Floriculture

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Section Editor and Moderator
Response of Ivy Geranium to Elevated Root Zone Temperature

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Index Words: Fe-EDDHA, Pelargonium peltatum

Significance to the Industry: Ivy geranium (Pelargonium peltatum) does not perform well in Southeastern U.S. summers. The development of whitening of the youngest leaves of actively growing ivy geranium has been observed as the season changes from late spring to summer. Iron deficiency has been suspected as being related to this whitening disorder. In the present study, the response of ivy geraniums to elevated root zone temperatures has been investigated. Results showed that elevated root zone temperature did not cause whitening of ivy geranium.

Nature of Work: Ivy geranium (Pelargonium peltatum) is an important floriculture crop, mainly used for hanging baskets. When grown in the Southern U.S., it is very susceptible to whitening of the young foliage thought to be caused by elevated root zone temperatures. Iron uptake and interaction is decreased by increased root zone temperature (Sartaz and Barthakur, 1995; Tagliavini et al, 1991). Although iron is the fourth most abundant nutrient in the lithosphere, its presence in the soil solution is negligible due to low solubility (Lucena, 2003). Fe-chelates have the capacity to maintain soluble iron in the soil solution over time (Cantera et al, 2002).

Rooted cuttings of Pelargonium peltatum, ‘Beach’ and ‘Butterfly’ were potted on 23 Sept. 2005 into 6-inch pots. They were potted in sphagnum peat and perlite (70:30 by volume) with gypsum at 3lb/50 ft³, lime at 13lb/27 ft³, and wetting agent at 1lb/50 ft³ added. Plants were fertilized with 200ppm N from 20-10-20 Peters Peat-lite fertilizer (Scotts Company, Marysville, Ohio) as a continuous liquid feed. The potted cuttings were grown until they developed a substantial root system. Styrofoam boxes were constructed with heating cables running on the bottom. The tops of the boxes had holes to set the pots in so the tops were unaffected by the heat. The root zone temperatures averaged 24 and 31°C with 3 replications of each temperature. Plants were placed in the frames on 29 Oct. 2005.

Iron was applied at 0mg Fe (control), 0.54mg Fe foliar spray, 1.08mg Fe drench or 108mg Fe (Sprint 138, Fe-EDDHA, 6% Fe, Becker Underwood Inc, Ames, Iowa) drench per pot on 3 Nov and 3 Dec 2005. Surfactant (Ortho X-77 at 1/2 tsp/gallon) was added in Fe-EDDHA for foliar spray. Plant height (from the rim of the container), width (an average of two widths measured, one at the widest point and another at 90°), chlorophyll (SPAD-meter) and leachate Fe content were measured. Growth index was calculated as: G.I. (cm³) = 2*3.14*(width/2)² *height. Leachate was collected using the
Virginia Pour-through technique to determine leachate iron. Iron in the filtered leachate was determined by ICP. The experiment was a split plot design split by temperature.

Results and Discussion: In both cultivars, there was no difference due to root zone temperature among height, width, growth index, chlorophyll content, and leachate Fe at the end of the experiment (20 Dec 2005).

In ‘Beach’ (Table 1), the maximum plant width was obtained with 1.08mg Fe foliar spray. This was not greater than that the control, 0.54mg Fe foliar spray or 54mg Fe drench/pot. Although plant width was smaller at the 108mg drench dose of Fe-EDDHA, it was not different from the control, 54mg Fe drench/pot or 0.54 mg Fe foliar application. Plant height and chlorophyll was not affected by Fe-EDDHA application (data not shown). Growth index was the greatest at 1.08mg Fe foliar spray than at all remaining Fe-EDDHA applications and control, but all of them were not different from each other. Leachate iron levels were the greatest at 108mg Fe drench/pot, followed by 54mg Fe drench/pot. Control and foliar treatments were not different.

In ‘Butterfly’ (Table 1), the plants receiving no Fe application were widest. As Fe application increased, plant width decreased. Control plants grew largest as indicated by the growth index, however, this was not greater than the plants receiving 0.54mg Fe foliar spray. Drench at 108mg Fe per pot resulted in the lowest growth index. Plant height and chlorophyll under all the treatments was not different (data not shown). Leachate iron levels were the highest with 108 mg Fe drench/pot, followed by 54mg Fe drench/pot. There was no difference in leachate Fe between the control and foliar applications.

