (unacceptable) to 5 (outstanding) by a group of ten greenhouse and nursery growers. The evaluators were asked to rate plants for appearance, color, vigor, and size. Growth measurements were taken 28 weeks after treatment on September 27. Growth index (GI) = [(maximum width + minimum width / 2) + height] / 2.

**Results and Discussion:** There was some variation in the early release of nutrients with the Coor product and the Wilbro/Polyon 6-7 month product providing the greatest early release. By week seven, however, there was no statistical difference in fertility among all treatments with EC generally less than 0.4 millisiemens. There was likewise no statistical difference in plant size. Qualitative evaluations ranged from 3.1 to 4.1 for 'albo-marginata'. 'Patriot' ratings ranged from 3.3 to 3.6. All plants were considered saleable.

**Significance to Industry**: The VTEM technique has been shown an effective strategy by which nursery operators can monitor the fertility status of their crops. Plant growth and appearance were not statistically different in the Hosta cultivars studied. However after observing the monitoring procedures throughout the season, Mike Duckwall purchased his own meter and began to make observations. By seeing a graphic illustration of how the fertilizers were performing, he had better information on which to base his selection as well as application strategy. He is now better qualified to monitor and evaluate his own crops and has a new management tool for fertilizer rate application and a strategy for irrigation based upon EC.

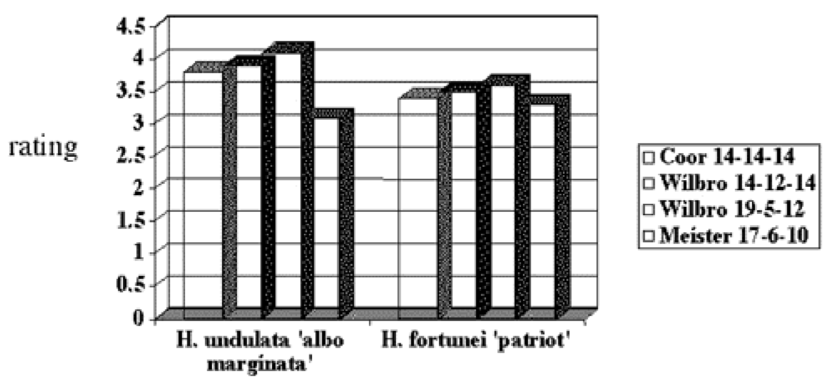


**Figure 1.** Appearance, color, vigor and size ratings of two Hosta cultivars. Rating values 1 = unacceptable appearance; 5 = outstanding appearance.

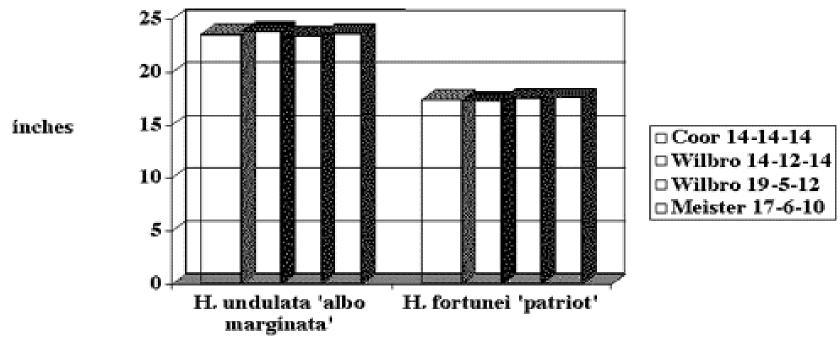


**Figure 2.** Growth Index of two Hosta cultivars. Data not significantly different as determined by LSD, P=0.05.

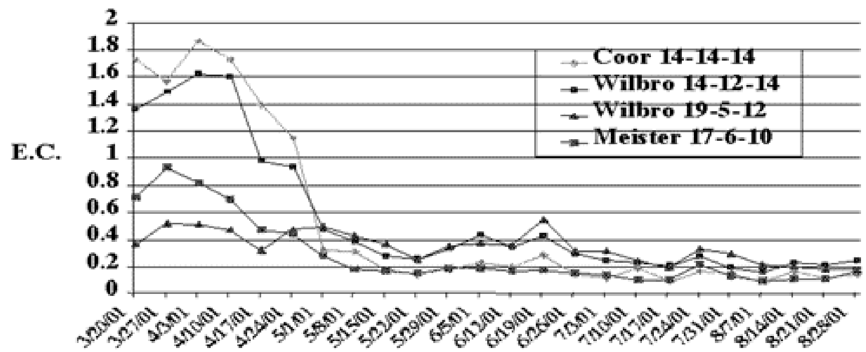


**Figure 3.** EC of leachate from containers of *Hosta Fortunei* 'patriot.' Data not significantly different as determined by LSD, P=0.05.

# Effect of Isobutylidene Diurea on Post-production Quality of Ornamental Cabbage

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**Index Words:** Ornamental cabbage, *Brassica oleracea* var. *acephala*, isobutylidene diurea, slow release fertilizer, nutrient deficiencies

**Nature of Work:** Ornamental cabbage is an important fall crop for southeastern U.S. growers. During the establishment and growing phase of the crop, growers traditionally use a continual liquid fertilization (CLF) program of 150 to 300 $mg{\cdot}L^{-1}$ (ppm) N (1, 2, 3, 5). All of the above references suggest fertilizers should be “reduced”, “discontinued”, or “not be present in the soil” during color development in the upper-central foliage, which occurs when air temperatures drop below 55°F (12.8°C). Unfortunately the strategy of discontinuing fertility can lead to an increased incidence of mineral deficiencies in ornamental cabbage during retail sales. In order to study the effects of discontinuing fertilization, a number of end-of-the production cycle fertilization treatments were investigated with ‘Osaka Red’ ornamental cabbage.

Ornamental cabbage plugs (2.1 x 2.5 cm [0.8 x 0.95 inch] cells) were transplanted into 2.96-L (0.78-gal) (20.8-cm diameter [8-inch]) round plastic containers on 5 Sept. 2000. The root substrate was Fafard 4-P (Fafard, Anderson, SC), which contained (v/v): 4 sphagnum peat : 2 pine bark : 2 vermiculite: 1 perlite. Plants were fertilized at each watering with Peters 20-10-20 (Scotts, Marysville, Ohio) (20-N-4.4P-16.6K) at 200 $mg{\cdot}L^{-1}$ (ppm) N. A daminozide foliar spray was applied 14 d after potting (using a volume of 204 $mL{\cdot}m^{-2}$ [0.5-gal/100 $ft^2$]) at 2500 $mg{\cdot}L^{-1}$ (ppm). Six weeks after potting (17 Oct.), plants were subjected to one of 4 fertilization programs: 1) continual liquid fertilization (CLF), 2) a supplemental isobutylidene diurea (IBDU) slow release fertilizer (SRF) application, 3) CLF + SRF, or 4) no fertilizer (NF) [tap water only]. The rate of IBDU used was 12 g/ pot (medium-high recommended rate for a gallon container). The experiment was a randomized complete-block design with five single-plant replications of the 4 treatments. On 2 and 16 Nov., total plant height (measured from the pot rim to the top of the foliage), plant diameter, and the diameter of the center color (all diameters measured at the widest dimension and turned 90°, and averaged) were recorded. Leachate was also collected on these dates using the PourThru method to monitor pH and electrical conductivity (EC) (4). Data were tested by analysis of variance by general linear model (SAS Inst., Cary, NC). Means were separated by least significant differences (LSD) at $P \leq 0.05$.

**Results and Discussion:** Two weeks after treatments were initiated, EC readings from the SRF and NF treated plants were below the recommended PourThru values of 1.0 mS/cm for actively growing ornamental cabbage (4) (data not shown). Plants fertilized with CLF or CLF + SRF were 17% taller than plants irrigated with NF, but all treatments produced similar plant and color diameters (data not shown). The NF plants had 50% more chlorotic lower leaves than the plants on CLF (data not shown). Four weeks after treatments were initiated, pH values were higher with plants treated with NF or SRF (Table 1). Surprisingly, CLF treated plants had higher EC values than plants fertilized with CLF + SRF. Plants treated with CLF or CLF + SRF were taller than plants treated with NF or SRF (Table 1). Plant diameters of 'Osaka Red' plants were wider only when fertilized with CLF + SRF. After 4 weeks, color diameters were similar for all 4 fertilizer treatments. The NF plants had 4 and 2.5 times more chlorotic leaves when compared to the CLF and CLF + SRF treated plants, respectively (Table 1).

**Significance to Industry:** Normal fertilization practices for floricultural crops at visible flower bud suggest that fertilization be discontinued or reduced significantly because plants require less nutrients for growth during flowering. Ornamental cabbage should be considered an exception and fertilization needs to be continued throughout the production season. The SRF or NF treatments resulted in a greater incidence of nutrient deficiencies and an EC level of 0.2 mS/cm or lower. In order for growers to maximize sales, ornamental cabbage plants should be fertilized at 200 $mg \cdot L^{-1}$ (ppm) N with a soluble fertilizer, and during coloration the EC levels should be greater than or equal to 0.4 mS/cm.

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**Table 1.** Leachate pH and EC values, growth data, and number of chlorotic leaves from ‘Osaka Red’ ornamental cabbage plants subjected to irrigation treatments. Data taken 4 weeks after treatments began.

| Treatment[z] | pH | EC (mS/cm) | Plant height (cm) | Plant diameter (cm) | Color diameter (cm) | No. of chlorotic leaves |
|---|---|---|---|---|---|---|
| CLF with SRF | 6.1 | 0.4 | 20.0 | 49.0 | 13.2 | 2 |
| CLF | 6.2 | 0.5 | 18.5 | 44.4 | 17.2 | 2 |
| SRF | 6.6 | 0.1 | 12.3 | 42.4 | 15.2 | 5 |
| NF | 6.5 | 0.2 | 13.3 | 42.4 | 14.5 | 8 |
| Significance[y] | *** | *** | *** | * | NS | *** |
| LSD ( $\leq$ 0.05) | 0.12 | 0.09 | 2.88 | 3.64 | — | 1.48 |

[z] CLF = continual liquid fertilization;
SRF = slow release fertilizer;
NF = no fertilizer (only tap water applied)
[y] NS, ***, * Significant at the *P* $\leq$0.001, 0.05, respectively.

# Starter Fertilizer and Plant Water–Use Can Modify Fertilizer Requirements

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**Index words:** Begonia*, Begonia semperflorens*, electrical conductivity, EC, Water-Use-Efficiency

**Nature of Work:** Subirrigation systems have become more popular in recent years due to zero runoff and increased efficiency in fertilizer and water use (1). As leaching from the growing medium is practically absent in subirrigation, starter fertilizer can remain in the growing medium for a longer period and affect fertilizer requirements by supplying a substantial amount of nutrients to plants. A change in plant water use can also affect fertilizer requirements of subirrigated plants. To assure that the appropriate amount of nutrients is applied, plants consuming a relatively large amount of water to produce one gram of dry matter (or low water use efficiency, WUE) should be fertilized with a lower concentration of fertilizer than plants which use water more efficiently. The required N concentration in the fertilizer for optimum tissue N ($N_{FERT}$, in ppm or mg/L) can be calculated as the desired tissue N concentration (in mg/g) times the WUE (in g/L).

As light intensity affects WUE due to its effect on growth and transpiration in plants, changes in light intensity can affect optimum fertilizer concentration of plants. Surprisingly, there is only one research report on the effect of WUE on optimum fertilizer concentrations of subirrigated plants (2). We hypothesized that a change in light intensity would affect WUE and thus the optimal fertilizer concentration of subirrigated plants.

Plug seedlings of Wax begonia ‘Cocktail vodka’ were obtained from a commercial grower and transplanted into 4 inch containers filled with soilless growth medium (Fafard 2P mix), with or without (leached with tap water) starter fertilizer. The average electrical conductivity (EC) of these media was 2.1 and 0.9 mS/cm, respectively. After transplantation, seedlings were placed on 4' x 8' ebb and flow benches, and subirrigated with fertilizer solutions made from Peter’s 20 10 20 Peat Lite Special. Two groups of plants (with and without starter fertilizer), consisting of 30 plants each, were grown under three different light intensities (63, 35 and 0 percent shade resulting with an average photosynthetic photon flux of 4.4, 6.2 and 9.8 mol/m$^2$/day, respectively) and subirrigated with one of the four fertilizer concentrations (0, 50, 130, or 210 ppm N, corresponding ECs of 0.15, 0.33 , 0.86 and 1.4 mS/cm, respectively). Shoot dry weight, leaf area, flower number, $N_{FERT}$, and WUE of plants were measured at the end of the experiment. To determine water use efficiency, net photosynthesis and dark respiration ($P_n$ and $R_d$, expressed in mol/s) were measured using a whole plant gas exchange system (3). Water lost in evapotranspiration (ET) was measured as the difference in the weight of the pots before and after the gas exchange measurements. Growth rate (GR) was calculated as follows:

$$GR = (P_n \times t_{light} - R_d \times t_{dark}) \times 0.0036 \times 12 / f_c,$$

where $t_{light}$ and $t_{dark}$ are the durations of light and dark period (in hours), the factor 0.0036 converts mol/s to mol/h, 12 converts moles of carbon to grams of carbon, and $f_c$ = carbon content of the plants (in g/g, converts g of C to g of dry matter). Water use efficiency (grams of dry matter per liter of water lost in ET, expressed in g/L ) was calculated as WUE = GR/ET.

The treatments were organized in a split-split plot design with three replications. Data were subjected to ANOVA and regression analysis with $P < 0.05$ considered to be statistically significant. To describe the effect of increasing light intensity (light) and fertilizer concentration (ppm) on the plants, we fitted the following polynomial regression with an interaction term:

$$Y = \beta_0 + \beta_1 \times ppm + \beta_2 \times light + \beta_3 \times ppm^2 + \beta_4 \times light^2 + \beta_5 \times ppm \times light,$$

where Y is the dependent variable of interest and $\beta_1 \ldots \beta_5$ are regression coefficients. The fitted polynomial regression was reduced further by backward selection ($P < 0.05$).

**Results and Discussion**: When the growing medium contained a starter fertilizer, shoot dry weight did not respond to increasing fertilizer concentration, but without a starter fertilizer, dry weight responded quadratically with increasing fertilizer concentration (Fig. 1A). Maximum growth was obtained with fertilizer concentrations of 130 to 210 ppm, independent of light intensity. Leaf area and number of flowers per plant responded similarly (data not shown).

There was an interactive effect of light intensity and fertilizer concentration on WUE and $N_{FERT}$ of plants (Fig. 1B). Water use efficiency and $N_{FERT}$ were higher for plants grown at 9.9 mol/m$^2$/day than for those at 6.2 or 4.4 mol/m$^2$/day, especially at high fertilizer concentrations. Treatment effects on WUE and $N_{fert}$ suggest that plants at high light intensity should be grown with higher fertilizer concentrations. However, this was not confirmed by the treatment effects on dry weight or leaf area of the plants. Those data indicated that the optimal fertilizer concentration was the same at all light intensities (130 - 210 ppm N in a growing medium without starter fertilizer). The absence of an interactive effect of fertilizer EC and light intensity on dry weight or leaf area indicates that the fertilizer concentration does not need to be adjusted based on light intensity. Based on our findings, begonias should be fertilized with 130 - 210 ppm N (equivalent to an EC of 1.2 mS/cm) if the growing medium does not contain a starter fertilizer, while low concentrations (about 50 ppm N) can be used for media with a starter fertilizer.

**Significance to Industry:** Quality of bedding plants greatly depends on the supplied fertilizer concentration. Subirrigated wax begonias can be produced with very little fertilizer if the growing medium contains a starter fertilizer. This would also reduce potential toxic effects of excess fertilizer, which could reduce plant quality and result in a monetary loss. If the growing medium does not contain a starter fertilizer, concentrations of 130-210 ppm should be used. These concentrations do not need to be adjusted based on light intensity.

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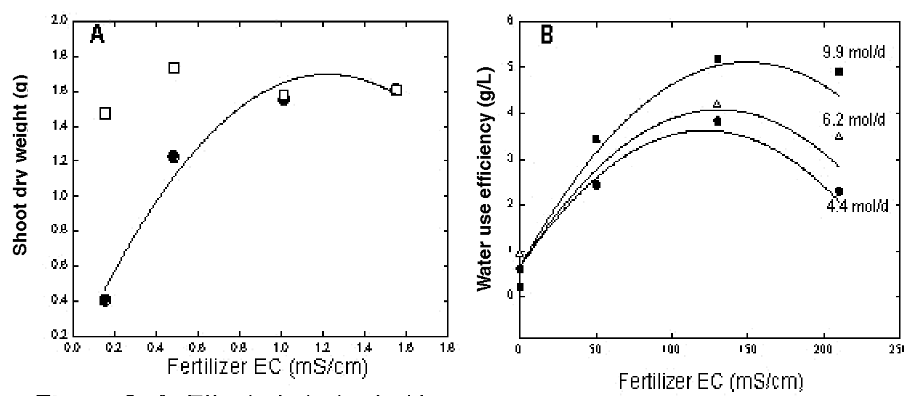


**Figure 1.** A. Effect of starter fertilizer a
tion on shoot dry weight of subirrigated wax begonias at the end of experiment, '•' indicates without starter fertilizer and '^' indicates with starter fertilizer. B. Effect of light intensity and fertilizer concentration on water use efficiency of wax begonias at the end of the experiment. The lines indicate a significant quadratic effects.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 4.4 | 0.03 | 0.05 | 63 | 0.04 | 0.61 | 27 |
| 0 | 6.2 | 0.04 | 0.08 | 71 | 0.07 | 0.94 | 42 |
| 0 | 9.9 | 0.05 | 0.06 | 123 | 0.04 | 0.21 | 10 |
| 50 | 4.4 | 0.09 | 0.31 | 146 | 0.35 | 2.44 | 110 |
| 50 | 6.2 | 0.09 | 0.44 | 162 | 0.55 | 3.43 | 154 |
| 50 | 9.9 | 0.13 | 0.52 | 190 | 0.62 | 3.43 | 154 |
| 130 | 4.4 | 0.09 | 0.41 | 139 | 0.53 | 3.84 | 173 |
| 130 | 6.2 | 0.12 | 0.54 | 168 | 0.71 | 4.18 | 188 |
| 130 | 9.9 | 0.21 | 0.76 | 179 | 0.92 | 5.19 | 234 |
| 210 | 4.4 | 0.10 | 0.30 | 162 | 0.34 | 2.31 | 104 |
| 210 | 6.2 | 0.16 | 0.55 | 193 | 0.66 | 3.48 | 157 |
| 210 | 9.9 | 0.21 | 0.77 | 200 | 0.94 | 4.92 | 222 |
| results | intercept | 0.05*** | 0.080* | 42^NS | 0.070^NS | 0.65* | 29.5* |
| | ppm | NS | 0.004*** | 1.06** | 0.006*** | 0.041*** | 1.86*** |
| | ppm$^2$ | -0.000002* | -0.00002*** | -0.003* | -0.00003*** | -0.0002*** | -0.0090*** |
| | light | NS | NS | 7.94* | NS | NS | NS |
| | ppm x light | 0.0001*** | 0.0004*** | NS | 0.0005*** | 0.002*** | 0.097*** |

# Use of Arcillite to Buffer Nutrient Loss from Container-grown Chrysanthemum

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**Index Words:** Fertilization, Substrate, Water Quality

**Nature of Work:** Arcillite is a processed montmorillonite and illite clay that is used as a substrate in studies where the roots of containerized plants must be recovered without damage or substrate adherence (2,3,5). Arcillite has also been used as an amendment to other substrates, since heterogeneous substrates offer the combined advantages of their components. Specifically, an optimal substrate has good aeration and high water-holding and nutrient-holding capacities. When arcillite was combined with other substrates, available water holding capacity was increased (4,7). Substrate ammonium, phosphorus and potassium concentrations also increased with increasing arcillite, suggesting that arcillite improved nutrient retention (7). Growth of smooth Arizona cypress grown in arcillite was maximized at a low concentration (20 ppm) of nitrogen (6). Arcillite incorporated into a peat-based substrate at 10 or 20% (v/v) reduced discharge of excess nutrients from container-grown chrysanthemum without reducing plant quality (1); however, it reduced plant height and dry weight. The objective of this study was to determine whether various placements of arcillite in a peat-based substrate can decrease discharge of excess nutrients from containers without limiting growth and quality of chrysanthemums.