As plant height, width, growth index, chlorophyll, and leachate iron levels were not affected by temperatures and no whitening was observed, it is concluded that elevated root zone temperature is not responsible for whitening of ivy geraniums. Our results indicate that high levels of Fe-EDDHA, which have been observed to prevent whitening, actually suppress growth.

Literature Cited:
Table 1. Effect of iron chelate (Sprint 138, 6% Fe) on plant width, growth index and leachate iron in ivy geranium ‘Beach’ and ‘Butterfly’ at the end of experiment.

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<th>Growth</th>
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<td></td>
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<td>Index (cm³)</td>
<td>Iron (ppm)</td>
<td>Width (cm)</td>
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<tr>
<td>54mg drench/pot</td>
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<td>108mg drench/pot</td>
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</table>

Means within column separated using LSD P=0.05.
Nutrient Deficiencies of Herbaceous Perennials: Symptoms and Growth Effects

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Index Words: fertilizer, foliar analysis, Verbena canadensis ‘Homestead Purple’, Heliopsis helianthoides ‘Bressingham Doubloon’, and Veronica x ‘Goodness Grows’

Significance to Industry: Nutrient deficiencies of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, copper, zinc, manganese, and boron were induced in three representative herbaceous perennial taxa. Foliar analysis criteria were established by correlating nutrient levels with initial and advanced stages of symptoms. Over 60 images chronicling incipient and advanced deficiency symptoms, both of individual leaves and whole plant including roots, for all three taxa can be found at http://www.floriculture.vt.edu.

Nature of Work: Despite the increase in container-grown perennial production, little information has been published regarding their mineral nutrition requirements, specifically nutrient foliar standards and nutrient deficiency symptoms. Most research in these areas has focused on annual floriculture crops (1, 2), leaving plant producers, researchers, and commercial laboratories to rely on past experience or adapt recommendations for hardy herbaceous perennials. Most standards are based on various growth stages and may not represent the sufficiency range for efficient fertilization (3). Foliar analysis interpretation values based on growth effects over a range of fertilizer levels are published for a select group of perennials (4). Our research generated visual symptoms of nutrient deficiencies in the chronological order in which they appear from incipient to advanced stages, and established foliar analysis standards by correlating nutrient levels with initial and advanced stages of deficiencies for N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, and B in herbaceous perennial plants.

Taxa selected for study were representative of commonly-grown varieties and of differing families; Verbena canadensis (L.) Britt ‘Homestead Purple’ (clump verbena), Heliopsis helianthoides (L.) Sweet ‘Bressingham Doubloon’ (false sunflower) and Veronica (L.) x ‘Goodness Grows’ (speedwell). Unrooted cuttings were stuck in Oasis cubes and held under mist until rooted. Once rooted, plants were grown in a hydroponic system with modified Hoagland’s solutions as treatments minus the element of interest, along with complete nutrient solution controls (as described in Pitchay, 2002). An experimental unit for each treatment consisted of one 4.8 liter tub containing 6 plants each, there were six replicates of each treatment and the same number of controls. Three replicates were harvested at first sign of visible symptoms (incipient deficiency) and the remaining tubs harvested when symptoms were deemed “severe” (necrotic spots and/or margins, new foliage severely distorted). Recently-matured leaves were analyzed for tissue content of essential elements (QAL, Panama City, FL). Data taken included days after start of treatment (DAT) to appearance of
symptoms, description of symptoms, shoot and root dry weights, foliar elemental concentrations, and photographic images of foliage, roots, individual leaves, and whole plants as compared to the controls. Data were subjected to analysis of variance using PROC GLM at $\alpha = 0.05$; model included deficiency treatment, harvest, and treatment x harvest.

**Results and Discussion:** Tissue concentration of tested elements was considered in the “critical” range once the symptoms became visible (Table 1). Tissue concentrations were significantly different from controls for all treatments and taxa with the exception of N for Veronica (not enough tissue was available for analysis when first symptoms appeared. Time elapsed from the beginning of deficiency treatment to first visible symptoms varied by taxa and element (Tables 2, 3, and 4). Calcium and Fe symptoms appeared relatively rapidly in all three taxa - two notably non-mobile elements. Symptoms were slowest to appear in Veronica, for example N deficiency symptoms appeared 30 DAT compared to 15 and 7 DAT for Heliopsis and Verbena, respectively; probably attributable to slower growth at winter light levels (other taxa were grown spring and fall). Absence of some of the secondary macroelements and microelements had the most marked effect on shoot and root growth; such as C, B, and Cu. Due to space considerations, not all elements and stages of deficiency can be displayed here. Research will continue through 2006 with three additional taxa.

**Acknowledgements:** This research was funded in part by the Fred C. Gloeckner Foundation. We thank Dr. Joel Shuman of the Virginia Bioinfomatics Institute, Virginia Tech, for his statistical assistance.

**Literature Cited:**


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*Not enough tissue for N analysis.
Table 2. Days to visible symptoms and concurrent root and shoot dry weight (DW) in *Verbena canadensis* 'Homestead Purple'.

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<th>Days to visible symptoms</th>
<th>Mean shoot DW (g)</th>
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Table 3. Days to visible symptoms and concurrent root and shoot dry weight (DW) in *Heliopsis helianthoides* 'Bressinghan Doubloon'.

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<tr>
<th>Deficiency treatment</th>
<th>Days to visible symptoms</th>
<th>Mean shoot DW (g)</th>
<th>Mean root DW (g)</th>
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Table 4. Days to visible symptoms and concurrent root and shoot dry weight (DW) in *Veronica x ‘Goodness Grows’*.

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n=3.
Establishing Best Management Practices for Avoiding Boron Deficiency in Pansy Plugs

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Index Words: Calcium, calcium deficiency, foliar analysis, macro nutrient deficiency, micro nutrient deficiency, tissue analysis

Significance to Industry: Plants with boron or calcium deficiencies both produce symptoms on the newly developing tissue which can cause confusion. When comparing symptoms of the two deficiencies, a set of characteristics stand out to easily differentiate between the problems. Calcium deficient plants will typically be small and leaves quickly turn necrotic, while boron deficient plants will have distorted growth which remains green. This research suggests the distorted growth in pansy plugs is caused by boron deficiency.

Nature of Work: Over the past six years, a number of greenhouse growers have expressed concern about distorted terminal growth of their fall pansy crops during plug production. The problem has been thought to be a deficiency of either boron or calcium. The occurrence and severity of the problem can vary: from year to year, within a particular period of the season, by stage of plant development, or by geographical location.

Symptoms of boron deficiency typically manifest in the young leaves, and unlike other micronutrient deficiencies, can also be observed in the roots [1]. Many of the symptoms can be seen by the naked eye, including aborted growing tips, fast growing axillary shoots, strapped or crinkled leaves, stunted leaves, upward cupping leaves, chlorosis of upper leaves and less leaf expansion [2-5].

Symptoms of calcium usually start with the upper leaves because it is considered a mobile element. Visual symptoms include deformed, straplike leaves, chlorosis, and leaves that curl and develop yellow to tan margins turning to necrosis [6].

Seeds of pansies (‘Dynamite Yellow’) were sown in oasis foam and kept moist using deionized water until seeds germinated. After germination plants were grown hydroponically in complete modified Hoagland’s all nitrate solution, minus B, minus Ca, 0.25x B or 0.25x Ca formulations [7]. Plants were grown in a greenhouse with day/night temperature set points 75/64 °F, under HID lights to provide a minimum of 170 mol•m-2•s-1 for 12 hr per d. Solutions were replaced on two week intervals. Plant tissue was harvested when visual symptoms occurred and an adequate amount of biomass had been accumulated, which occurred 26 d after initial treatment.

Results and Discussion: Boron. Plants exhibiting a slight deficiency had leaves which began to curl. Plants with moderate boron deficiency symptoms had leaves more prominently curled and were thicker. Severe deficiency symptoms included thickened, smaller leaves and distortion of meristems and young leaves. Tissue values for boron are shown in Fig. 1.
Calcium. Plants showing slight calcium deficiency were initially discolored, turning purplish on the petioles and leaf tips, as well as having a slight leaf curl. Moderate symptoms included greater discoloration and more prominent leaf curling as well as necrosis of the leaf tips. At advanced stages of deficiency, whole leaves and the apical meristem became necrotic. Tissue values for calcium are shown in Fig. 2.