Rooted cuttings of ‘Dark Bronze Charm’ chrysanthemum [*Dendranthema* x *grandiflorum* (Ramat.) Kitamura ‘Dark Bronze Charm’] were grown in 15 cm (6 inch) azalea containers according to standard commercial practices in a glass greenhouse. A peat-based commercial substrate (Fafard 2, Conrad Fafard Inc., Agawam, MA) was used alone or amended with 10% (v/v) (100 lb/yd$^3$) arcillite (Turface MVP, AIMCOR Consumer Products, Buffalo Grove, IL). Arcillite was either layered at the bottom of the container or incorporated throughout the substrate (Figure 1). Fifty-four plants were laid out in a randomized complete block design with 6 replications. All plants received a topdressing of 12 g (0.4 oz) Osmocote 14N-6.0P-11.6K (14-14-14, 3-4 mo.) controlled release fertilizer (The Scotts Co., Marysville, OH) at potting. Containers were irrigated with tap water when they dropped to 40% of container capacity (determined by weight), and a precalculated volume of water was applied to ensure 20% discharge. Container leachate was collected at each irrigation and analyzed for electrical conductivity and pH. Final growth data, which included plant size and weight data and a visual quality rating, was collected 11 weeks after potting, and then shoot tissue nutrient concentrations were determined. Data were adjusted to compensate for tissue dilution effects.

**Results and Discussion:** Quality of the finished crop, plant height and plant width were comparable among the substrates tested (data not shown). However, shoot dry weight was reduced when arcillite was layered at the bottom of the container. Since nutrient analysis data reveal no nutrient deficiencies for plants with arcillite at the bottom of the container, reduced shoot growth was likely due to altered pore size distribution within substrate. Large particles at the bottom of a container can result in decreased drainage and reduced air space in the root environment.

Nutrient discharge (measured as electrical conductivity) decreased by up to 14% with arcillite early in the crop growth cycle, suggesting that arcillite particles provided some nutrient adsorption. Potassium levels were higher in mature shoots of plants grown with incorporated arcillite, similar to findings with other crops (7). The same trend was exhibited for manganese. However, a reverse trend was exhibited with zinc and iron. Although these data suggest specific changes in plant nutrient uptake due to the chemical properties of arcillite, these changes may be distinct from altered physical properties caused by arcillite. More data are needed on how substrate chemical and physical properties affect plant nutrient uptake and discharge of excess nutrients.

**Significance to Industry:** Arcillite incorporated into a peat-based substrate reduced discharge of excess nutrients from container-grown chrysanthemums early in the production cycle without negative effects on plant growth or quality. Arcillite can buffer against nutrient loss from containers when nutrient supply exceeds demand. The use of substrate amendments that improve nutrient and water holding capacity, along with other best management practices, enables crops to use fertilizers and irrigation water efficiently, thereby protecting water resources.

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# Effects of Irrigation Water Alkalinity on Nutrient Availability and Foliar Nutrient Levels in Thyrallis (*Galphimia glauca*)

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**Index Words:** Alkalinity, Carbonates, Bicarbonates, pH, Irrigation, Acid Injection, Plant Nutrition

**Nature of Work:** Dissolved carbonates and bicarbonates are the major contributors to alkalinity in irrigation water sources. Irrigation water alkalinity (i.e., buffering capacity), not pH, has the major influence on media solution chemistry. Groundwater sources in Florida typically contain carbonates ($CO_3^{2-}$) and bicarbonates ($HCO_3^-$) of calcium and magnesium. Such water is also referred to as being "hard". Repeated application of high alkalinity water (i.e., bases/liming materials) may cause media solution pH to rise, subsequently altering nutrient availability/nutrient balance, and possibly leading to the development of nutrient disorders. Current recommendations for correcting high irrigation water alkalinity are to either neutralize to an end-point alkalinity (80% neutralization of bases is recommended), or to an end-point pH (pH 5.8 is recommended) by acidification with sulfuric, nitric, or phosphoric acid (Kidder and Hanlon, 1997; Baily, 1996).

A commercial nursery located in Fort Pierce, Florida identified a production problem with Thyrallis. A general pattern of interveinal chlorosis would often develop on leaves of plants in 3 gal containers after several months in production, requiring supplemental applications of slow-release fertilizers to correct the problem. Media and leaf tissue analyses of affected plants revealed a pH greater than 6.0, and a nutrient imbalance, particularly for micronutrients, respectively. The irrigation water source for this nursery contains a high level of carbonates and bicarbonates (Table 1). To investigate this problem, we conducted a short-term (2 month) preliminary study to begin to assess (objectives) the effects of alkalinity level on media solution chemistry, and on foliar nutrient levels in Thryallis using plant material, media, and water from the commercial nursery.

Thryallis, originally established in 4 inch pots, were transplanted into 3 gal containers filled with a peat:aged pine bark:sand (1:1:0.2) media, incorporated with a 30-45 day slow-release N-P-K fertilizer. Plants were grown in a greenhouse maintained at venting/heating temperatures of 85/74 °F (29.4/23.3 °C). Osmocote 19-6-12 (N-P-K) (Scotts-Sierra Horticultural Products Co., Marysville, OH) was applied to the media surface at the rate of 0.46 oz/pot (13g/pot) 34 days after transplanting/ start of the experiment. Irrigation water was collected from a 60 ft-deep well used for irrigation on a commercial nursery in Ft. Pierce, Florida (see Table 1 for chemical analysis). Alkalinity level was estimated by titration with 0.1N sulfuric acid using the indicator bromocreosol green to a pH end point of 4.0 (green to yellow indicator color change) (method 2320B, Standard Methods for the Examination of Water and Wastewater, 1995). Alkalinity was neutralized to an end point alkalinity of 0% (control) or 80% with sulfuric acid (94%), and treatments (800 ml) were applied every other day. Plants were arranged in a complete randomized design with 6 replications per treatment. At harvest, 56 days after transplanting, dry weight of leaves were recorded, and filtered media extracts, collected by the 1:2 dilution method (200 ml media and 400 ml distilled-deionized water, 45 min incubation), were analyzed for pH, electrical conductivity (EC), and elements. Leaves were analyzed for nutrients after processing via microwave digestion. Phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), and sodium (Na) were determined by inductively couple plasma (ICP), and nitrogen (N) by dynamic flash combustion and GC separation.

**Results and Discussion:** Media receiving water that was 80% neutralized had higher levels of Ca, Mg, and P, and lower levels Fe and Mn relative to the 0% neutralization treatment (Table 2). The concentrations of other nutrients (K, Cu, and Zn) were not significantly different between treatments (Table 2). Media pH was 0.6 units lower and EC level 0.15 dS/cm higher in the 80% than 0% neutralization treatment (Table 2). Acceptable media pH for the production of most nursery crops is 5.0 to 6.0 (Yeager et al., 1997). The pH in the 0% treatment (6.02) was at the upper limit of this range (Table 2). Neutralizing alkalinity/acidifying irrigation water (80% treatment) maintained a pH (5.42) well within the acceptable pH range for most nursery crops (Table 2).

Treatments did not significantly affect leaf dry weight, averaging 6.63 g per plant (data not shown). Foliar nutrient concentration was not different between treatments except for Mn, which was nearly 2-times greater in the 80% than 0% treatment (Table 3). Although, foliar Mn and Fe concentrations in both treatments were at levels considered “low” for most nursery crops (Yeager et al., 1997), leaves in both the 0% and 80% alkalinity neutralization treatments appeared normal with no visible signs of Fe or Mn deficiencies. Foliar N, P, K, Ca, Mg, Zn, and Cu were at levels generally considered “sufficient” for most nursery crops (Yeager et al., 1997) (Table 3).

**Significance to Industry:** Repeated application of irrigation water containing carbonates and bicarbonates will cause media pH to rise, subsequently altering the balance of nutrients available to the plant (Mn in this preliminary study). Acidification of irrigation water with acid will neutralize alkalinity and maintain media pH at levels acceptable for the production of most nursery crops.

**Acknowledgement:** Authors thank Martin R. Kinnamon for technical assistance.

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**Table 1.** Elemental concentration, pH, electrical conductivity (EC), and alkalinity ($CaCO_3$) of well water collected from a 60 ft-deep well used for irrigation on a nursery in Ft. Pierce, Florida. Well water was acidified with sulfuric acid to neutralize alkalinity 0% or 80% (Trt). Values are means of nine water samples collected weekly over a period of nine weeks, ± standard error.

| | Elements (ppm$^z$)$^y$ | | | | | | $CaCO_3$ | |
|---|---|---|---|---|---|---|---|---|
| Trt | Ca | Mg | K | Na | pH | EC (dS/cm) | me/L$^x$ | ppm |
| 0% | 99.5 ± 3.7 | 7.8 ± 0.3 | 3.0 ± 0.6 | 37.4 ± 0.3 | 7.6 ± 0.1 | 0.68 ± 0.04 | 5.2 ± 0.0 | 260 ± 0 |
| 80% | —- | —- | —- | —- | 4.7 ± 0.2 | 0.74 ± 0.19 | —- | —- |

$^z$1 ppm = 1 mg/L
$^y$Nutrients P, Fe, Mn, and Zn were at levels less than 0.1 ppm in water.
$^x$milliequivalents per liter of $CaCO_3$. 1 me/L $CaCO_3$ = 50.04 mg/L $CaCO_3$.

**Table 2.** Nutrient concentration, pH, and electrical conductivity (EC) of the filtered media extracts collected from a 1:2 dilution method on media from the 0% and 80% alkalinity neutralization treatments (Trt) at harvest, 56 days after initiating treatments. Values are means of six extracts.

| | Nutrients (ppm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Trt | Ca | Mg | K | P | Fe | Mn | Cu | Zn | pH | EC (dS·cm$^{-1}$) |
| 0% | 12.23b$^z$ | 4.02b | 5.15a | 4.15b | 0.77a | 0.05a | 0.01a | 0.04a | 6.02a | 0.20b |
| 80% | 27.18a | 9.20a | 6.32a | 4.71a | 0.40b | 0.03b | 0.01a | 0.05a | 5.42b | 0.35a |

$^z$Mean separation within columns by LSD, $P \leq 0.05$.

**Table 3.** Leaf nutrient concentration for the 0% and 80% alkalinity neutralization treatments (Trt) at harvest, 56 days after initiating treatments. Values are means of six samples.

| | Macronutrients (%) | | | | | Micronutrients (ppm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Trt | N | Ca | Mg | K | P | Fe | Mn | Cu | Zn |
| 0% | 2.36a[z] | 1.54a | 0.38a | 1.87a | 0.34a | 37.24a | 32.39b | 4.87a | 29.87a |
| 80% | 2.43a | 1.43a | 0.38a | 1.77a | 0.33a | 45.01a | 60.37a | 4.52a | 32.73a |

[z]Mean separation within columns by LSD, $P \leq 0.05$.

# Mycorrhizal Fungi and Slow Release Fertilizer Source Influence the Growth and Development of Bush Morning Glory (*Ipomoea carnea*)

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**Index Words:** Arbuscular Mycorrhiza, Colonization, Organic & Inorganic Slow Release Fertilizer, Plant Growth

**Nature of Work**: This study investigated the utilization of arbuscular mycorrhiza fungi (*AMF*) to enhance the efficiency of slow release organic and inorganic fertilizers during container production of bush morning glory (*Ipomoea carnea*). Uniform rooted liners of *Ipomoea carnea* were planted into 2-gallon (9.6 L) pots containing a pasteurized soilless medium [3:1 (v/v) pine bark to sand]. The mycorrhizal treatments consisted of two commercial *AMF* inocula: Bioterra Plus and Mycorise Pro, and a noninoculated control [*NonAMF*]. Fertilizer treatments included an organic slow release fertilizer [SRF] (Nitrell; 5N-3P-4K) and an inorganic SRF (Osmocote; 18N-7P-10K). Nitrell was tested at three levels: 8.4 kg $m^{-3}$ (14 lb $yd^{-3}$), 12 kg $m^{-3}$ (20 lb $yd^{-3}$), and 16.8 kg◊$m^{-3}$ (28 lb $yd^{-3}$), which were, respectively, 70%, 100% and 140% of the manufacturer's recommended rate. Osmocote was tested at two levels: 6 lb $yd^{-3}$ (3.5 kg $m^{-3}$) and 12 lb $yd^{-3}$ (7.0 kg $m^{-3}$) which were, respectively, 50% and 100% of the recommend rate. With organic and inorganic SRF, both mycorrhizal inocula significantly enhanced the marketability, growth index, root, leaf, shoot and total plant dry mass of bush morning glory. The greatest growth response occurred with the highest level of Osmocote colonized with Bioterra Plus. The mycorrhizal enhanced growth response was in part due to greater N, P, K, B, Fe and Mn uptake. Organic and inorganic SRF regimes did not inhibit mycorrhizal development, which ranged from 12% to 27% colonization.

The incorporation of new production systems to reduce fertilizer and pesticide usage without reducing plant quality is one of the most important challenges facing the nursery industry. The utilization of best management practices (BMP) such as recycling irrigation water, increased slow release fertilizer usage and biological pest control are some of the practices that the nursery industry has implemented. There is much potential in utilizing arbuscular mycorrhiza fungi (*AMF*) in nursery production systems since *AMF* enhance plants nutrient and water relations (Davies et al., 1996; Nelsen, 1987, Smith and Read, 1997), and increase plant tolerance to environmental stress (Davies et al., 2000). *AMF* can also increase disease resistance (Linderman, 1992), increase photosynthesis and plant vigor (Aguilera-Gomez et al., 1999), and reduce transplant stress (Sylvia et al., 1998) — all benefits that enhance crop production value.

The objective of this research was to demonstrate that *AMF* can enhance the efficiency of organic and inorganic SRF, therefore improving growth and marketability of ornamental plants during production. A long term goal in utilizing *AMF* is to enhance fertility efficiency, minimize environmental pollution during production, and increase plant marketability.

**Results and Discussion**: With organic (Nitrell) and inorganic (Osmocote) SRF, both commercial *AMF* inocula significantly enhanced the growth, nutrient uptake and marketability of bush morning glory. Plants colonized with Bioterra and Mycorise Pro had a greater growth index, root, leaf, shoot and total plant dry mass, regardless of the SRF source. The greatest total dry mass accumulation was obtained at the highest level of inorganic SRF. While P levels were equilibrated between the organic-140% and inorganic-100% SRF, the nitrogen levels of inorganic SRF were higher, which in part led to the greater growth response. The organic-150% depressed plant growth compared to the 70% and 100% recommended levels.

There were higher yields (shoot, root and leaf dry mass, and leaf area) with the commercial SRF recommended levels (inorganic-100%) followed by inorganic-50% and organic-70%. The greatest growth response was obtained with Bioterra commercial inoculum with inorganic-100% at the commercial nursery recommended level of 12 lb $yd^{-3}$ (7.0 kg $m^{-3}$). These results are promising since under commercially recommended fertility levels, the addition of mycorrhiza can improve plant growth.

Plant biomass and growth index increased as the levels of inorganic SRF increased. With organic-70% plants colonized with *AMF* had a greater total plant mass and growth index than plants at 100% and 140% of the recommended rate. The lowest plant dry weight for *AMF* treatments was the SRF organic-140 %. Growth depression at the higher rate was likely due to ammonium stunting plant growth.

When comparing *AMF* within a reduced inorganic SRF level (Osmocote-50%), Bioterra increased the total plant dry mass of bush morning glory two fold [(2X) (21 g)] and Mycorise Pro increased the total dry mass more than three fold [(3X) (32 g)] compared to *NonAMF* plants [10g].

In general, total leaf elemental status of Bioterra Plus and Mycorise Pro *AMF* plants were significantly higher than *NonAMF* plants. Leaf tissue N, P, K, B, Fe and Mn were highest at inorganic-100% SRF compared to any level of the organic SRF. *NonAMF* plants fertilized with organic SRF had greater leaf tissue N, P, K, B, Fe and Mn at 100% than 70% or 140% of the recommended levels. When colonized with Bioterra Plus, organic-70% SRF had greater elemental uptake than either the 100% of 140% levels. Mycorise Pro colonized plants treated with the organic SRF had similar P and K regardless of fertility level, however, high organic fertility levels depressed leaf N, B and Mn.