Literature Cited:
5. Stuart, J., Cultural practices are the primary reason for boron deficiency. Under Cover, Univ. of Mo., Columbia, 1991.

Figure 1. Boron concentrations in leaf tissue of pansies treated with a complete, 0.25x boron, or minus boron fertilizer solution.
Figure 2. Calcium concentrations in leaf tissue of pansies treated with a complete, 0.25x calcium, or minus calcium fertilizer solution.
Taking the “Art” Out of Interpreting Tissue Analysis of Geraniums

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Index Words: Foliar analysis, nutrient analysis

Significance to Industry: Using these newly established sufficiency ranges for light or dark-colored-leaf geraniums will remove much of the “art” required for interpreting tissue analysis results. Growers can use these standards which are based on age of crop and color of foliage to more accurately interpret results from tissue analysis on geraniums.

Nature of Work: Geranium tissue analysis standards for sufficiency range, or the general normal range of macro nutrients for geraniums are available [1-5]. Optimal ranges vary among sources and are not adjusted for difference in physiological age of the plant or cultivar differences due to leaf color. Differences in nutritional levels have been reported with dark-leaf and light-leaf poinsettia cultivars [6]. Because current tissue analysis standards for geraniums do not account for age differences or leaf color, the process of trying to determine if a nutrient is the cause of a geranium disorder often becomes an “art” of interpreting nutrient levels instead of being a “science”.

Rooted liners of ‘Tango Dark Red (dark-colored leaves) and ‘Rocky Mountain Dark Red’ (light-colored leaves) were transplanted one plant per pot into 6-inch pots. Plants were fertilized with one of five constant liquid fertilizer levels (50, 100, 200, 300, or 400 ppm N). Plants were irrigated as needed using a drip system utilizing sump-pumps, and harvested six times, at two week intervals. At each harvest date, plant height (measured from the pot rim to the uppermost part of the plant) and plant diameter (measured at the widest dimension, turned 90 º, and averaged) were recorded. The experiment was a completely randomized block design with five single-plant replications of 5 treatments. The youngest fully expanded leaves were sampled from each replicate 2, 4, 6, 8, 10, or 12 weeks after transplanting. Harvested tissue was washed, dried, and ground to pass a ≤ 0.5 mm sieve. Tissue was then analyzed for macro nutrients at the N.C. Department of Agriculture Laboratory, Raleigh, NC.

Results and Discussion: Upper and lower limits were established for each element over time by analyzing the growth of ‘Rocky Mountain Dark Red’ (light-colored leaves) and ‘Tango Dark Red’ (dark-colored leaves) plants over time using relative growth rate (RGR) (equation 1). Data were tested by analysis of variance using general linear model (SAS Institute, Cary, NC) and means were separated by least significant differences (LSD) at $P \leq 0.05$. Plants fertilized with 50 ppm N had a significantly lower RGR. Therefore, the values from the next higher fertilizer rate (100 ppm) for the lower limit or our range. To determine the upper limit of the sufficiency ranges RGR was used. However, the fertilizer treatments 100 to 400 ppm were statistically similar. Drawing from experience,
cost of fertilizer, and environmental impacts, it was concluded that at 400 ppm plants were entering a situation of luxury consumption and the added cost of the fertilizer was not beneficial to quality. Therefore, the values from the next lower fertilizer rate (300 ppm) as the upper recommended limit of our range.

**Nitrogen. Light-colored cultivar.** Two weeks after transplant (referred to as young plants in the remainder of the text) the geraniums had a nitrogen concentration within the range of 3.55 to 4.10% (Fig. 1A). As the plants matured to 12 weeks of age after transplant (referred to as mature plants in the remainder of the text), the nitrogen concentration decreased linearly to the range of 2.80 to 3.50%.