Mycorrhiza colonization among inoculated treatments was high, ranging from 12% to 27 %. The higher fertility rates for organic and inorganic fertilizer did not depress *AMF* colonization. These results suggest that the commercial isolates under study are able to survive, colonize and be effective in a commercial nursery container production system.

The overall improved plant growth of selected *AMF* and SRF treatments was also reflected in the marketability of plants evaluated after 56 days of container growth (just prior to terminating the experiment). Marketable plants had compact growth, dark green leaf color, good branching, and the presence of blooms or floral buds. Plants that did not meet this criterion were considered nonmarketable (nonsalable). Mycorrhizal plants were more marketable among all SRF treatments. In general, *AMF* plants fertilized with inorganic SRF were more marketable than with organic SRF. Bioterra at 50% and 100% inorganic SRF, and Mycorise Pro at inorganic-100% SRF had the greatest number of marketable plants. This is an important result since mycorrhiza inoculation can effectively reduce fertilizer inputs, i.e. high marketability occurred with *AMF* treated plants at 50% of the recommended inorganic and 70% of the organic SRF.

**Significance to Industry:** There are excellent opportunities to incorporate arbuscular mycorrhizal (AMF) in nursery production systems that help reduce fertility and pesticide usage, and enhance crop vigor, productivity, and plant survival rates during transplanting to field conditions. *AMF* and inorganic and organic SRF fertilizer regimes increased overall plant growth (plant root, leaf, shoot and total dry mass) and marketability of container-grown bush morning glory. Mineral elemental status of colonized plants was significantly higher than *NonAMF* plants. *AMF* enhanced growth response was in part due to greater N, P, K, B, Fe and Mn uptake. Both commercial inocula were able to survive and be effective in improving the growth and development of containerized plants at even the highest level of fertility. *AMF* also enhanced the growth and marketability of inorganic and organic SRF at lower than recommended fertility levels – hence the potential to lower fertility inputs and still maintain high marketability.

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# Day/Night Temperature Effects on Growth of Selected Herbaceous Perennials

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**Index Words:** average daily temperature, diurnal temperature range, *Delphinium*, *Rudbeckia*

**Nature of Work:** It is widely believed among researchers and growers that optimal temperature conditions for plant growth require night temperature to be lower than day temperature. This belief originated with Went (5), who proposed the term “thermoperiodism” to designate the hypothesized increase in growth under diurnal temperature cycling, as opposed to constant temperature. His research on the subject, however, is difficult to interpret for two reasons. First, all of Went’s experiments were conducted using 8 hr days and 16 hr nights (5, 6). Therefore, average daily temperature and day/night differential can be calculated with equal validity on the basis of either temperature settings for each period, or total heat input over the duration of each period. Those two approaches lead to completely divergent conclusions. Second, data reported consisted of stem length, fruit yield, and other developmental or morphological measurements that may or may not be representative of total plant productivity (5, 6). Some critics of Went (1, 3, 4) subsequently conducted experiments where the primary measurement of growth was dry weight (DW), and the diurnal temperature cycle was equally divided into two 12 hr periods. Conclusions regarding the benefits of diurnal temperature cycling varied greatly with plant species. However, no attempt was made in these studies to characterize the response of plant growth beyond the presence or absence of an effect of diurnal temperature differential.

In floriculture, it has been shown that for many species, increasing late night temperature above day temperature, a technique referred to as DIF, alters morphology by reducing internode length (2). However, an exhaustive survey of the literature reveals that, of the few studies of DIF where growth data (DW) were reported, none included enough temperature combinations to reach any conclusions with regards to the response of DW to more than a narrow range of differentials.

Furthermore, increased interest in herbaceous perennials and movement of segments of the United States population to warmer regions of the country have resulted in more perennial taxa being cultivated in regions where summer temperature is above their tolerance. At the same time, some species appear to be capable of much broader adaptation. In the continental United States, the main gradient of diurnal temperature range (day-night difference) lies in an east-west direction, in contrast to the north-south gradient followed by average daily temperature. Little is known currently of the effect of diurnal temperature range on the growth of perennials, in the landscape and in production. Therefore, the objectives of this study were to establish whether any advantage can be gained from optimizing day/night temperature difference during production of selected herbaceous perennials, and to determine the potential impact of variations in diurnal temperature range between regions of the country.

On April 25 , 2001, 270 transplants each of *Delphinium* X *cultorum* Voss 'Magic Fountains' ('Magic Fountains' delphinium) and *Rudbeckia fulgida* var. *sullivantii* L. 'Goldsturm' ('Goldsturm' black-eyed susan) were potted in 3 qt (#1) containers filled with a substrate of 8 composted pine bark : 1 sand (by vol.) amended with 2 lb/yd$^3$ dolomitic lime. Following acclimation in a heated greenhouse, the plants were transferred to six growth chambers set at constant temperatures of 50, 59, 68, 77, 86, or 95°F, and treatments were initiated on May 17. The experiment was in a completely randomized design with a factorial arrangement of the following eighteen 12 hr day/12 hr night temperature combinations, and fifteen plants of each species per treatment:

| $T_{day}$ (°F) | 50 | 50 | 50 | 59 | 59 | 59 | 68 | 68 | 68 | 77 | 77 | 77 | 86 | 86 | 86 | 95 | 95 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_{night}$ (°F) | 50 | 68 | 86 | 59 | 77 | 95 | 50 | 68 | 86 | 59 | 77 | 95 | 50 | 68 | 86 | 59 | 77 | 95 |

Temperature combinations were achieved by moving plants to appropriate chambers at the beginning and end of the 12 hr photoperiod. Plants were fertigated as needed with a complete nutrient solution providing N at 106 ppm. Ninety plants of each species were harvested after 13, 34, and 55 days. At each harvest, leaf count and leaf area were recorded in addition to leaf, stem, flower, and root DWs after at least 96 hr of drying at 158°F. Data were subjected to analysis of variance, and fitted with response surfaces. Data presented hereafter consist of total plant DW after 55 days of treatment.

**Results and Discussion:** Plant growth responded independently to both day and night temperature, or alternatively to average daily temperature and day/night difference (Fig.1). These effects were present whether constant temperature was optimum, as in delphinium, or not, as in black-eyed susan. The range of day  temperatures at which delphinium and black-eyed susan reached 90% of maximum growth was equally broad, but almost 18°F lower for delphinium. Optimal night temperature was remarkably similar for both species in value and in range. Given the much smaller geographic range suitable for cultivation of the former, this suggests that summer temperature is only one of several relevant climatic factors. In this case, most regions with temperatures suitable for delphinium in the growing season, experience minimum yearly temperatures that are below the tolerance of that species.

**Significance to Industry:** Results demonstrated that average daily temperature is insufficient to determine the range of adaptation of particular herbaceous perennial species. Both day and night temperatures are necessary. They should also both be controlled during production. Delphinium and black-eyed susan would be expected to reach 90% of maximum size when grown within 10 to 20°F of both optimal day and night temperature.

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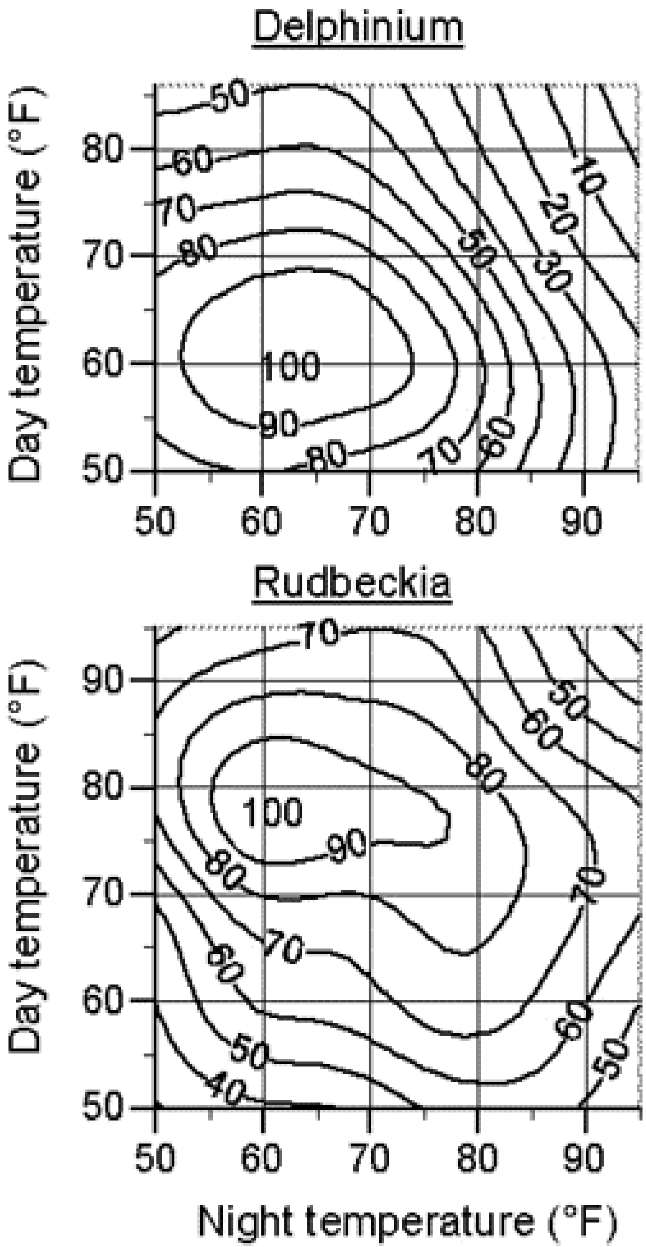


**Fig. 1.** Total plant DW after 55 days. Contour lines are percentages of maximum vaues

## Impact of Chilling on Budbreak of *Ginkgo biloba* L.

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**Index Words:** Dormancy, Rest, Ornamental Trees

**Nature of Work:** *Ginkgo biloba* L. is an ornamental tree of prominence and value in the green industry. Often referred to as a 'living fossil', *G. biloba* grows well in USDA Hardiness Zones 3 through 9 (5), reaching a mature height up to 80' tall and 40' wide. With a slow to medium growth habit, trees are often pyramidal when young and become wide spreading when older. *G. biloba* is insect and disease resistant making it an excellent choice for a city tree with over 40 cultivars available (3). Most studies with *G. biloba* have been for medicinal purposes (4). Though much work has been done with fruit species with respect to dormancy and chilling requirements (1, 2), no work has been reported regarding chilling requirements with *G. biloba*. Chilling units are generally based on the number of hours accumulated below 45°F. The objectives of this study were to determine chilling and dormancy requirements for this species in order to increase production efficiency.

Eighteen-inch tall seedlings of *G. biloba* were obtained from Musser Forest, Inc. (Indiana, PA) in 1999. Trees were potted into 1, 2 and 3-gal nursery containers for years one, two and three respectively, using a standard 6:1 pine bark:sand mixture amended with dolomitic limestone, Micromax (The Scotts Co., Marysville, Ohio), and 18-6-12 Osmocote (The Scotts Co.). Thirteen treatments were used with 100 chill hour increments. Treatments 0 -12 represent 0 - 1200 total chill hours accumulated. There were 12 single tree replications per treatment. Treatment 0 was placed into a greenhouse maintained at a minimum of 72°F before accumulating any chill hours. On December 21, 2001, treatment 1 was placed into a greenhouse upon receiving 100 ambient chill hours. Upon receiving 200 ambient chill hours (December 28, 2001), which allowed trees to defoliate naturally, treatment two was placed into the greenhouse. Trees receiving 300-1200 total chill hours were then placed into a cooler maintained at 38°F until desired forced chilling was accumulated. At the appropriate times, trees were removed from the cooler and placed into the greenhouse. Plants were monitored twice weekly for foliar budbreak for approximately 17 weeks. At termination of study all trees were measured for total percent budbreak, new shoot extension, number of limbs and average length of each limb. Statistical analysis was conducted using ANOVA by Duncan's Multiple Range Test and regression. All work was conducted at the Paterson Greenhouse Complex in Auburn, Alabama.

**Results and Discussion:** Increasing the number of chill hours led to a decreased amount of time required inside the greenhouse to reach 50% foliar budbreak. In most cases, increased chilling produced a higher percent foliar budbreak. Over the period of the study, trees receiving 800, 1100, 1000 and 900 chill hours respectively, were the first to reach the point of 50% foliar budbreak. Trees receiving 100, 200, 300 and 400 chill hours were consistently the slowest, and trees receiving less than 300 total chill hours never reached a point of 50% foliar budbreak in two of three years. Chilling not only increased percent foliar budbreak overall, but also allowed the trees to do so at a faster rate (Fig. 1). After the eleventh date for bud counts (March 3, 2002), budbreak percentages for all treatments leveled off (Fig. 1), after which budbreak percent responded quadratically with increasing chill hours (Fig. 2). That is, budbreak percent increased with increasing chill hours up to around 1000 hours. Trees that were in the cooler for an extended period of time were able to reach the point of 50% foliar budbreak with less accumulated time inside the greenhouse. This was evident with trees receiving 800 – 1100 chill hours when compared to all other treatments.

**Significance to the Industry:** This work shows chilling to be a determinate factor in foliar budbreak of *G. biloba*. Increased chilling led to a decreased heat requirement to initiate budbreak. For growers producing *G. biloba* liners in greenhouses, adjusting environmental conditions to allow chilling can accelerate and lead to more efficient production for container grown *G. biloba*. As for field or outdoor production, while it is possible to produce *G. biloba* in USDA Hardiness Zones 3 through 9, our work indicates trees may reach a profitable size more rapidly in regions that accumulate greater than 800 hours of chilling.

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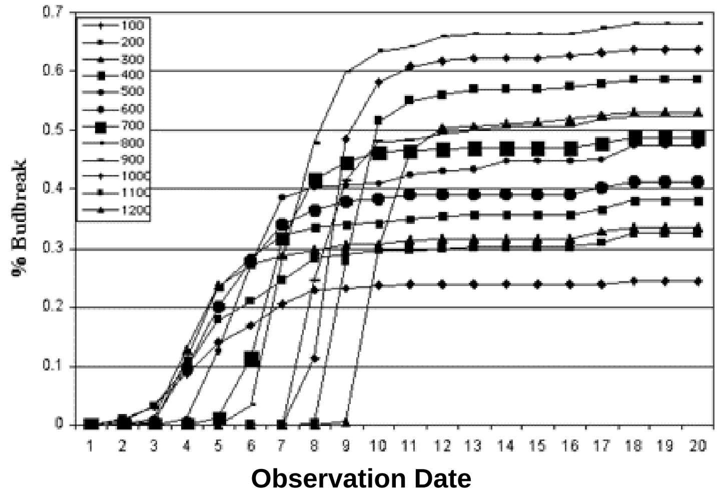


**Figure 1.** *Ginkgo biloba* budbreak percentage over time in response to chilling.

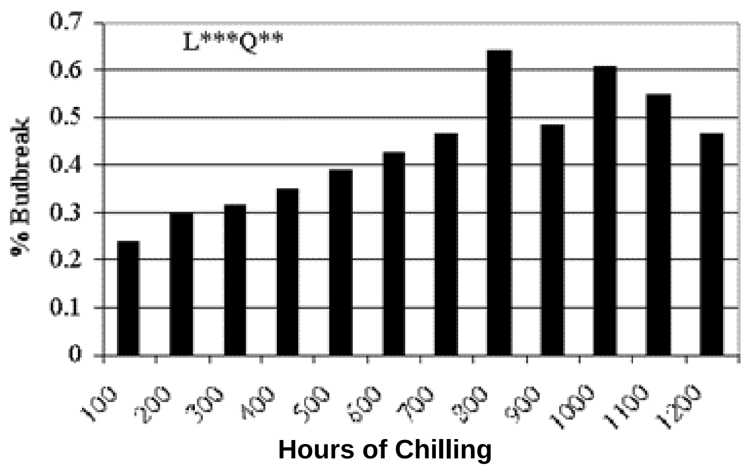


**Figure 2.** *Ginkgo biloba* budbreak response to chilling where trees were placed incrementally into heated greenhouse following each 100 hours of forced chilling with heat accumulation greater for trees receiving less chilling on any given observation date (March 3).

# Effect of Media Type on the Growth of Container-Grown Woody Ornamentals

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**Index Words:** Container, Media, *Azalea* 'Hershey's Red', *Euonymus alatus*, *Ilex glabra*

**Nature of Work:** Retailers and growers in Arkansas have several options for container media including compost, pine bark, wood products, rice hulls, soil, peatmoss, and combinations of these components. A primary consideration in selecting media components in Arkansas appears to be cost. A great deal of published research has been conducted in other states evaluating the effect of media type on plant growth. This study was conducted to assist Arkansas growers in selecting a container media based on media parameters and plant growth.

Research was conducted at a small commercial nursery in central Arkansas. Plants used in this study were azalea (*Rhododendron* 'Hershey's Red'), dwarf burning bush (*Euonymus alatus 'Compactus')*, and inkberry holly (*Ilex glabra* 'Shamrock'). Plants were received as liners and potted on September 7, 2000 into 1-gal plastic containers using 5 different media (Table 1). All media evaluated are commercially available except the PSGB+ which was hand formulated by mixing PSGB with Pioneer Southern coarse pine bark in a ratio of 3:1 (v:v). Media samples were also screened for a particle size analysis (Table 2). Dry media samples were screened using U.S. Standard sieves: #40=420 microns, #18= 1 mm, #8=2.4 mm, #4=4.8 mm.

Plants were fertilized at planting with a slow-release fertilizer (Scotts Pro 19-5-9 plus minors 12-14 month). Fertilizer was incorporated at a rate of 2 lb N/yd$^3$. Media was not amended with limestone. Plants were watered as needed using an overhead irrigation system. Containers were placed in a completely randomized design with 5 single plant replicates.

Data were collected when a significant number of roots reached the outside of the media ball. Final data were collected for burning bush on April 18, 2001 and for holly and azalea on June 22, 2001. Data collection included a final growth index, shoot fresh weight, root dry weight, media shrinkage, and 'moist' media/root weight. The growth index was calculated by the formula, p*h*r$^2$, where h is shoot height and r is calculated by multiplying _ times the mean of two diameter measurements taken at a 90∞ angle from each other. Media shrinkage was determined by measuring the difference between the initial media height and the final media height. Final 'moist' media/root weight was determined at container capacity.

**Results and Discussion:** The initial pH of the 5 media based on a saturated aqueous paste ranged from 4.7 (PSGB+) to 6.8 (HA) (Table 1). Considering that many sources suggest a desirable media pH range of 5.5 to 6.5 for most crops, three media (J&B, PSGB, AC) would fit this requirement without further amendment. The PSGB+ (amended with coarse bark) medium would certainly be a desirable medium for Ericaceous plants such as azalea and blueberries.

At the end of the study, a random sample was taken from the center of the medium rootball for the holly plants. The final media pH for the 5 media evaluated varied among substrates. The final pH of 2 media, PSGB and HA, was significantly more acidic than the initial pH. A rise in media pH was measured for the J&B and AC media. The amended Pioneer Southern Growers Base (PSGB+) showed no change in media pH. It is possible that these results might be different if collected from another plant species.

Guidelines for container media at a large commercial nursery in Oklahoma indicate that a desirable container medium should have over 65% of the particles larger than 2.4 mm. Based on that set of guidelines, none of the media evaluated had 65% of their particles larger than 2.4 mm (Table 2). Both Pioneer Southern products were the closest to this guideline with PSGB and PSGB+ having percentages in this size range of 49 and 52%, respectively. The J&B media had the highest percentage of 'fine' particles (<420 m)

Media had a significant effect on the weight and amount of shrinkage during production (Table 1 & 3). While all 5 media had an acceptable range of dry bulk density (Handreck and Black, 1994), the J&B media approached this upper limit of 37 $lb/ft^3$. The grower involved in this study commented on the heavy weight of this media whether dry or wet. Three media (PSGB, PSGB+, HA) tend to be the lightest whether dry or wet. The final 'moist' media weight was recorded to reflect potential considerations for shipping and handling.

Significant media shrinkage was noted after 9-10 months of production (Table 3). The most shrinkage was measured for the AC and J&B media and least with the PSGB and HA media.

Based on the initial measurements and published guidelines for container substrates (Yeager, 1995) 2 media (PSGB and HA) have acceptable air-filled porosities (Ea) (Table 1). The J&B medium had the lowest

Ea (4%). This corresponds well with the particle size analysis which indicated this medium has the highest percentage of fine particles.

Container media type had a significant effect on the growth of all 3 woody ornamental plants tested (Table 4). Mean root DW for plants grown in the J&B medium was larger than for plants grown in the AC medium. Mean shoot DW for plants grown in the J&B medium was also larger than for plants grown in PSGB, PSGB+ and HA media. These differences were independent of plant species since statistical analysis indicated no significant species by media interaction for either shoot or root growth. All plants were considered as being saleable by the commercial grower at the end of the experiment. Growth index did not appear to be a suitable parameter to monitor the effect of media type on plant growth.

**Significance to Industry:** Overall results were quite surprising in that physical parameters thought to be negative prior to planting (weight, porosity, % of 'fines') did not appear to decrease the growth of 3 woody plants. Results obtained in this study will hopefully be used by growers and retailers to select the proper medium for their situation. The study also emphasizes the practical value to growers of conducting on-site testing of media under their conditions and not basing a purchase decision simply on cost.

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**Table 1.** Parameters for container media evaluated.

| Media Composition | Media | Initial Ea$^{X}$ (%) | Initial Dry Bulk Density (lb/ft3 ) | Initial pH | Final pH$^{Y}$ | Approx. cost/ 1-gal pot$^{Z}$ ($) |
|---|---|---|---|---|---|---|
| Pioneer Southern Grower's Base (**PSGB**) | Aged pine bark | 20 | 17 | 5.7 | 4.6 | 0.09 |
| P.S.G.B. amended w/ coarse pine bark (3:1) **(PSGB+)** | Aged pine bark | 43 | 16 | 4.7 | 4.7 | — — |
| Hope Agri (**HA**) composted fine bark | Composted fine pine bark | 18 | 15 | 6.8 | 6.1 | 0.06 |
| American Composting (**AC**) compost | 'yard' waste compost | 8 | 26 | 5.8 | 6.4 | 0.036 |
| J&B (**J&B**) 'garden mix' | Soil, sand, sphagnum peat, pine bark | 4 | 34 | 5.9 | 6.1 | 0.074 |

$^{Z}$ Cost is a delivered price to Little Rock for 40-45 cu. yards
$^{Y}$ Samples collected from inkberry holly containers
$^{X}$ Ea = air-filled porosity

**Table 2.** Particle size analysis for container media samples. Percent retained.

| Media | Pan | #40 sieve (420 m) | #18 sieve (1 mm) | #8 sieve (2.4 mm) | #4 sieve (4.8 mm) |
|---|---|---|---|---|---|
| PSGB | 11 | 15 | 25 | 25 | 24 |
| PSGB+ | 11 | 13 | 24 | 24 | 28 |
| HA | 10 | 16 | 36 | 29 | 9 |
| AC | 25 | 20 | 22 | 16 | 17 |
| J&B | 38 | 18 | 20 | 13 | 11 |

**Table 3.** Final media physical properties

| Media main effects | Mean final media/rootball ‘moist’ weight (kg) | Mean final media shrinkage (cm) |
|---|---|---|
| PSGB | 1.67 c | 4.5 b |
| PSGB+ | 1.56 d | 5.0 ab |
| HA | 1.50 d | 4.4 b |
| AC | 2.03 b | 5.4 a |
| J&B | 2.51 a | 5.4 a |

Numbers within a column followed by the same letter are not significant at the 5% level.

**Table 4.** Effect of media type on final growth measurements for azalea 'Hershey's Red', burning bush, and inkberry holly.

| Media main effects | Mean Shoot FW (g) | Mean Root DW (g) | Mean Growth Index ($cm^3$) |
|---|---|---|---|
| PSGB | 47.8 b | 19.4 ab | 16,230 a |
| PSGB+ | 45.9 b | 16.7 ab | 14,840 a |
| HA | 46.3 b | 19.1 ab | 17,120 a |
| AC | 50.3 ab | 13.8 b | 11,670 a |
| J&B | 66.5 a | 27.3 a | 14,410 a |

Numbers within a column followed by the same letter are not significant at the 5% level.

# Use of Pelletized Poultry Litter as a Container Substrate

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**Nature of Work:** Kentucky has 2050 (T. Pescatore, U.K. Poultry Extension Specialist, personal communication) poultry houses producing approximately 150 tons of animal waste per house each year (7). Poultry litter is potentially an inexpensive and readily available product for the Kentucky nursery industry. While studies have indicated that various sources and forms of composted animal waste can be used as a container substrate (1, 4, 5) literature indicates that 10-20% is the maximum amount by volume that can be utilized (6, 3, 2).

The objectives of this preliminary study were to determine if pelletized poultry litter could be used as a container substrate and if so, determine the maximum amount of poultry litter that could be utilized.

Uniform rooted cuttings of *Euonymus fortunei* 'Emerald Gaiety', *Spirea* x *bumalda* 'Goldflame', and *Euonymus alatus* 'Compactus' were potted on August 9 - 10, 2000 into 3.8 liter (#1) containers with pine bark and 0, 5, 10 or 20% pelletized poultry litter (All Natural Organic Flower & Vegetable Fertilizer, 3-4-3, Plant Right, Inc., Purdy, MO) by volume. The experiment was a randomized complete block design with 10 replications of each treatment. Plants were grown on a gravel pad with overhead irrigation, consistent with normal production practices at Metcalfe Landscaping and Garden Center, Madisonville, Kentucky. Plants were not top dressed with commercial fertilizer.

A visual assessment was made whether plants were alive or dead and growth was measured on August 28, 2000. Plant quality rating criteria are shown in Table 1. Data were subjected to statistical analysis using ANOVA and mean separation.

**Results and Discussion:** For all species studied, addition of poultry litter did not significantly improve plant quality as compared to untreated plants (Tables 2-4). However, addition of poultry litter at 20% by volume significantly reduced quality for all three species, indicating that this level exceeds that which could be used in a nursery setting. For *Euonymus alatus* ‘Compactus’, substrate of 10% poultry litter significantly reduced plant quality.

**Species Effect:**
*Spirea* x *bumalda* ‘Goldflame’ had higher plant quality than *Euonymus alatus* ‘Compactus’ under all treatment conditions.

Flies congregated and laid eggs on the bottoms of containers, creating unsavory working and retail sales conditions. In addition, a strong odor necessitated the experiment being relocated to a site further away from retail customer traffic. While this may not be a serious concern for wholesale nurseries, it may impact shipping to retail locations. Shrinkage of 25% was a concern observed in the pots containing 20% poultry litter.

**Significance to the Industry:** An abundance of poultry litter is found throughout many states in the southeastern U. S. Poultry litter is an acceptable substrate in small quantities for some nursery crops. While some crops may tolerate 10%, a maximum of 5% by volume poultry litter should be observed for certain crops. Testing for the optimum percent poultry litter for each new crop is necessary. Testing each new source of poultry litter is also advised.

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Metcalfe Landscape and Garden Center, Madisonville, Kentucky
Plant Right, Inc. Purdy, Missouri.

**Table 1.** Criteria used to assess plant quality of three ornamental species grown in pine bark substrate supplemented with pelletized poultry litter.

| Rating | Criteria |
|---|---|
| 0 | Dead |
| 1 | Alive, some burning or chlorosis |
| 2 | Alive, green, no new growth |
| 3 | < 1.5” of new growth |
| 4 | 1.5” - 2.5” of growth |
| 5 | > 2.5” of growth |

**Table 2.** Plant quality evaluation of *Euonymus alatus* 'Compactus' grown in pine bark substrate with addition of 0, 5, 10 or 20% poultry litter by volume.

***Euonymus alatus* 'Compactus'**

| Poultry Litter Concentration | Rating |
|---|---|
| 0 | 2 a |
| 5 | 1.7 ± 0.48 a |
| 10 | 0.4 ± 0.52 b |
| 20 | 0 b |

**Table 3.** Plant quality evaluation of *Euonymus fortunei* 'Emerald Gaiety' grown in pine bark substrate with addition of 0, 5, 10 or 20% poultry litter by volume.

***Euonymus fortunei* 'Emerald Gaiety'**

| Poultry Litter Concentration | Rating |
|---|---|
| 0 | 2.1 ± 0.32 a |
| 5 | 2.3 ± 1.25 ab |
| 10 | 1.8 ± 1.14 ab |
| 20 | 0.3 ± 0.95 b |

**Table 4.** Plant quality evaluation of *Spirea* x *bumalda* 'Goldflame' grown in pine bark substrate with addition of 0, 5, 10 or 20% poultry litter by volume.

***Spirea* x *bumalda* 'Goldflame'**

| Poultry Litter Concentration | Rating |
|---|---|
| 0 | 4.4 ± 0.84 a |
| 5 | 4.8 ± 0.42 a |
| 10 | 3.6 ± 1.17 a |
| 20 | 0 b |

# Use of Animal Bedding as a Media Component for Container-Grown Perennials

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**Index Words**: Wood Chips, Coir, Peat, Pine Bark, Fertilization

**Nature of Work**: Availability and cost of growing media is a primary concern in production of container-grown perennials. While peat moss and pine bark and mixes containing these materials are the industry standard, alternative materials such as yard waste and wood chips continue to be evaluated for use as container media components to help reduce media costs. These materials usually are composted before use and generally have favorable results with container-grown plants (1, 2). However, if stabilization through composting has not been completed competition for nitrogen and/or phytotoxins from incomplete composting can have negative effects on container plant growth (3). One example of sources producing potential media components is the Hyder-Burks Agricultural Pavilion at Tennessee Tech University. Each year this facility hosts over 30 animal/livestock events and uses approximately 2000 $yd^3$ of bedding materials consisting of wood shavings from a local tool handle plant. After use, this material is placed in static windrows for composting. The objective of this study was to evaluate alternative container media using this bedding material as a container media component on subsequent growth of herbaceous perennials.

This project was conducted at the Nursery Research and Service Center at Tennessee Tech University. Liners of *Heuchera sanguinea* 'Bressingham Hybrids', *Scabiosa columbaria* 'Pink Mist', and *Rudbeckia* 'Goldstrum' were transplanted into 2.8L trade gallon containers on April 27, 2001. Media treatments included ProMix BX (commercial control media), 100% pine bark fines, 100% coir, 50/50 coir/composted bedding (COHB), 50/50 coir/fresh bedding (CNHB), 50/50 peat/composted bedding (POHB), and 50/50 peat/fresh bedding (PNHB). Fertilization treatments were topdressed and consisted of control (unfertilized), 12g 18-6-12 Osmocote (SR) (The Scotts Company, Marysville, OH), or 12g 18-6-12 Osmocote plus 10g 14-14-14 nursery granular fertilizer (SR+GR). All plants were grown in full sun and irrigation was applied overhead as needed. Growth (as determined by foliar color) and root ratings were recorded 90 and 120 days after treatment (DAT), respectively, while electrical conductivity (EC) and pH were measured 15, 30, 60, and 120 DAT from two replications of the *Scabiosa columbaria* 'Pink Mist'. Treatments were arranged in a randomized complete block design with four replicates of four plants each. All data was analyzed using analysis of variance (ANOVA) and if significant means separation by least significant difference (LSD), *P*=0.05.

**Results and Discussion**: Electrical conductivity (EC) measurements were greatest for media treatments top-dressed with either SR or SR+GR compared to the unfertilized control regardless of media treatment through 90 DAT (data not shown). All treatments were similar 120 DAT. Media pH for all treatments were similar through 120 DAT (data not shown).

*Heuchera sanguinea* 'Bressingham Hybrids': Growth ratings were greatest for media treatments receiving fertilization (Table 1). Growth rating of plants grown in peat, coir, POHB, and COHB were similar regardless of fertilization compared to the controls, however for plants receiving SR only and grown pine bark, PNHB, or CNHB the growth rating was reduced compared to plants receiving SR+GR. Fertilization treatments produced root ratings greater than the controls except for pine bark receiving SR.

*Scabiosa columbaria* 'Pink Mist': The greatest growth ratings were among the fertilization treatments compared to the controls (Table 1). Among the SR treatment growth rating of PNHB and CNHB were reduced compared to plants receiving SR+GR. Root ratings were similar regardless of fertilization or media treatment.

*Rudbeckia* 'Goldstrum': Growth ratings were similar for the SR or SR+GR fertilization treatments regardless of media treatment compared to the controls (Table 1). The growth ratings of the controls were all similar. The control pine bark and coir had lowest root ratings while SR and SR+GR generally had higher ratings.

**Significance to the Industry**: Adequate growth of *Heuchera*, *Rudbeckia*, and *Scabiosa* was achieved with the use of composted wood chips and sufficient fertilization. The use of wood chips as a media component for herbaceous perennial production could help growers with media choices.

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**Table 1.** Foliar color and root rating of three herbaceous perennials grown in container media with differing alternative components and three fertilization treatments.

| | Heuchera | | Rudbeckia | | Scabiosa | |
|---|---|---|---|---|---|---|
| | GR[z] | RR[y] | GR | RR | GR | RR |
| Control (unfertilized) | | | | | | |
| Peat | 2.5 c[x] | 1.0 c | 2.9 b | 4.0 ab | 2.3 d | 3.3 ab |
| Pine Bark | 1.0 d | 1.0 c | 3.0 b | 2.0 d | 1.0 e | 2.7 ab |
| Coir | 1.8 cd | 1.0 c | 2.8 b | 2.0 d | 1.0 e | 2.0 b |
| PNHB | 1.0 d | 1.3 c | 2.5 b | 2.3 cd | 1.0 e | 2.8 ab |
| POHB | 1.3 d | 1.0 c | 3.3 b | 3.8 bc | 1.0 e | 3.3 ab |
| CNHB | 1.3 d | 1.3 c | 2.8 b | 3.0 cd | 1.0 e | 3.0 ab |
| COHB | 1.0 d | 1.5 c | 2.8 b | 3.5 bc | 1.3 e | 2.7 ab |
| 18-6-12 Osmocote | | | | | | |
| Peat | 5.0 a | 2.5 ab | 5.0 a | 4.5 ab | 5.0 a | 2.8 ab |
| Pine Bark | 3.0 bc | 1.8 c | 4.8 a | 4.3 ab | 4.8 ab | 3.5 ab |
| Coir | 4.3 a | 2.5 ab | 5.0 a | 5.0 a | 4.3 abc | 3.0 ab |
| PNHB | 3.0 bc | 2.0 b | 4.5 a | 3.5 bc | 3.8 bc | 2.5 ab |
| POHB | 4.3 a | 2.3 ab | 5.0 a | 3.3 bc | 4.0 abc | 3.0 ab |
| CNHB | 3.3 b | 2.8 a | 4.5 a | 4.3 ab | 4.0 abc | 4.3 a |
| COHB | 4.3 a | 2.0 b | 4.8 a | 5.0 a | 4.8 ab | 3.3 ab |
| 18-6-12 Osmocote + 14-14-14 Nursery Granular | | | | | | |
| Peat | 4.8 a | 2.7 a | 5.0 a | 4.0 ab | 5.0 a | 3.7 ab |
| Pine Bark | 4.3 a | 2.0 b | 5.0 a | 4.3 ab | 4.8 ab | 3.5 ab |
| Coir | 5.0 a | 2.0 b | 5.0 a | 4.3 ab | 5.0 a | 3.3 ab |
| PNHB | 3.5 b | 2.0 b | 4.8 a | 3.8 bc | 4.3 abc | 3.3 ab |
| POHB | 4.5 a | 2.8 a | 5.0 a | 4.5 ab | 4.8 ab | 3.5 ab |
| CNHB | 4.8 a | 2.8 a | 5.0 a | 5.0 a | 5.0 a | 4.0 ab |
| COHB | 4.0 ab | 3.0 a | 4.5 a | 4.5 ab | 5.0 a | 3.8 ab |

[z]Growth rating determined by foliar color, 5 to 0 scale, 5 = dark green and 0 = dead.
[y]Root rating determined by root ball coverage, 5=100%, 4=75%, 3=%0%, 2=25%.1=0%.
[x]Mean separation within each column by least significant difference (LSD), *P*=0.05.

# Variation in Physical and Chemical Properties of Compost-amended Pine Bark Substrates

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**Index Words:** Water Holding Capacity, Porosity, Bulk Density, pH, Electrical Conductivity, Media, Substrate, Compost, Pine Bark

**Nature of Work:** Container nursery growers are faced with decreased availability of pine bark-based growing media and a frightening lack of viable, tested alternatives. New products are being tested and introduced but no clear alternatives or supplements have emerged to fulfill the important criteria for soil-less substrates of consistent quality and availability and low cost (4). Several candidate alternative substrates are composted livestock litter, biosolids, yard waste and other composted materials which are becoming more locally and regionally available (1).