**Dark-colored cultivar.** Young plant levels of nitrogen were between 3.91 to 4.15% and 3.16 to 3.28% for mature plants. Both the upper and lower limits decreased linearly over time (Fig. 1B).

These values, with the exception of the lower limit at the mature stage of 2.80% and 3.16% for the light and dark-colored cultivars, respectively, were similar to those previously published of 3.29 to 4.80% N (Table 1). In previous work, the age of the plant was not stated nor was the fertilization rate used to determine the optimal levels. These practices could account for differences from data in this study.

**Phosphorus. Light-colored cultivar.** The observed recommended range for phosphorus in young geraniums was between 0.32 to 0.49% and for mature plants between 0.17 to 0.35% (Fig. 1C). The upper limit decreased linearly and the lower limit decreased quadratically over time. The range for young plants was within previously published ranges. The lower limit range for mature plants in the current study of 0.17% P is lower than previous reports of 0.30 to 0.40%.

**Dark-colored cultivar.** Levels of phosphorus in young plants were between 0.44 to 0.64% and between 0.17 to 0.47 for mature plants. (Fig. 1D). Both the upper and lower limits decreased linearly over time. The upper limit for young plants was within published ranges with the exception of that reported by Dole and Wilkins [1]. The upper lower limit for mature plants (0.47%) was lower than any published ranges.

In the current study a low phosphorus containing fertilizer was used, and this may account for the reason why observed levels were lower than those previously reported. In addition, fertilization practices have changed significantly in the past 20 years from when growers used high P containing fertilizers such as 15-15-15 Geranium Special or 20-10-20. Higher levels reported with other studies may include luxurious uptake of P by the plant.

**Potassium. Light-colored cultivar.** For young plants the potassium levels were between 3.30 to 3.46% and for mature plants 2.12 to 2.53% (Fig. 1E). The upper and lower limits decreased linearly over time.

**Dark-colored cultivar.** Potassium levels for young plants were between 3.17 to 3.36% and 2.59 to 2.81% for mature plants (Fig. 1F). The upper and lower limits decreased linearly over time.
Ranges for potassium observed the current study were narrower, but fell within those previously reported by other researchers. Many of the nutritional values reported by Mills and Jones [4] were based upon sampling of actively growing plants and the upper level of 6.26% K may represent luxurious uptake of K by the plant.

**Literature Cited:**


**Equation 1.** Relative Growth Rate where $W1$ and $W2$ are the dry weight at weeks 2 and 12 weeks, respectively, and $T1$ and $T2$ are 14 and 84 days after transplant, respectively.

$$RGR = \frac{W_2 - W_1}{\sqrt{T_2 - T_1}}$$
Table 1. Comparison of sufficiency ranges for three essential elements for geraniums (*Pelargonium × hortorum*) with light-colored and dark colored leaves.

<table>
<thead>
<tr>
<th>Element</th>
<th>Dole and Wilkins</th>
<th>Fortney and Wolf</th>
<th>Kofranek and Lunt</th>
<th>Mills and Jones</th>
<th>Price et al. young*</th>
<th>mature*</th>
<th>young</th>
<th>mature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>3.80-4.40</td>
<td>3.30-4.80</td>
<td>3.30-4.80</td>
<td>3.29-4.80</td>
<td>3.30-4.80</td>
<td>3.55-4.10</td>
<td>2.80-3.50</td>
<td>3.91-4.15</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.30-0.50</td>
<td>0.40-0.67</td>
<td>0.40-0.67</td>
<td>0.30-1.24</td>
<td>0.40-0.67</td>
<td>0.32-0.49</td>
<td>0.17-0.35</td>
<td>0.44-0.64</td>
</tr>
<tr>
<td>Potassium</td>
<td>2.60-3.50</td>
<td>2.50-4.50</td>
<td>2.50-4.30</td>
<td>2.50-6.26</td>
<td>2.50-4.50</td>
<td>3.30-3.46</td>
<td>2.12-2.53</td>
<td>3.17-3.36</td>
</tr>
</tbody>
</table>