Many ornamental plants respond positively to compost amendment of pine bark up to 10-15% by volume (2). Practical challenges related to availability and heterogeneity of products remain for incorporating composted materials into container substrates. There are reasons to expect that net reductions in irrigation and fertilization requirements and decreased leaching of nutrients may be possible due to increased water and nutrient holding capacity of compost (3).

Here we report some of the physical and chemical properties of compost-amended pine bark that are important to container substrates for ornamental plants. Four different composts were donated by commercial producers in Virginia from their general inventory. Feedstocks used in their production are as indicated in Figure 1 and represent much of the variety of composts currently available. Each compost was mixed at five different proportions with milled pine bark. Water-holding capacity, percent total porosity and air space, and bulk density were measured using porometers and protocol from the North Carolina State University substrate laboratory. For pH and electrical conductivity analysis, substrate solutions were extracted from 1 gallon pots of each mix at container capacity using the pour-through procedure.

**Results and Discussion:** There were significant statistical interactions between compost and proportional mix in pine bark for all properties measured in this study (ANOVA data not shown). We conclude that substrate physical and chemical properties depend both on compost product and proportional mix with pine bark. The proportion of compost in a pine bark mix had a larger effect than the compost source in most of these measures. This could be encouraging to growers who may need to acquire composts from several sources in order to meet production demand.

Water-holding capacity and total porosity of container substrates decreased with small additions of compost and then generally increased with increasing compost in the mix, though this was not true for all composts (Fig 1a, b). The non-linear response of these properties to increasing compost in the mix is reminiscent of the effects of increasing sand in pine bark mixes in which additions up to some threshold amount merely fill pores; whereas at and above this threshold (about 20% compost in this case), particle bridging can increase porosity and water holding capacity. Air space generally decreased with increasing compost in the mix (Fig 1c) but not for all composts, and each compost product exhibited a peak percent air space at a different proportion in the pine bark mix. These responses suggest that each product has a unique particle size distribution and therefore a unique volumetric threshold at which particle bridging is maximized. Bulk density generally increased with increasing compost in the mix, though again not for all composts (Fig 1d). These data suggest that most compost products had a smaller mean particle size than milled pine bark. Compost amendments could have the effect of filling macropores (and air spaces), but increasing micropores (and water holding capacity), without changing total porosity very much. Trade-offs between aeration and water holding capacity may help define the potential for benefits of compost-amended container substrates. This will be especially true as water resources become more expensive or more limiting in nursery production, and as the ability of composts to mediate root disease potentials in denser, wetter substrates becomes clear.

Both pH and electrical conductivity generally increased with increasing proportion of compost in the substrate mix (Fig 1e, 1f). Compost #3 which was produced from lime-dewatered wastewater sludge (buffered pH 7.5) and wood chips was especially dramatic in this regard. Compost #4 is also a biosolids compost that did not exhibit such high pH or EC. Because of this variability, growers are advised to test biosolids compost carefully before incorporating them into general production practices. Proportional mixes of the remaining compost products up to 50% by volume exhibited acceptable physical and chemical properties for container substrates. Recommendations of not more than 15% compost by volume may be too conservative, and may not allow growers to capitalize on some of the other purported benefits of compost to plant growth.

**Significance to Industry:** Container nursery growers have become increasingly dependent on milled pine bark as a general production substrate. Market fluctuations in the availability of pine bark are becoming more common and threaten to limit nursery production. Our research demonstrates that compost amendments up to 50% by volume in pine bark exhibit many acceptable physical and chemical properties important to container substrates and may provide dividends in water savings. Growers are advised to (1) have composts analyzed for some properties such as pH and EC prior to use and (2) consider compost amendments in limited and experimental production (especially with pH and salt–sensitive plants) until plant responses are observed, and irrigation and fertilization practices are adjusted for each new substrate.

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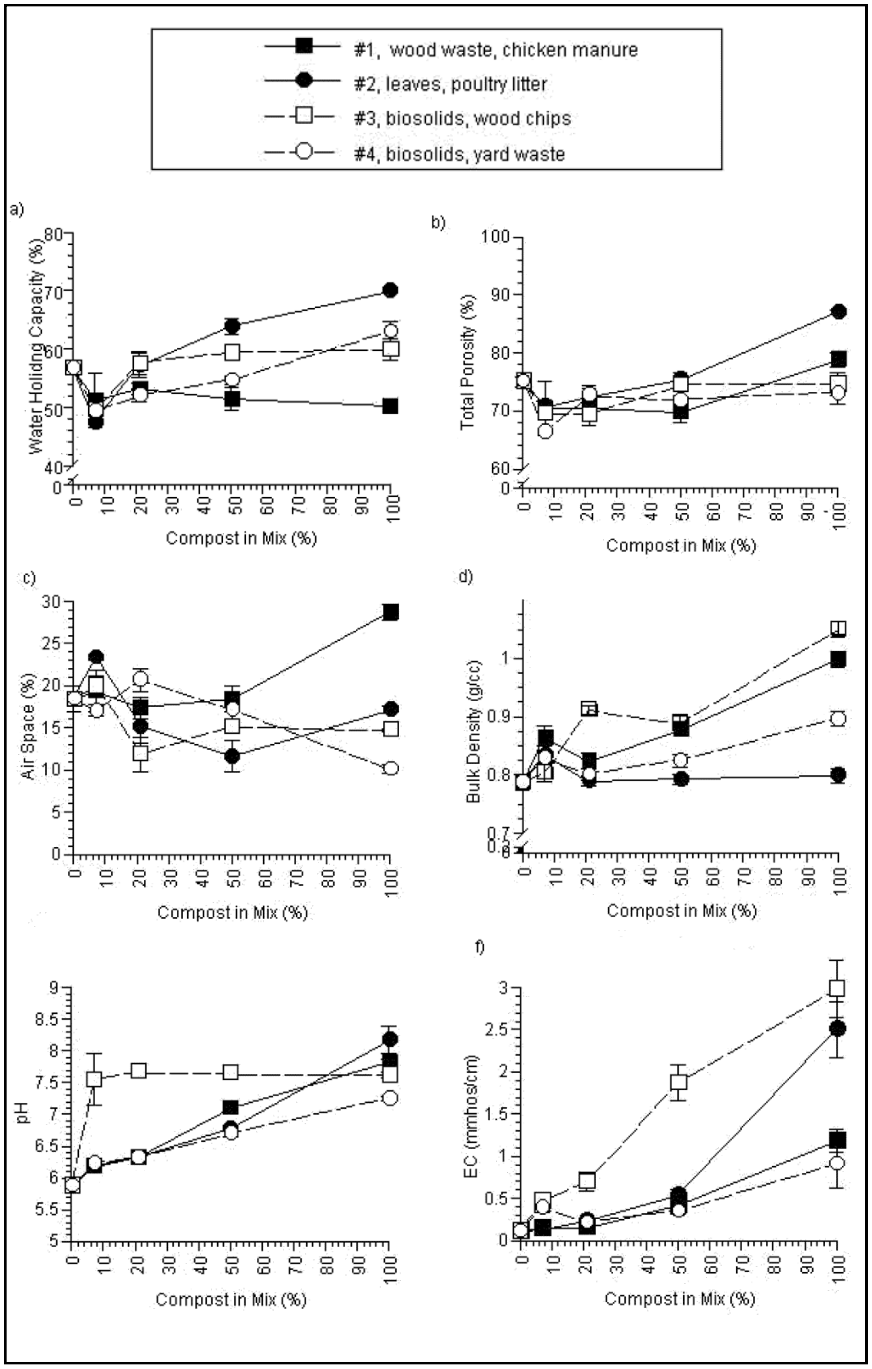


**Figure 1.** Physical and Chemical Properties of Four Compost Products at Five Proportional Mixes with Milled Pine Bark

# Medicinal Quality of Greenhouse-Grown Feverfew as Influenced by Preharvest Conditions

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**Index words:** *Tanacetum Parthenium*, Harvest, Stress, Ethylene, Ethephon, Plant Spacing

**Nature of Work:** Feverfew, an ornamental herb from the Compositae family (daisy), has been associated with control of migraine and of arthritis-related pain (Murphy et al., 1988). Parthenolide is considered to be the primary active principle responsible for these medicinal effects (Groenewegen et al., 1992). In the USA, herbal products are not yet regulated. In most countries, however, feverfew quality is assessed by parthenolide content. The Canadian Protection Branch of Health and Welfare and the French Ministry of Health recommend 0.1-0.2% parthenolide for commercial products (Awang et al., 1991).

Feverfew has been studied for relatively short time and little is known about the physiology of the accumulation of parthenolide. Medicinal compounds are commonly part of what is considered the secondary metabolism of plants. Secondary metabolite concentration in plants may fluctuate during the day (Veit et al., 1996) and could be particularly enhanced by stress-producing factors such as UV light (Lois, 1994). Cutlan et al. (2000) found significant variation in parthenolide among North American feverfew varieties. The trend was that plants with light green/yellow leaves had higher parthenolide than dark green plants.

Southern states such as South Carolina have demonstrated interest in promoting medicinal plants as an option for growers of tobacco and of other traditional horticultural crops. Success of new feverfew growers entering the nutraceutical business, an industry with annual sales exceeding 15 billion dollars, relies on the level of parthenolide present in their plants (Lollis, 2001).

In this study we investigated the influence of UV light, ethephon (2-chloroethylphosphonic acid), spacing modification and time of day of harvest on parthenolide content in greenhouse-grown feverfew.

*Plant Production.* Feverfew seeds in 48-cell trays were germinated under an automatic mist system at Clemson University. After a month plants were transferred to 1 gal pots. A minimum of 8 plants was utilized for each treatment in this study. All the experiments were repeated at least one time.

*Effect of UV light, ethephon, and planting spacing.* Before transplanting plants were exposed to UV-A or UV-B (3.5 µw $m^2$ $s^{-1}$) for 6 hours continuously the day before or one hour daily for 6 days. A week before harvesting, the UV-treated plants and controls were split in three treatments: 0%, 0.1% and 0.5% ethephon. The plant spacing was then widened from 6 to 18 inches, with a control harvested the first and final day. The experiment was planned with a subsampling design.

*Effect of UV light applied before harvesting.* Plants were exposed to UV-A and UV-B light (7 µw $m^2$ $s^{-1}$) for 12 hours during day light before harvesting at 6 PM (February, 2002) and were compared to control treatments that did not receive UV light.

*Effect of time of day of harvest.* Plants were harvested at different times of the day. A group of plants harvested at night were exposed to fluorescent light (8 µmol $s^{-1}$ m-$^{2}$).

*Analysis of Parthenolide.* Plants were dried, ground to <0.0197 inches particle and extracted with 90% acetonitrile for 10 min. Aliquots were filtered through 0.2 µm membranes and injected onto a RP-HPLC system (Waters 1525 pump) (8 min 55% acetonitrile isocratic, 1.5 ml/min). The peaks were analyzed at 210 nm, using a standard curve of parthenolide.

**Results and Discussion:** When plant spacing was widened before harvesting, the increased radiation and/or subsequent reduction of above-ground competition caused loss of green color (data not shown) and increased parthenolide levels (Fig. 1) . Exposure to UV light (UV-A and UV-B) continuously for 6 hours prior to final transplanting resulted in dark green foliage throughout the plant growth (data not shown) but decreased parthenolide content (Fig. 1). Yellowing of leaves and decreased parthenolide was observed in plants sprayed with ethephon (Fig. 1). The parthenolide concentration decreased in plants exposed to UV light for 12 hours before harvesting (Fig. 2). Plants harvested during the afternoon contained significantly more parthenolide than plants harvested in the morning (Fig. 3). Our results suggest that photosyntentically active radiation (PAR) during the time immediately before harvesting is an important factor for enhancing the content of parthenolide in feverfew.

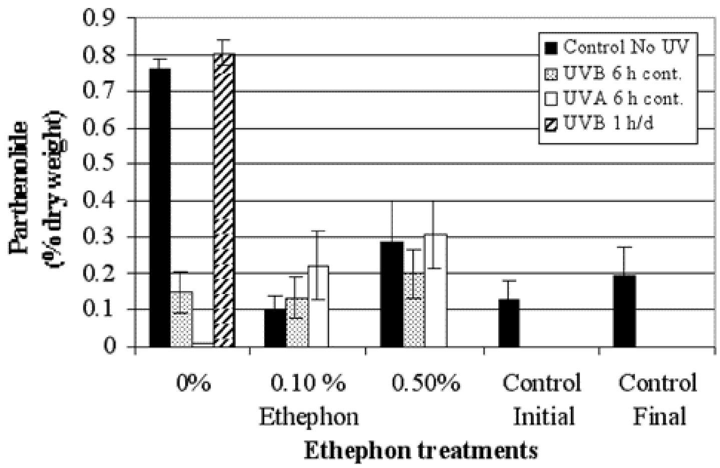


**Fig 1.** Influence of ethephon (ethrel), UV light applied before transplanting and plant spacing on the parthenolide content in feverfew. Control Initial and Final were at 6 inches spacing, other treatments at 18 inches spacing. Data for "UVB 1h/d" at 0.1 and 0.5% ethephon is missing. Bars indicate SE.

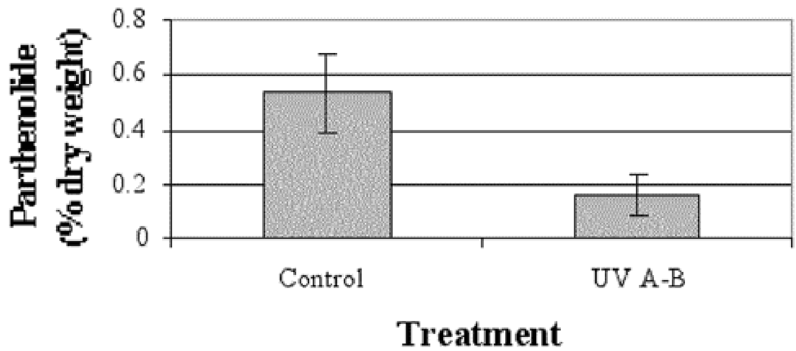


**Fig 2.** Effect of UV-A and UV-B applied continuously for 12 hours before harvesting on the parthenolide accumulation in feverfew. Bars indicate SE.

**Significance to Industry:** The results obtained in this study clearly demonstrates that medicinal quality of feverfew is affected by a number of environmental factors. Remarkably, the visible light or PAR immediately before harvesting appear crucial in obtaining high quality feverfew.

In this sense, simple practices such as harvesting during afternoon hours (sunny day) and widening plant spacing or crop thinning during the days before harvesting can substantially increase the medicinal quality of commercial feverfew.

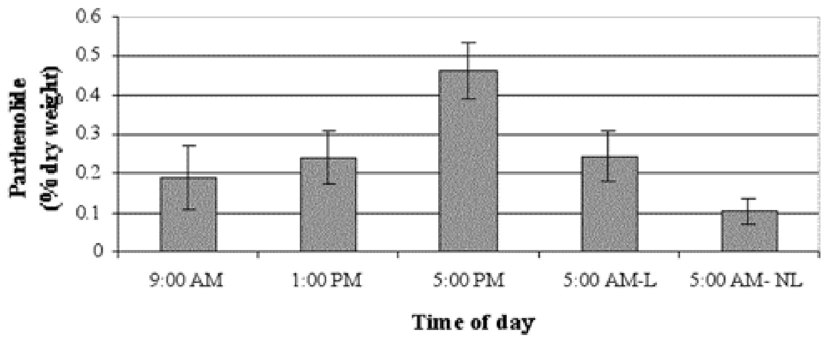


**Fig 3.** Effect of time of day of harvest on parthenolide content in feverfew. L, means that plants were exposed to artificial light during night hours, while NL indicates no exposure to light. Bars indicate SE.

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# Colored Reflective Surfaces Affect Growth of *Coreopsis*

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**Index Words**: Light Quality, Reflected Light, *Coreopsis*, Flowering

**Nature of Work**: Production of herbaceous perennials is among the increasing sectors in ornamental horticulture. These plants are primarily purchased by the consuming public for their flowering displays in spring and summer. Salability and profits could increase if producers could increase flowering potential during production as plant quality is perceived to be greater with more flowers or flowering potential

Quality of reflected light has been reported to influence plant growth and development. A phyto-regulatory role on tomato growth of upwardly reflected light from the polyethylene mulches has been reported (Decoteau et al., 1988). Differences in tomato development are altered by subtle changes in light quality (wavelength changes) from different polyethylene mulch colors. Subtle changes in the red (R) and far-red (FR) ratios resulted in morphological changes in plant development thus implicating phytochrome as the sensing mechanism (Decoteau et al., 1988).

The color of the reflective surface has an influence on tomato flowering as the light environment perceived by early growth stages has been shown to affect subsequent tomato flowering. Tomatoes grown with red or black mulch produced more flowers at an earlier growth stage than plants grown with white polyethylene mulch (Decoteau et al., 1989). This indicates an increase in flower initiation and formation occurring in tomato plants grown over the red and black mulches. This project is seeking to increase herbaceous perennial flowering by using a production method commonly used for field-grown tomatoes. The objective of this research project was to examine the effects on growth and flowering of *Coreopsis grandiflora* 'Early Sunrise' by altering the reflected light perceived by the plants.

The project was conducted at the Nursery Research and Service Center (NRSC) at Tennessee Tech University. The project was initiated May 1, 2001 and concluded in August 2001. *Coreopsis grandiflora* 'Early Sunrise' was selected due to flowering characteristics in late spring and early summer. Liners were transplanted into 2.8l containers and grown in 100% pine bark fines. Each container was top-dressed with 1 TBS of 18-6-12 Osmocote (Scotts Co., Marysville, OH) and irrigation was applied overhead as required.

The reflective surfaces consisted of gravel painted using the colors described by Csizinszky *et* al. (1995). Alkyd-oil paints (Ace Hardware Corp., Oak Brook, IL) used consisted of blue (197A110 Royal Blue), black (197A105 Gloss Black), red (197A114 Vermillion), yellow (197A116 Jonquil), or orange (197A123 Dutch Orange) and applied using a back pack sprayer. The paints were diluted 1:1 with minerals spirits and applied with a back pack sprayer at about 3.8 liters/200 $ft^2$. An unpainted control were included.

Plant growth data was collected non-destructively and include height, growth index [(ht + w1 + w2)/3], flowering percentage, and flower/bud totals. Container media temperature will be monitored and recorded every 15 minutes using mini temperature data-loggers (Spectrum Technologies). Temperature sampling will be replicated twice for each reflective surface treatment. The experimental design was a randomized complete block design (RCBD) with 35 plants per block. All data was analyzed using analysis of variance (ANOVA) and if differences are detected, data was further tested using least significant difference (LSD).

**Results and Discussion**: Flowering percentage was significantly different as affected by reflective color. Black (40%) and Orange (44%) had the greatest flowering percentage compared to Blue (25%), Yellow (5%), and Control (2%) at 42 days after treatment (DAT) (Table 1). All of the reflective colors had greater flowering percentage at 54 DAT compared to the Control and there were no differences in flowering percentage 66 DAT. Orange (6.79) had the greatest flower/bud number compared to the other treatments 42 DAT (Table 1). Flower/bud totals were greatest for Orange, Yellow, and Black while Control, Blue and Yellow were similar at 54 DAT. There were no differences in flower/bud number at 66 DAT. Plant height was similar for the reflective color treatments with the Control being similar to Blue and Yellow. The growth index of plants grown over reflective colors tended to be greater than the control except Yellow which was similar. There was no difference in container temperature between the reflective color treatments (data not shown).

**Significance to the Industry**: This experiment demonstrates the use of a management strategy from a different sector of horticulture for herbaceous perennials. Flowering occurred earlier, flower number, and growth index increased for *Coreopsis grandiflora* 'Early Sunrise' when grown over reflective colors compared to the control. While the painting of gravel beds may not be optimum, colored ground cloths may be more practical for the commercial grower.

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**Table 1.** Flowering percentage, flower number height, and growth index of *Coreopsis grandiflora* 'Early Sunrise' grown over reflective colors.

| | Flowering Percentage | | | Flower/bud Number | | | Height | GI |
|---|---|---|---|---|---|---|---|---|
| Reflective Color | 42 DATz | 54 DAT | 66 DAT | 42 DAT | 54 DAT | 66 DAT | 66 DAT | 66 DAT |
| Control | 2 c | 40 b | 97 a | 1.74 d | 10.6 b | 15.9 a | 19.9 b | 46.1 c |
| Black | 25 b | 81 a | 94 a | 5.06 b | 13.3 a | 16.6 a | 23.3 a | 51.3 ab |
| Blue | 40 a | 94 a | 96 a | 4.71 bc | 11.5 b | 15.4 a | 22.4 ab | 49.7 ab |
| Yellow | 5 c | 84 a | 92 a | 3.46 c | 11.7 ab | 15.1 a | 21.4 ab | 48.3 bc |
| Orange | 44 a | 91 a | 97 a | 6.79 a | 13.2 a | 17.4 a | 23.6 a | 51.8 a |

zMean separation within each column by least significant difference (LSD), P=0.05.

# Pruning Influence on Shoot Development with Container Grown *Aesculus parviflora*

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**Index Words:** *Aesculus Parviflora*, Bottlebrush Buckeye, Pruning, Liner

**Nature of Work:** *Aesculus parviflora* (bottlebrush buckeye) has been awarded elite status by being named to several outstanding plant lists or to State Plant Recognition programs. Individual plants displayed in retail settings have not always had comparable sales appeal. Instead of irregular or tall lanky growth it was thought that lower branched and more uniform plants would be more acceptable by the buying public. Research was established to evaluate stem number, placement, and length as influenced by pruning plants during production. Seeds were collected from *Aesculus parviflora* and planted on the University of Kentucky Horticulture farm during the fall of 2000. The resulting seedlings (6 to 30 inches tall) were harvested in November 2001 and individually placed in three quart containers. Plants were overwintered in a 13 X 48 foot unheated quonset house covered with opaque poly. During February 2002, 130 plants were divided into three groups of 40+ plants. Three treatments consisted of unpruned stems, stems cut back to within 2 inches of the substrate line, and stems cut back to within 6 inches of the substrate line.

Data was analyzed by analysis of variance using the General Linear Models Procedure (SAS).

**Results and Discussion:** During June 2002, data were collected as new stem counts originating from two positions on the remaining plant: originating above substrate line or from the base or below the substrate line.

The average number of shoots per plant was determined by averaging the count from two positions on the plant (above and below the substrate line) (Table 1). Unpruned plants showed apical dominance within the population. This resulted in the fewest shoots per plant (0.81), as many terminal buds continued to elongate without producing many additional shoots either above or below the substrate line. Pruning encouraged additional bud break whether pruned at 2 or 6 inches. Plants pruned at 6 inches had more of the stem remaining and thus had more buds. This yielded more total shoots (1.97) than plants pruned at 2 inches (1.58) (Table 1).

Plants pruned at 2 inches produced more shoots below the substrate line (1.90) than above the substrate line (1.26) (Table 3). Plants pruned at 6 inches produced more shoots from above the substrate line (2.47) than below the substrate line (1.47)(Table 4). For shoots that were produced, pruning did not influence average new shoot length(Table 1). Average new shoot length (in.) on unpruned plants did not differ from lengths on plants pruned at 2 or 6 inches (Table 1). Average total shoot length did present differences among treatments. On unpruned plants, average total shoot growth from below the substrate line (13.00) exceeded shoot growth originating above the substrate line (4.67) (Table 2). For plants pruned at 2 inches, no difference occurred for shoot growth for the below (14.75) and above (12.37) substrate positions (Table 3). For plants pruned at 6 inches, average total shoot length above substrate level (15.28) was statistically different from average total shoot length below substrate level (12.73) (Table 4).

Plants that were pruned did not produce flower buds, regardless of pruning height (data not shown). Unpruned plants did occasionally produce flower buds.

**Significance to Industry:** Plant branch height, compactness, and uniformity can be influenced by pruning *Aesculus parviflora* during production practices. Pruning at 2 or 6 inches above the substrate line increased branching and improved the quality of the plant versus those unpruned. Pruning at 2 inches above the substrate line increased the number of stems arising from the base versus pruning at 6 inches. This should benefit the appearance of plants marketed in three or four quart container sizes. Work is continuing to see if either of these pruning heights will influence plant quality when it is moved to three gallon or larger production sizes. By achieving better quality in plant appearance through more stem development and lower branching, *Aesculus parviflora* may have better sales appeal at the retail level.

**Acknowledgement:** Statistical analysis was completed with the assistance of Dr. John Snyder, Dept. of Horticulture, University of Kentucky.

**Table 1.** Average total number of shoots per plant (including above and below the substrate counts) and average length (in.) of those shoots for three pruning treatments on *Aesculus parviflora*.

| Pruning Treatment | Number of shoots [y] | Ave. length of shoots [z] (in.) |
|---|---|---|
| unpruned | 0.81 C | 5.17 A |
| Pruned at 2 inches | 1.58 B | 5.93 A |
| Pruned at 6 inches | 1.97 A | 6.20 A |

[y]Means with the same letter for each variable are similar at p#0.01; n=260
[z]Means with the same letter for each variable are similar at p#0.01; n=182

**Table 2.** Total number of shoots and average total shoot length (in.) produced at two positions on plants which were not pruned.[z]

| Position | Number of shoots | Ave. total shoot length (in.) |
|---|---|---|
| Above substrate | 1.30 A | 4.67 B |
| Below substrate | 0.32 B | 13.00 A |

[z]Means with the same letter for each variable are similar at p#0.01; n=182

**Table 3.** Total number of shoots and average total shoot length (in.) produced at two positions on plants which were pruned at 2 in.[z]

| Position | Number of shoots | Ave. total shoot length (in.) |
|---|---|---|
| Above substrate | 1.26 B | 12.37 A |
| Below substrate | 1.90 A | 14.75 A |

[z]Means with the same letter for each variable are similar at p#0.01; n=182

**Table 4.** Total number of shoots and average total shoot length (in.) produced at two positions on plants which were pruned at 6 in.[z]

| Position | Number of shoots | Ave. total shoot length (in.) |
|---|---|---|
| Above substrate | 2.47 A | 15.28 A |
| Below substrate | 1.47 B | 12.73 B |

[z]Means with the same letter for each variable are similar at p#0.01; n=182

# Physical Properties of Substrates Evaluated During Educational Programs in Manatee County Florida

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**Index Words**: Air Space, Water Holding Capacity

**Nature of Work:** Physical properties of container substrates are important factors to consider for irrigation management. For example, water-holding capacity of substrates dictate how much water is potentially available for crop use while the aeration after drainage should be sufficient to promote adequate root growth. Water holding capacity is that portion of applied water retained by the substrate immediately following drainage while air space is the volume of air in the container immediately following drainage.

Plant available and unavailable water comprises the water holding capacity of the substrate. Water available to the plant is dependent upon several factors, including distribution of substrate particle sizes and ratio of substrate components. However, a low profile container will contain more total water (quarts) following drainage than a container of equal volume with smaller diameter. Suggested water holding capacity and air space as a percentage of container volume are given in *Best Management Practices: Guide for Producing Container-Grown Plants* (3).

In 2001 and 2002, four irrigation management workshops were conducted in Manatee County, Florida. Participants of the workshops volunteered to determine their substrate physical properties. Most substrates were prepared commercially and purchased by the nurseries. The following procedure adopted from R. C. Beeson, Jr. (2) and the Australian Standards (1) was used to determine substrate air space as a percentage of container volume.

Air Space Procedure: Glue a PVC cap to a length of 3-inch diameter PVC pipe so height of pipe and cap is equal to depth of substrate in container, then determine the total volume inside of assembly (cap and pipe). Flatten the cap with appropriate tool so the assembly will stand upright. Drill four 0.25-inch holes in the bottom of the cap, with one in the center. Loosely, place a 3-inch diameter PVC coupling with 4.5-inch long pipe extension on top of assembly and fill assembly and pipe extension with a moist sample of substrate. Drop the assembly twice from 3 inches. Refill after the second drop but do not pack.

Place the assembly in water so that the top of the coupling is at the surface of the water. Three hours later, remove from water and drain for five minutes. Remove coupling with pipe extension and level substrate to the top of the pipe attached to cap. Cover substrate with a cloth held in place with a rubber band. Submerge for 10 minutes, lift, drain, and submerge again. After 30 minutes, lift the assembly with fingers covering the holes in the cap, let water drain from your hands, and place the assembly above a pan for 10 minutes to allow drainage. Divide drainage volume by total volume of the assembly to calculate the percent aeration.

$$\frac{\text{Drained Volume (ml)} \times 100}{\text{Assembly Volume (ml)}} = \text{\% Air Space}$$

Available water holding capacity is calculated from the difference in weight of wet substrate after drainage and air-dry substrate weight, assuming air-dry substrate weight is the point where plants would remain wilted overnight, but would recover if watered.

$$\frac{\text{Wet substrate wt (g)} - \text{air dry substrate wt (g)} \times 100}{\text{Assembly Volume (ml = gram)}} = \text{\% Available Water}$$

One to 6 samples were evaluated for each substrate. The purpose of this report is to present a summary of physical properties for the substrates evaluated, thus emphasizing the need for nurseries to conduct substrate physical property evaluations.

**Results and Discussion:** From Table 1, it is evident that large differences in air space (7-47%) and available water holding capacities (10-51%) exist among substrates. Available water holding capacity tended to decrease to 10 and 12% as proportion of pine bark increased to 80 and 90%, respectively, in substrates composed of pine bark and Florida peat. However, there were exceptions where substrates composed of Florida peat and 50 or 60% pine bark had available water holding capacities of 39 and 42%, respectively. Thus, two substrates with the same ratio of components may have different physical properties, likely due to different particle sizes. This means that nursery operators need to monitor irrigation amounts in order to ensure excess water does not leave the substrate.

**Significance to Industry:** Nursery operators can evaluate their substrates to determine available water capacity so the amount of irrigation water applied does not exceed the amount that can be retained by the container substrate. Hence, this will minimize leaching and runoff.

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| Key to Table 1 | |
|---|---|
| **APB = AGED PINE BARK** | **GPB = GREEN PINE BARK** |
| **CP = CANADIAN PEAT** | **HM = HORSE MANURE** |
| **CPB = COMPOSTED PINE BARK** | **PB = PINE BARK** |
| **CSAW = CYPRESS SAWDUST** | **PER = PERLITE** |
| **CVER = COARSE VERMICULITE** | **S = SAND** |
| **FP = FLORIDA PEAT** | **SP = SPHAGNUM PEAT** |
| **FPB = FINE PINE BARK** | **VER = VERMICULITE** |

**Table 1.** Air space and available water holding capacity for substrates evaluated during four educational programs in Manatee County Florida, 2001-2002.

| Substrate | Air Space (%) | Available Water Holding Capacity (%) |
|---|---|---|
| 6.5PB:2.0FP:1.5COIR | 18 | 51 |
| 6.5PB:2.0FP:1.5COIR | 20 | 49 |
| 7.3FPB:1.8CP:0.9S | 16 | 48 |
| 5.0FPB:4.0FP:1.0CSAW:1.0S | 19 | 48 |
| 7.5CP:2.5PER | 16 | 47 |
| 3.0CPB:1.3CP:3.0COIR:1.5VER:1.0PER | 15 | 46 |
| 6.0FP:2.0VER:2.0S | 7 | 44 |
| 5.0FPB:4.0FP:1.0CSAW:1.0S | 25 | 44 |
| 1.5CPB:7.0CP:1.5PER | 14 | 44 |
| 6.0PB:4.0FP | 14 | 42 |
| 6.5CP:1.9VER:1.6PER | 19 | 41 |
| 3.0GPB:4.0APB:3.0FP:1.0S | 19 | 41 |
| 6.0PB:4.0FP:1.0S | 10 | 40 |
| 5.0PB:5.0FP | 23 | 39 |
| 4.5CP:2.0COIR:1.9CVER:1.6PER | 19 | 38 |
| 8.0CP:1.0VER:1.0PER | 18 | 38 |
| 2.5APB:3.5COIR:2.5VER:1.5PER | 24 | 37 |
| 7.5CP:2.5PER | 13 | 37 |
| 6.0PB:4.0FP | 11 | 37 |
| 6.0PB:4.0FP:1.0S | 25 | 37 |
| 4.0PB:6.0FP:1.0S | 10 | 37 |
| 6.5CP:1.9CVER:1.6PER | 19 | 37 |
| 5.0PB:4.0FP:1.0S | 12 | 36 |
| 6.0PB:4.0FP | 15 | 36 |
| 4.0FP:1.5PB:3.0CSAW:1.5S | 15 | 36 |
| 2.0COIR: 4.5CP:1.9CVER:1.6PER | 24 | 36 |
| 6.0PB:4.0FP:1.0S | 23 | 34 |

**Table 1** – Cont. on next page

**Table 1** — (cont.)

| Substrate | Air Space (%) | Available Water Holding Capacity (%) |
|---|---|---|
| 5.0APB:2.0GPB:2.0FP:1.0S | 20 | 33 |
| 8.0CP:1.0VER:1.0PER | 12 | 33 |
| 1.5PB:4.0FP:3.0CSAW:1.5S | 10 | 32 |
| 6.0PB:4.0FP:1.0S | 24 | 32 |
| 5.0PB:5.0FP | 25 | 32 |
| 5.0PB:5.0FP | 25 | 31 |
| 5.0PB:5.0FP | 13 | 31 |
| 5.0PB:5.0FP | 21 | 30 |
| 5.0PB:5.0FP | 20 | 30 |
| 6.8PB:2.3FP:0.9S | 15 | 29 |
| 6.0PB:3.0FP:1.0S | 11 | 28 |
| 6.0PB:4.0FP | 15 | 26 |
| 6.0PB:4.0FP | 11 | 25 |
| 7.5PB:1.5SP:1.0S | 27 | 24 |
| 6.5PB:3.5FP:1.0S | 13 | 24 |
| 7.0PB:3.0FP:3.0S | 30 | 23 |
| 2.0PB:8.0HM | 14 | 22 |
| 7.0PB:3.0FP:3.0S | 38 | 21 |
| 7.5PB:0.8SP:0.8COIR:1.0S | 45 | 19 |
| 9.0PB:1.0FP | 47 | 12 |
| 8.0PB:2.0FP | 44 | 10 |

## Varying Growth and Sexual Reproduction Across Cultivars of *Ruellia brittoniana*

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**Index words**: Light, Temperature, Exotic Plants, Invasive, Ornamentals

**Nature of Work:** Invasive species have disrupted thousands of acres of natural areas in the U.S. Some of these plants were originally introduced as ornamentals (Reichard, 1997) and highly prized by both producers and consumers for their rapid growth, durability, and ease of propagation. The State of Florida is the second largest producer of ornamental plants in the U.S. with an estimated 9.908 billion in total industry sales during 2000 (Hodges and Haydu, 2002). Mexican petunia (*Ruellia brittoniana* Leonard ex Fernald) is widely used as an ornamental in the Florida landscape but ranked by the Florida exotic pest plant council (FLEPPC) as a Category I invasive due to observed ecological invasion and disruption of native plant communities. The wildtype form of *R. brittoniana* is inferior to the cultivated forms and rarely found for sale. There are at least 8 cultivars that have been commercially selected for pink, purple, and white flowers in both tall and dwarf forms, but their invasive potential is unknown. The overall objective of the present study was to characterize potential invasiveness of *R. brittoniana* across cultivars. Specific objectives were to 1) determine the effect of temperature and cultivar on germination rate, 2) relate viable germination to estimated total seed production per season, and 3) compare growth and flowering across cultivars of mature plants.

Seeds of the wildtype *R. brittoniana* and 6 cultivars (Table 1) were collected and allowed to dehisce naturally. Preliminary experiments showed that seed germinated readily with or without light and without dormancy requirements. Seeds were germinated in petri-dishes lined with filter paper and placed in incubators (12 hour photoperiod) at 15, 24, and 30/20°C (59, 75, and 86/68°F) for 28 days. In addition to incubator treatments, parallel germination studies were conducted in a greenhouse (36.7/23.5°C max/min) (98.1/74.3°F) using a commercial germination media. Seedlings were transferred to 1 gal pots and after 12 weeks plant height, shoot dry weight, and flower number were recorded from a subsample. The remaining plants were relocated outdoors under open pollination conditions. To compare percent germination relative to total seed production, seed capsules of 5 plants of each cultivar were collected before capsules opened for 3 months. The number of seed pods were determined per plant and the number of seeds in each capsule were averaged to obtain an estimated seed count.