\*Light-colored-leaf cultivar.
\*Dark-colored-leaf cultivar.
\*2 weeks after transplant.
\*12 weeks after transplant.
Figure 1. Nitrogen, phosphorus, and potassium ranges for ‘Rocky Mountian Dark Red’ (light-colored cultivar) A, C, and E; and ‘Tango Dark Red’ (dark-colored cultivar) B, D, and F.
Increasing Irrigation Efficiency: Water Requirements of Petunia and Salvia

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Index Words: automation, irrigation, leaching, Petunia × hybrida, Salvia splendens

Significance to Industry: More efficient water use would reduce water needs for irrigation, as well as the potential for leaching and runoff of water and fertilizer. Using soil moisture sensors may help to achieve this goal: growth of salvia and petunia can be controlled by adjusting the amount of water the plants get using such sensors. Even rapidly growing plants needed surprisingly little water, from approximately 15 ml per plant per day during early growth to about 40 ml near the end of the experiment. Using soil water sensors to control irrigation may be an effective way to use water more efficiently and adjust the volume of the applied irrigation water automatically based on plant needs.

Nature of Work: Since manual irrigation is labor-intensive and repetitive, it is one of the first greenhouse tasks that should be automated. Although automating irrigation is easy, current systems are not necessarily efficient. The greatest challenge in setting up efficient irrigation systems is that there is little information on how much water plants actually need. More efficient irrigation systems would reduce the amount of water needed to produce a crop, while also reducing leaching and runoff of water and fertilizer.

There are a few problems that prevent growers from irrigating according to the actual water needs of plants. Since plant water use, and thus the required irrigation frequency, increases as plants grow, it is difficult to irrigate efficiently using a timer. In addition, timers do not adjust irrigation based on environmental factors such as light and humidity levels. The use of soil water sensors, such as ECH₂O probes (Decagon Devices, Pullman, WA), can overcome these problems. The basic idea behind using soil water sensors to control irrigation is simple: when plants use water, they take it up from the substrate, so the substrate water level drops. Soil water sensors detect these changes and can automatically turn on irrigation when the substrate water content drops below a grower-determined set-point. This results in frequent applications of small amounts of water, and the frequency of irrigation is adjusted automatically based on the rate of substrate water depletion. By irrigating with the amount of water actually needed by the plants, water use and leaching can be reduced greatly.

The objectives of this study were to determine whether ECH₂O-10 soil water probes can be used to automate greenhouse irrigation, and quantify water requirements of salvia and petunia.

Standard 1020 greenhouse trays were filled with a peat/perlite substrate (Fafard 2P, Fafard, Anderson, SC) and 35 g of incorporated 14-14-14 Osmocote
slow release fertilizer. One half of each tray was seeded with salvia (*Salvia splendens* ‘Bonfire’ the other half with petunia (*Petunia × hybrida* ‘Dreams salmon’). Both species were grown together in the same tray to assure that they were exposed to the same substrate water level. Substrate water levels were measured every 20 min with ECH₂O-10 soil water probes, connected to a datalogger. The datalogger then controlled irrigation by turning on a drip irrigation system that applied 30 ml of water per tray whenever the substrate water content was below the set point for a particular tray (Nemali, 2005). Set points were 9, 13, 17, 21, 25, 29, 33, and 37% substrate water content (v/v). Measurements included plant dry weight at 37 days after the start of the treatments, and the daily amount of water applied in each treatment. Water use efficiency (plant dry weight / liter of water) was calculated from these data. The volumetric water content of the substrate was measured weekly with a ThetaProbe (delta T devices) to check the accuracy of the ECH₂O-10 probes.

**Results and Discussion:** Initially, the automated irrigation system appeared to be working well, but after comparing the ECH₂O-10 measurements to data collected with the ThetaProbe, it became clear that not all ECH₂O-10 probes were working correctly. ECH₂O-10 measurements became less accurate during the course of the experiment. Thus, instead of analyzing plant growth as a function of the set point for the substrate water content, data were analyzed as a function of the amount of water applied to each treatment. The amount of water applied ranged from 8 to 23 liters/tray during the 37 day treatment period. Plant growth of both petunia and salvia was closely correlated with the amount of water applied \( r^2 \geq 0.92 \), Fig. 1. This indicates that plant growth can be controlled by adjusting the amount of irrigation. The total amount of water used per plant was surprisingly low. Plants with the most growth used approximately 1 liter of water/plant during the 37 day period, or on average 25 ml/day (Fig. 2). Water use efficiency was not affected by treatments and averaged 3.5 g/liter for both salvia and petunias. There was no leaching in any of the treatments, even though some trays remained very moist.

Although the performance of the ECH₂O-10 probes was disappointing, the data show that plant growth can be controlled by adjusting the amount of water applied. We do not recommend the ECH₂O-10 probes for irrigation control in greenhouses, but newer and better sensors are now available. Decagon Devices now has ECH₂O-5 and ECH₂O-TE probes, which have low sensitivity to temperature and EC and perform much better in soilless substrates than ECH₂O-10 probes. In addition to measuring the water content of the substrate, the ECH₂O-TE probes can measure the substrate EC, thus potentially allowing for control of both irrigation and fertilization. These probes may be interfaced with greenhouse control systems, which allows for completely automated control of irrigation, based on plant water needs. Such automated systems are likely to be much more water efficient than existing automated systems.

**Literature Cited:**

Figure 1. The correlation between the water quantity applied during a 37 day period and the final plant dry weight. Dry weights are the total for 12 plants, while the irrigation volume is the amount of water applied to those 12 plants.

\[
\text{Petunia DW} = 6.03 + 2.67 \times \text{volume} \\
\text{Salvia DW} = 1.20 + 3.31 \times \text{volume}
\]

\[r^2 = 0.92\]  
\[r^2 = 0.96\]
Figure 2. Daily irrigation volume during the experiment for plants in two treatments with good growth. Although there was a trend indicating increasing water needs during the experiment (due to increasing plant size), there are large day-to-day fluctuations in the volume of irrigation water applied. These fluctuations are at least partly due to changing weather conditions. The dotted line represents the average amount of water applied per plant per day. This makes it clear that applying the average amount of water each day would over-water the plants during the early part of production and underwater them later.
Photoperiod Induction, Mulch and Row Cover Effects on Fresh Cut Flower Production of *Rudbeckia hirta* L. ‘Irish Spring’

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Index Words: Photoperiod, *Rudbeckia hirta* ‘Irish Spring’, Mulch, Row Cover

Significance to Industry: Due to its long day photoperiod requirement for flowering, *Rudbeckia hirta* L. typically blooms early to midsummer. The normal *Rudbeckia* flowering schedule results in its availability as a fresh cutflower after peak market demand has diminished. Photoperiod induction, mulch and row cover treatments provide a means of obtaining an earlier bloom period coinciding with greater market opportunities for *Rudbeckia* cultivars.

Nature of Work: Fresh cut flower production is an important part of American agriculture. In the year 2000, wholesale value of fresh cut flower production reached 4.57 billion dollars in the United States (Nelson, 2003a). One of the most important aspects of production is the harvest of high quality floral crops at a time when the market reflects consistent consumer demand. Such demand typically peaks around major holidays such as Valentine’s Day and Mother’s Day (Monthly Retail Trade Survey, 2005).

*Rudbeckia* species are well known and widely used as ornamental bedding plants and fresh cut flowers. *Rudbeckia* spp. have the potential to produce multiple, marketable floral stems. Once flowering begins, *Rudbeckia hirta* L. may produce blooms until frost, however, at first harvest, flowering occurs outside of peak market demand.

Previous research suggests that photoperiod induction by means of night interruption or day length extension may affect the timing of floral initiation of *Rudbeckia* spp. and may affect floral quality (Murneek, 1936; Tanimoto and Harada, 1985; Harkess and Lyons, 1994b). If *Rudbeckia* can be forced to bloom earlier in the year, perhaps as early as Mother’s Day, without a significant loss in floral quality, demand for this crop may increase, production volume enlarged and profit potential improved.

Photoperiod studies have been the subject of horticultural research projects for decades. *Rudbeckia* was used regularly for research once it was discovered to be a long-day plant in the 1920’s (Garner and Allard, 1924). These former projects were primarily directed toward understanding floral initiation mechanisms of long day plants as it applies to production of greenhouse grown nursery crops. Photoperiod manipulation has not been used to the same extent for fresh cut flower production.