For the cultivar germination study, a split block experimental design was used with each treatment administered to 25 seeds and replicated 5 times. The experiment was repeated twice. The main block was experiment and cultivars were split plots. Percent germination data was arcsin transformed. A combined ANOVA for each temperature was performed across cultivars. Significant experiment x cultivar interactions occurred for all treatments except 15C. Therefore, data from each trial was subjected to ANOVA and if significant, cultivar means were separated by Duncan's multiple range test at 0.05 level.

**Results and Discussion:** With the exception of 'Purple Showers', all cultivars produced seed (Table 1). Estimated seed production per season was greatest for the wildtype, with plants generating almost 3 times the amount of seed than the second highest seed producer, Chi Chi (Table 1). Katie Pink, Katie White, and Morado Chi produced similarly low amounts of seed in comparison to other cultivars (Table 1).

There was no significant interaction between experiment x cultivar for germination at 15°C. Main treatment effects at 15°C showed highest germination (88-98%) with Chi Chi, Katie White, and Morado Chi and lowest germination (22%) with the wildtype. Interestingly, 96% of the wildtype seeds germinated in the greenhouse. For the remaining temperature treatments, a differential response occurred for trial 1 and trial 2. In trial 1, Chi Chi, Morado Chi, and Snow White generally had the highest germination at 15, 24, and 30/20 °C in the incubators, as compared to other cultivars. In the greenhouse, germination was similarly high for all cultivars (91-100%), with the exception of Snow White (82%). In trial 2, highest germination occurred for Chi Chi, Katie White, and Morado Chi (93-97%) at 15 °C. At 24 and 30/20, highest germination occurred for Chi Chi (67%) and Snow White (95%), respectively. In the greenhouse, germination was 100% for all cultivars, with the exception of Katie Purple (94%).

Plant growth was significantly different between cultivars (Table 2). Wildtype and Snow White plants were the tallest with greatest shoot dry weight as compared to the other tall cultivars. Dwarf Katie cultivars were similar in plant height and shoot dry mass. However, Katie Pink produced less flowers than Katie Purple. Seed germination from dwarf forms produced 9-16% of wildtype (tall, purple) seedlings.

**Significance to Industry:** The wildtype *R. brittoniana* has several invasive qualities, including (1) tolerance of variable conditions including light, temperature, and moisture, (2) fast growth, (3) preference to disturbed sites, (4) ability to produce much seed over a long reproductive period, and (5) no special seed germination requirements. Cultivars performed differently under various germination temperatures in the incubators but had similarly high germination percentages in the greenhouse.

Invasive species have biological characteristics in common that predispose them toward invasiveness. The Tampa Bay Wholesale Growers, Florida Nurserymen and Growers Association, and the American Nursery and Landscape Association Boards of Directors are the first in the nation to adopt voluntary codes of conduct (referred to as invasive plant BMP's) for the nursery industry. The codes of conduct involve adoption of risk assessment methods that consider plant characteristics and prior observations or experience with the plant elsewhere in the world. Research on invasive plants is critical to provide scientific evidence of whether a plant is currently invasive or has great potential to become invasive.

**Achnowledgement:**

This study was funded by the Florida Department of Environmental Protection.

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**Table 1.** Seed production of containerized Mexican petunia (*Ruellia brittoniana*) cultivars and germination at various temperatures.

[z] Data collected during June, July, and August.
[y] Mean separation within columns by Duncan's Multiple Range Test at $P \leq 0.05$.
[w] Data not available since plants never produced any seed.

**Table 2.** Growth and development of Mexican petunia (*Ruellia brittoniana*) seedlings grown past maturity for 126 days from seed.

| Cultivar/species | Form/flower color | Stem length (cm) | Shoot dry weight (g) | Flower/ bud (no) |
|---|---|---|---|---|
| Chi Chi | Tall/pink | 77.40 c | 31.74 b | 26.33 abc |
| Katie Pink[z] | Dwarf/pink | 9.567 e | 17.36 c | 12.00 c |
| Katie Purple[z] | Dwarf/purple | 8.317 e | 17.36 c | 27.32 ab |
| Katie White[z] | Dwarf/white | 8.483 e | 14.18 c | 17.60 abc |
| Morado Chi | Tall/purple (thin leaves) | 46.17 d | 27.72 b | 13.17 bc |
| Snow White | Tall/white | 110.4 a | 38.76 a | 27.50 ab |
| Wildtype | Tall/purple | 93.98 b | 36.04 a | 31.33 a |

Mean separation within columns by Duncan's Multiple Range Test at $P \leq 0.05$.
[z]Data is indicative only of plants that were true to type after germination.

# Aglaonema Hybrids Vary in Basal Shoot Production

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**Index Words:** *Aglaonema*, Basal Shoots, Foliage Plants

**Nature of Work:** The genus *Aglaonema*, commonly called Chinese evergreen, is one of the most popular tropical foliage plant genera used for interior plantscaping (5). However, propagation of *Aglaonema* cultivars is still through shoot cuttings or division because commercial micropropagation has not yet become economical for this plant (4). In order to produce a full and compact potted *Aglaonema*, three or more cuttings, depending on container size, are usually potted in a container. As a result, large beds designated for stock plants have to be established and maintained year round for cutting production, which requires space and is extremely labor intensive.

Basal shoots are traditionally defined as those shoots that arise from underground buds of the main stem, but the meaning of this term has been blurred in popular usage and basal shoots are often considered synonymous with offsets or suckers (3). Basal shoot formation in ornamental Aroid plants, especially *Aglaonema*, is a desirable trait. A cultivar with more basal shoots will need fewer cuttings per container to produce a full appearance in the final product. Additionally, basal shoots can be removed and used as propagules.

With recently increased breeding activities and new cultivar releases, a series of *Aglaonema* hybrids have become available (1, 2). However, the genetic variability of these hybrids in producing basal shoots has not been documented. The objectives of this study were to evaluate *Aglaonema* hybrids in basal shoot formation and identify hybrids that produce multiple basal shoots.

Lateral shoots of 10 *Aglaonema* hybrids (Table 1) with 6-7 leaves were separated from stock plants and rooted singly in 20-cm (8") pots containing Vergo Container Mix A (Verlite Co., Tampa, FL): Canadian peat, vermiculite, and perlite (3:1:1 by vol.). Plants were grown in a shaded glasshouse at a maximum light level of 284 mmol/m$^2$/s (1,500 foot candles), temperature ranging from 20 $^{o}$C to 35 $^{o}$C (68 $^{o}$F to 95 $^{o}$F), and a relative humidity of 70 to 90%. Two weeks after potting, 6 g (0.21 oz) of a controlled-release fertilizer, 18N-2.6P-10K (Osmocote 18-6-12, The Scotts Co., Marysville, OH), were applied to the surface of each pot.

Plants were watered overhead 2-3 times a week. The experiment was arranged in a completely randomized design with 6 replications.

Eight months after potting, the number of basal shoots with at least one fully expanded leaf was counted. Differences in basal shoot formation among hybrids were determined by analysis of variance according to the general linear model procedure of the Statistical Analysis System (SAS Institute Inc., Cary, NC). Hybrid differences were separated by the least significant difference (LSD) procedure at $P < 0.05$ level.

**Results and Discussion:** Significant differences existed among hybrids evaluated for basal shoot production (Table 1). 'Manila Pride', 'Royal Queen', and 'Queen of Siam' produced, on the average, less than one sucker per cutting, whereas 'Black Lance', 'Jubilee', 'Silver Queen', and 'Stars' generated 2 or more per cutting. The remaining hybrids had basal shoots between 1 and 2 per cutting. These results indicate that the basal shoot production is genetically controlled and could be improved by appropriate choice of parents in breeding. 'Silver Queen', a hybrid derived from a cross between *A. curtisii* and *A. treubii* (4), is one of the more popular *Aglaonema* cultivars in the foliage plant trade and also produces the highest number of basal shoots, suggesting that basal shoot production is an important trait in determining a cultivar's ornamental value in the market.

**Significance to Industry:** This research shows that current *Aglaonema* hybrids differ in basal shoot production. The cultivation of high basal shoot producing hybrids will decrease the number of cuttings used per container, thus reducing time and cost in hybrid *Aglaonema* production. In addition, high basal shoot producing hybrids provide more propagules for propagation through division.

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**Table 1.** Mean number of basal shoots per plant of *Aglaonema* hybrids.

| Hybrid | Basal Shoots |
|---|---|
| Black Lance | 2.5 ab[z] |
| Green Majesty | 1.0 c |
| Jubilee | 1.9 b |
| Manila Pride | 0.8 cd |
| Mary Ann | 1.0 c |
| Patricia | 1.1 c |
| Queen of Siam | 0.8 cd |
| Royal Queen | 0.4 d |
| Silver Queen | 3.0 a |
| Stars | 2.0 b |

[z]Means within the column followed by different letters are significantly different from each other ($P \leq 0.05$, Fisher's Protected LSD).

# Red Maple Leaf Absorptance of Photosynthetically Active Radiation: Linking Spectral Characteristics to Chlorophyll Estimates

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**Index Words:** Absorptance, Reflectance, Transmittance, Stress

**Nature of Work:** Recent evidence in an agronomic food crop suggests that chlorophyll content and spectral properties are linked (Ercoli et al., 1993). If such relationships hold for ornamentals, it may be possible to estimate absorptance of the incident photosynthetic photon flux density (PPFD) from a measure of leaf chlorophyll. Furthermore, individual spectral characteristics of reflectance, transmittance, or absorbed radiation could provide an in-depth understanding of physiological responses to stress and a plant's ability to adapt (Carter and Knapp, 2001). Establishment of such a relationship in ornamentals could be used to determine photosynthetic rates of leaves with a chlorophyll fluorometer, a method that is much more rapid then currently possible with conventional gas exchange. The SPAD meter can provide a rapid, non-destructive estimate of extractable chlorophyll in leaves of several crop species (Marquard and Tipton, 1987; Monje and Bugbee, 1992), including red maple (Sibley et al., 1996), and thus could potentially give a faster estimate of leaf absorptance under field conditions. The link between the SPAD meter chlorophyll estimates and leaf spectral properties would eliminate the cumbersome and time consuming nature of integrating sphere measurements.

The purpose of this study is to determine the degree to which reflectance, and absorptance may be related to SPAD meter chlorophyll concentration estimates. Five genotypes of red maple were selected to represent a narrow range in spectral diversity and because basic information on chlorophyll concentrations and SPAD estimates already exist (Sibley et al., 1996).

Four South Carolina grown Acer rubrum (red maple) and one Acer x freemanii E. Murray cultivars were transplanted into 15 gal spin-out treated plastic pots containing a mixture of pine bark and sand (20:1, v/v), fertilized with 14 lbs per yard of Nutricoat ™ 20-7-10 N, P, K type 360 (Chiso-Asahi Inc., Japan), and placed on an outdoor pad. The five-foot maple cultivar whips were comprised of October Glory®, Red Sunset®, Autumn Flame®, Summer Red®, and Autumn Blaze. Initially, all pots were watered to saturation and permitted to drain for 18 hrs. Plants were irrigated six times daily to container capacity until drought was imposed (ML Irrigation Inc., Laurens, SC). Pots were spaced 1.5 m center-to-center. For each cultivar, treatments consisted of a well-watered control (n = 3). A spectroradiometer with the1800-12S integrating sphere attachment (LI-1800; LI-COR Inc., Lincoln, NE) was used to measure leaf reflectance and transmittance on the first fully expanded non-damaged leaf on the first lateral from the terminal tip.

Reflectance and transmittance were measured for each of three replicates per cultivar. Each leaf remained attached to the stem until immediately prior to absorptance determinations. Immediately upon excision, a reference scan and a sample scan were made from 400-900 nm at 2-nm intervals for both reflectance and transmittance. The sample scan was divided by the reference scan at each particular measurement and integrated over the wavelength range to obtain an average. Sample absorption at each wavelength was calculated as absorptance = (1 – reflectance – transmittance) and percentage leaf absorptance was computed as 100 – (reflectance + transmittance).

Upon completion of spectral estimates, leaf chlorophyll concentrations were estimated with a Minolta SPAD 502 chlorophyll meter (Minolta Camera Co., Ramsey, NJ). The SPAD reading, which is correlated with leaf chlorophyll concentration in red maple cultivars (Sibley et al., 1996), uses a silicon photodiode to derive the ratio of transmittance through the leaf tissue at the 650 nm and 940 nm wavelengths. For each leaf, the leaf area within a leaf that was sampled for spectral properties was designated and also used for SPAD measurements.

**Results and Discussion:** The relationship among leaf reflectance and absorptance with that of SPAD readings is shown in Figure 1. Clearly, regression analyses revealed a relationship between both leaf reflectance and absorptance in red maple. Furthermore, it appears that SPAD readings could be used to provide a rapid estimate of leaf absorptance in red maple. Caution must be taken however, because variation in SPAD units has been noted (Earl and Tollenaar, 1997). Further research is necessary in order to elucidate the potential ornamental species that present reflectance and absorbtance relationships to SPAD readings. Once the relationship for a particular chlorophyll meter has been determined, a rapid and accurate estimate of leaf absorbtance and reflectance can be taken in a non-destructive fashion.

**Significance to industry:** The cumbersome nature of an integrating sphere does not permit rapid determination of leaf absorptance, a necessary value in chlorophyll fluorescence determination of carbon assimilation. SPAD meters are rapid, relatively inexpensive, nondestructive instruments that can estimate extractable chlorophyll in leaves and potentially could be used in lieu of an integrating sphere to rapidly estimate leaf absorbtance under field conditions. Upon establishment of a relationship between the two instruments, the time and space resolution of leaf photosynthesis measurements in field studies could be greatly improved.

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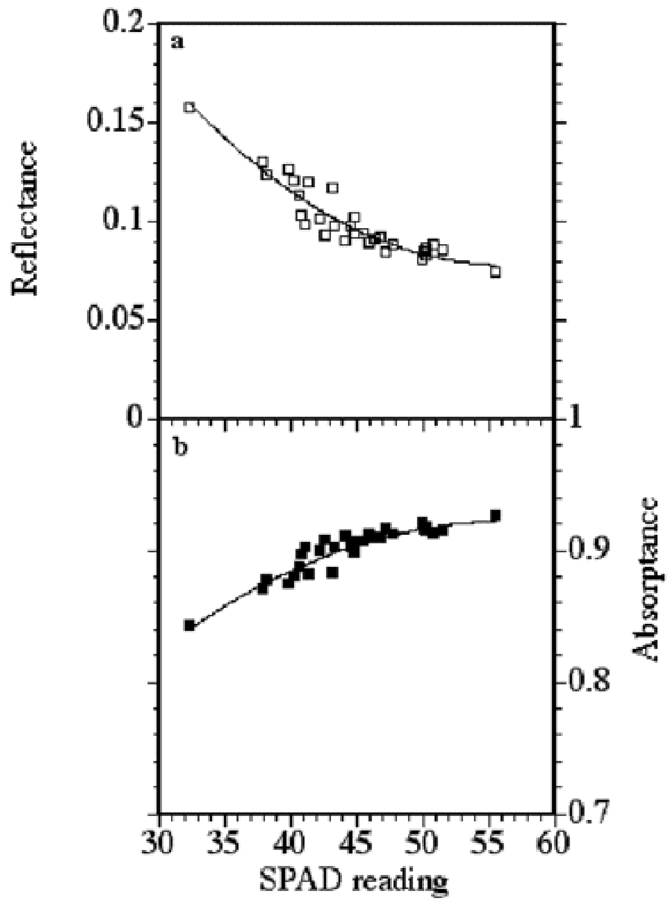


**Figure 1.** The relationship between leaf reflectance (a) and leaf absorbtance (b) and SPAD readings of sampled leaves. A 3" order polynomial was fit to each data set.

# Evaluation of Cultural Practices for Container Production of Passion Flowers

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**Index Words:** Passiflora, Paclobutrazol

**Nature of Work :** Passion flowers are members of the genus *Passiflora*, and are among the most beautiful and exotic flowers in cultivation (3). They are rarely grown outside of botanic gardens and arboreta. Passion flower is a high value crop with the potential for summer containers sales marketed in a similar fashion as other tropical vines like *Bougainvillea* and *Mandevilla*. Most passion flower hybrids and cultivars are easily grown from cuttings. However, there is limited information on commercial container production of passion flower (2). Therefore the objective of this study was to evaluate the effect of fertilizer and plant growth regulator treatment (Bonzi) on plant growth in container-grown passion flower.

In late February, two-node cuttings of *Passiflora*. 'Blue Bouquet' (*P. caerulea x P. amythestina*) were treated with IBA (1,000 ppm in talc) and stuck in Oasis rooting cubes. Cuttings were placed in an intermittent mist bed (5 sec. every 10 min.) with bottom heat (75 $^{o}$C). After two weeks cuttings were well-rooted and moved to 4-inch plastic containers with a peat/bark medium (Scott's 360 Metro mix). Greenhouse conditions were maintained with day/night temperatures of 65/55 $^{o}$F. Plants were fertilized with a 100 ppm fertilizer solution (Peter's 20-10-20) at each watering.

Plants were moved to 5-quart (Nursery Supplies, Inc. Classic 500) containers on May 15, 2001 and maintained in an outdoor nursery under trickle irrigation. The medium used was southern pine bark. Each container was treated with slow release fertilizer (Osmocote 14-14-14) at 1, 5, 10 or 15 grams per container and 300 ml of Bonzi (paclobutrazol) at 0, 50 or 100 ppm. Half the plants were retreated with an additional 500 ml of Bonzi at 25 or 50 ppm on June 15. Plants were harvested after two months of growth (July 15) and evaluated for number of stems, stem length, node number, dry weight, and flower number.

**Results and Discussion**:  Fertilizer had the biggest impact on shoot length (Figure 1) and flowering (Figure 2) in passion flower vines. There was a linear increase in shoot length as fertilizer concentration increased. The manufacturer recommends approximately 14 grams of fertilizer (14-14-14) per 1 gallon container. Blue Bouquet passion flower plants had nearly twice as many flowers produced with 15 grams of fertilizer compared to other fertilizer treatments.

Bonzi reduced overall shoot length and was more effective at the higher rates (Figure 1). Multiple applications further limited shoot growth. There was very little interaction effects between fertilizer concentration and Bonzi application. Single applications of Bonzi reduced total stem length by 20% averaged over fertilizer treatment. This is similar to our preliminary greenhouse studies, where Bonzi at 50 ppm applied once reduced plant height by 28% (2). Multiple applications of Bonzi limited growth compared to the control by 41% (50 ppm followed by 25 ppm) and 53 % (100 ppm followed by 50 ppm).

Flower number was greatest in plants treated with 15 grams of fertilizer (Figure 2). At this rate of fertilizer, Bonzi reduced flower number. However, there was no significant effect of Bonzi on flower number at the other fertilizer concentrations.

**Significance to Industry:** This is the first report on container production in a desirable Passion flower cultivar. It proved to be a fast growing container plant with high market potential. Commercially acceptable plants were produced using 15 grams of slow release fertilizer. A single application of Bonzi at 50 ppm reduced internode length and overall plant height to produce a more compact plant. However, flower production was delayed.

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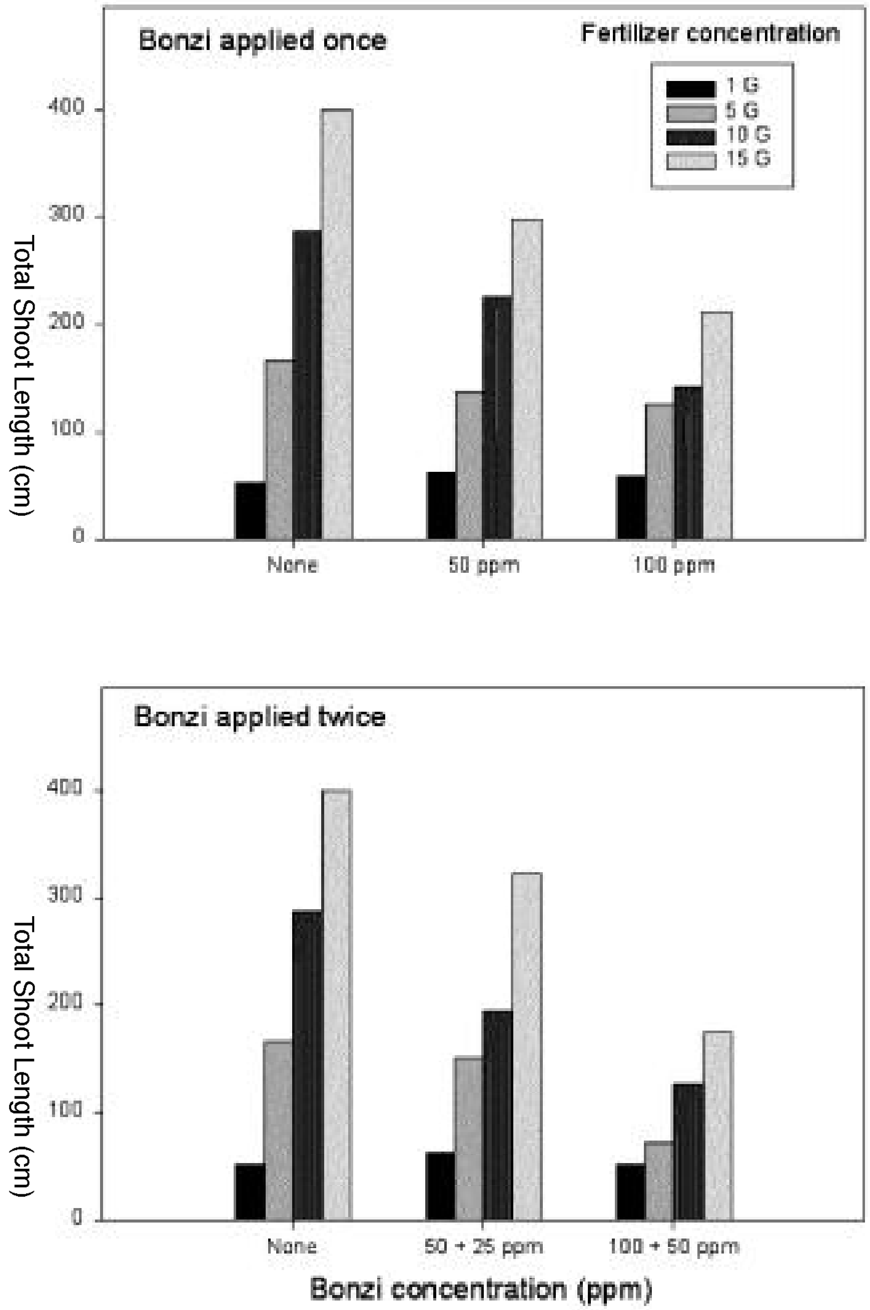


**Figure 1.** Total Shoot Length after two months of passion flower treated with different levels of Bonzi and fertilizer.

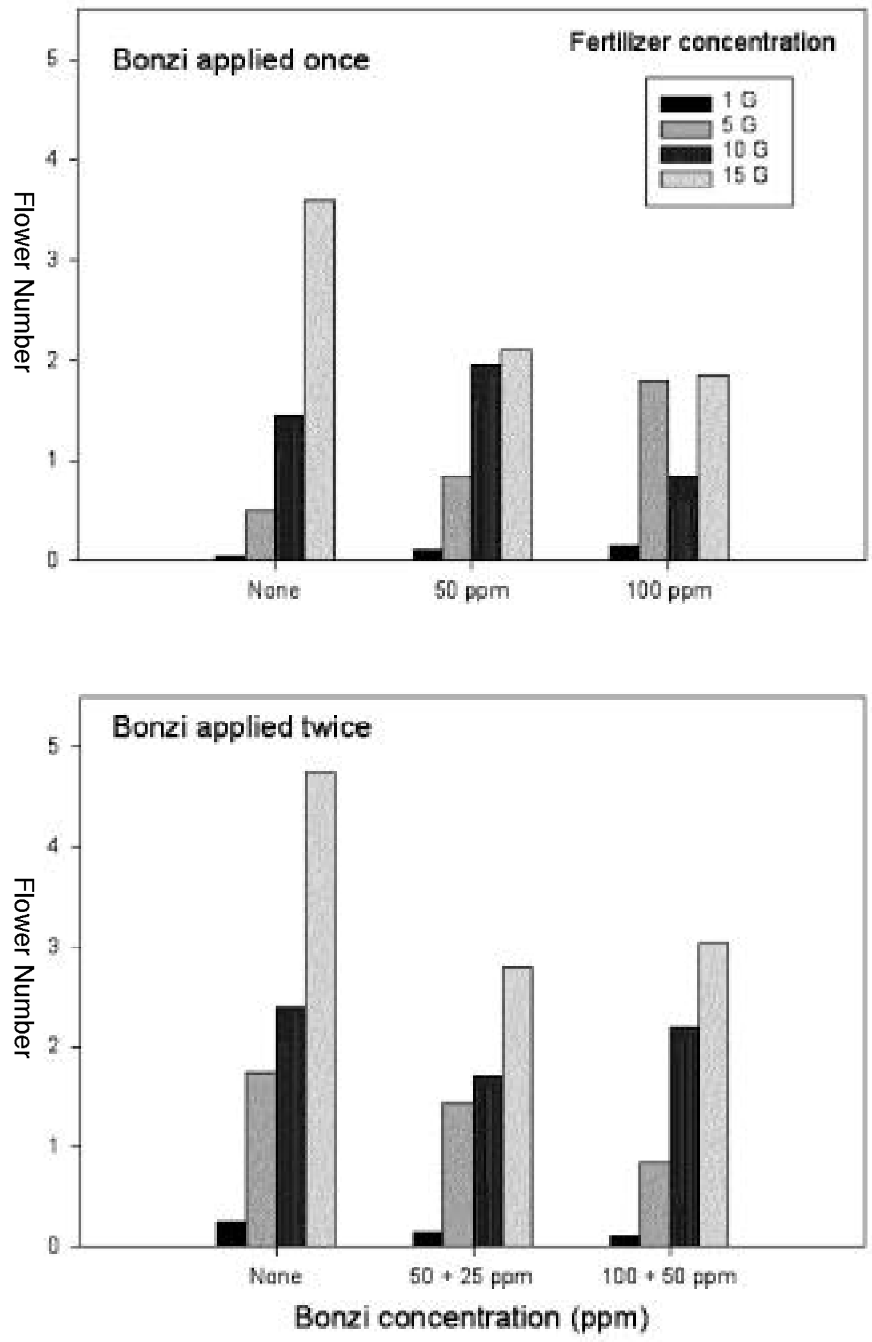


**Figure 2.** Flower number after two months of passion flower treated with different levels of Bonzi and fertilizer.

# Time of Pruning Effects on Cold Hardiness of Butterfly Bush

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Index Words: Butterfly Bush, *Buddleia Davidii* 'Royal Red' (Franchet) Cold Hardiness, Pruning

Nature of Work: *Buddleia davidii* 'Royal Red' (butterfly bush) is a woody shrub with rich purple, fragrant flowers in long panicles known to attract butterflies and bees. Butterfly bush grows as an arching shrub and blooms on new wood (Dirr, 1998), and is used in perennial borders, butterfly gardens or in mass shrub plantings.

Butterfly bush grows profusely throughout the summer and can become leggy and unkempt late in the season in the landscape. Growers also often find it necessary to prune butterfly bush throughout the growing season to maintain compactness for shipping, as a source of cuttings or to save valuable space for overwintering.

Low temperature is one of the most limiting factors affecting the distribution of plants, and cultural practices may affect cold acclimation and susceptibility to cold injury. Plants cold acclimate in response to low, non-freezing temperatures and this acclimation is enhanced by decreasing temperatures and shortening photoperiod. This process naturally occurs in the fall before winter temperatures arrive (Levitt, 1980). Growth cessation is a major prerequisite to cold acclimation (Weiser, 1970), thus cultural practices which delay growth cessation can increase the amount of cold injury. In a study with Chinese elm, Lindstrom and Dirr (1991) stated that all six cultivars studied had a higher lowest survival temperature before winter acclimation in the fall and after deacclimation in the spring in Georgia.

Pruning late in the season before plants are dormant stimulates new, tender growth if environmental conditions are conducive (Mika, 1986). Haynes et al. (1991) reported that to minimize cold injury, *Lagerstroemia indica* x *fauriei* 'Natchez' should be pruned in late winter or early spring and X *Cupressocyparis leylandii* 'Haggerston Grey' pruned in late winter. Because butterfly bush are pruned at various times of the year and there is no information on how this affects cold hardiness, a study was conducted at Auburn University to determine how time of pruning affects cold hardiness in *Buddleia davidii* 'Royal Red'.

Royal Red butterfly bush were grown outdoors in full sun under nursery conditions in one gallon pots. Substrate was a 7:1 bark/sand mix amended per $m^3$ with 6 lb Osmocote 17-7-12, 5lb dolomitic limestone, and 1.5 lb. Micromax. On November 1, 2001, 90 plants were pruned back to 4 inches above the soil line. On November 15, cold hardiness evaluations were begun using 30 pruned and 30 non-pruned controls subjected to six sample temperatures 2C apart. Plants were placed in a programmable temperature chamber, cooled to 4C and held for 8 hours to allow plants to reach a uniform temperature. The chamber was cooled at 2C per hour until it reached the first target temperature, -6C. Chamber temperature was held for 30 minutes at target temperatures to allow samples to reach a uniform temperature. Upon removal from the freezer, samples were placed in a cooler maintained at 4C to thaw slowly. Samples were removed the next morning, placed in a heated greenhouse and allowed to re-grow. November sampling temperatures ranged from -6C to -16C. January and March sampling temperatures were -10C to -20C. Starting one week after treatment (WAT), plants were rated weekly for injury (Table 1). Four weekly ratings were taken, and at 6 WAT percent mortality was determined. On January 1 and March 1, 2002, additional plants were pruned to 10 cm (4 in) above the soil line. The same protocol was followed for plants pruned in January and March as with November-pruned plants. Injury ratings at 2 WAT and percent mortality data only are presented. Treatments in this factorial experiment were arranged in a randomized complete block design. SAS statistical package version 8.2 was used to analyze data.

**Results and Discussion:**

Fall Freeze

Mean ambient air temperature between November pruning and freeze treatment was 17.2C and ranged from 6.7C to 27.2C. Plants were still actively growing and plant tissue was succulent and green. After pruning, re-growth was stimulated and new growth occurred. In November, there was a significant interaction ($P<0.05$) between pruning and freeze temperature for the injury rating. Pruning butterfly bush in the fall significantly increased the injury rating of plants at -6C, but not at lower temperatures where all injury ratings were high. Pruning x freeze treatment was non significant for percent mortality in the fall. Percent mortality increased linearly as temperature decreased, regardless of pruning treatment. In addition, percent mortality was greater in pruned plants (87%) than in non-pruned plants (67%) in the fall. One hundred percent mortality was reached at -16C (37F) for non-pruned plants and -14C (42F) for pruned plants.

**Winter Freeze**
Mean ambient air temperature between January pruning and freeze treatment was 2.8C and ranged from -2.8C to 13.3C. In winter, no new growth was stimulated by pruning. The plants were fully dormant with woody stems and grayish leaf color There were no interactions between pruning and freeze temperature for injury rating or percent mortality of butterfly bush frozen in January. Across pruning treatments, butterfly bush rating increased linearly in injury rating and mortality as temperature decreased, but pruning treatment did not affect either injury ratings or percent mortality. In January, the lowest temperature tested, -20C did not result in 100% mortality.

**Spring Freeze**
Mean ambient air temperature between the March pruning and freeze treatment was 10C and ranged from -5.6C to 25C. When pruned in the spring, plants were deacclimating and new growth was stimulated. There were no significant interactions for injury rating or mortality between pruning and freeze temperature for November, January or March pruned plants or control plants frozen in March. Both injury rating and percent mortality increased linearly as freeze temperature decreased, regardless of pruning treatment. In March, 100% mortality was reached at -14C for both non-pruned and March-pruned plants. November-pruned plants reached 100% mortality at -16C and January-pruned plants reached 100% mortality at -18C.

**Significance to Industry:** Our study demonstrates that pruning butterfly bush in the fall before the plants have become fully dormant and conditions are favorable for re-growth, increases the chance for low temperature injury and possible death. Since plants were fully acclimated in the winter, there was not significantly more injury when pruned. At the spring pruning, plants were more deacclimating and the killing temperature was higher than at the winter sampling. However, pruning at this time did not significantly alter the hardiness of the butterfly bush. Therefore, growers and homeowners alike should prune late in winter or early spring to minimize the chance of cold injury to butterfly bush.

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**Table 1.** Injury[z] for Royal Red butterfly bush in Fall, Winter, and Spring taken two weeks after freeze treatment.

| | Time of Freeze Treatment | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | November | | January | | | March | | | |
| Temp (C) | NP[y] | P | NP | P1 | P2 | NP | P1 | P2 | P3 |
| - 6 | 2.8a [x] | 4.8b | -[w] | - | - | - | - | - | - |
| - 8 | 3.8 | 4.4 | - | - | - | - | - | - | - |
| -10 | 4.6 | 4.8 | 1.8 | 2.0 | 1.6 | 2.0 | 2.4 | 2.6 | 2.6 |
| -12 | 4.8 | 4.8 | 2.2 | 2.8 | 2.2 | 3.0 | 4.0 | 4.2 | 4.8 |
| -14 | 4.8 | 5.0 | 2.0 | 2.4 | 2.2 | 5.0 | 4.4 | 5.0 | 5.0 |
| -16 | 5.0 | 5.0 | 2.8 | 3.6 | 2.4 | 5.0 | 5.0 | 4.8 | 4.8 |
| -18 | - | - | 4.0 | 4.0 | 3.8 | 5.0 | 5.0 | 5.0 | 5.0 |
| -20 | - | - | 4.0 | 3.4 | 4.2 | 5.0 | 5.0 | 5.0 | 5.0 |
| Significance | | | | | | | | | |
| Prune[V] | ** | | NS | | | NS | | | |
| Temp | L***Q* NS | | ----------L***---------- | | | --------------Q***-------------- | | | |
| P x T[U] | ** | | NS | | | NS | | | |

[z] Injury rating scale: 1=no injury; 2=marginal leaf chlorosis; 3=marginal leaf chlorosis; leaf tip necrosis; very little shoot necrosis; 4=marginal leaf chlorosis; leaf tip necrosis; shoot necrosis; 5=death.

[y] NP=non-pruned plants; P, P1, P2, P3= plants pruned November 1, 2001, and January 1, and March 1, 2002, respectively.

[x] Mean separation between pruning treatments within season significantly different at -6C.

[w] Denotes non-target temperatures.

[V] Regression not significant (NS), linear (L), or quadratic (Q) at P=0.05 (*), P=0.01 (**) or 0.001 (***).

[U] P x T=Prune by temperature interaction.

Table 2. Percent mortality of Royal Red butterfly bush in Fall, Winter, and Spring taken two weeks after freeze treatment.

| | Time of Freeze Treatment | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | November | | January | | | March | | | |
| Temp(C) | NP[z] | P | NP | P1 | P2 | NP | P1 | P2 | P3 |
| - 6 | 40 | 80 | - | - | - | - | - | - | - |
| - 8 | 40 | 60 | - | - | - | - | - | - | - |
| -10 | 80 | 100 | 0 | 0 | 0 | 20 | 20 | 20 | 20 |
| -12 | 60 | 80 | 0 | 0 | 0 | 0 | 40 | 60 | 60 |
| -14 | 80 | 100 | 0 | 0 | 20 | 100 | 60 | 80 | 100 |
| -16 | 100 | 100 | 20 | 0 | 0 | 100 | 100 | 80 | 80 |
| -18 | - | - | 40 | 40 | 40 | 100 | 100 | 100 | 100 |
| -20 | - | - | 60 | 40 | 20 | 100 | 100 | 100 | 100 |
| Significance | | | | | | | | | |
| Prune[x] | | * | | NS | | | NS | | |
| Temp[w] | | L*** | | ----------L***---------- | | | ---------Q***---------- | | |
| P x T [v] | | NS | | NS | | | NS | | |

[z]NP=non-pruned plants; P, P1, P2, P3= plants pruned November 1, 2001, and January 1, and March 1, 2002, respectively.
[y]Denotes non-target temperatures.

[x]Mean separation between pruning treatments within season non-significant (NS) at P=0.05.

[w]Regression not significant (NS), Linear (L), or quadratic (Q) at P=0.05 (*) or 0.001 (***).

[v]P x T= Prune by temperature interaction.