Traditionally, row covers have been used to increase earliness in vegetable crops (Hochmuth et al., 2000). Use of plastic film mulches in vegetable crops have
been shown to result in higher yields, earlier harvests, improved weed control and more efficient use of water and fertilizers (Lamont, 1999).

Cushman and others (2002) found that black plastic mulch and black plastic mulch with row covers produced higher yields than bare ground production of tomatoes (Lycopersicum esculentum Mill.) planted in early spring.

Black mulch and slit polyethylene tunnels have been used in bell pepper research. Row covers were determined to advance anthesis and delay harvest dates on the lower nodes and increased the duration of maturation over all branches and nodes (Gaye et al., 1992).

The objective of this study was to 1) examine the effect of photoperiod induction, mulch and row cover on Rudbeckia hirta 'Irish Spring' relative to earliness of bloom and 2) determine if blooms produced under certain growing conditions have sufficient postharvest life for use in floral markets.

Rudbeckia hirta 'Irish Spring' transplants were greenhouse-grown under two lighting regimes. Treatments were ambient light and ambient light plus 35 days with a 4-hour night interruption (NI). Night interruption was achieved with incandescent, 60-watt light bulbs. Transplants were set in the field at two locations on April 1 and April 5, 2006. Once plants were moved to the field they were arranged in a randomized complete block design with treatments consisting of bare ground (BG), black plastic mulch (BM), row cover and bare ground (RCBG) and row cover and black plastic mulch (RCBM). Row cover was clear, vented polyethylene. As each flower was harvested it was moved indoors, placed in distilled water at room temperature for postharvest evaluation.

**Results and Discussion:** Differences in height of transplants were noted prior to field transplanting. Thirty-five days of night interruption lighting produced transplants that were twice as tall as unlighted transplants (24.6 cm vs. 10.0 cm).

At Verona, there were no differences in days to first flower (DFF) or terminal bloom diameter (TBD). The average days-to-first-flower was 40.5. Only those plants receiving 35 NI bloomed. Unlit plants remained in rosette stage for the duration of the experiment. 75% of plants produced blooms in RCBM plots, 92% from RCBG, 50% from BM and 42% from BG. Terminal bloom diameter ranged from 12.0 cm to 12.9 cm with an overall mean diameter of 12.4 cm (Table 1). There was a difference in stem length at Verona (Table 8). All treatments were equally effective in increasing stem length compared to bare ground (BG) (Table 1). Stem length over all treatments was 43.0 cm. Range of stem length was 36.4 cm to 50.3 cm.

There were no differences in days to first flower (DFF) or stem length (SL) among treatments at Mayhew (Table 2). Days to flower ranged from 31 to 34 days after transplanting with a mean of 33.2 days to flower. Plants that received 35 NI flowered. Unlit plants remained in rosette stage for the experiment duration. 100% of potential blooms were harvested from RCBM plots, 92% from RCBG plots, 58% from BM plots, 33% from BG plots (Table 2).
Both row cover treatments were equally effective in obtaining maximum air temperature (MXAT) compared to the control (BG). Neither row cover treatment, however, was different from black mulch (BM). Maximum air temperatures ranged from 31.5 to 43.3°C (Table 3).

Mean air temperature (MAT) was increased by RCBM and RCBG but not by BM as compared to control (BG). Treatments RCBM and RCBG had significantly warmer air temperatures than treatments without row cover (BM, BG). Air temperatures ranged from 17.0°C to 19.8°C (Table 3).

At both locations, highest percentage blooms were harvested in plots with row cover. Plants receiving 35 days night interruption in the greenhouse bloomed much earlier than unlighted plants and only slightly missed target harvest date.

**Literature Cited:**


Table 1. Effect of Row Cover/Mulch Treatment on Days to First Flower (DFF) After Transplanting, Terminal Bloom Diameter (TBD), Stem Length (SL), Percent Blooms Harvested (BH), for *Rudbeckia hirta* L. ‘Irish Spring’ at Verona, MS.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>DFF</th>
<th>TBD (cm)</th>
<th>SL (cm)</th>
<th>BH (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Cover/Black Mulch</td>
<td>40.0</td>
<td>12.5</td>
<td>43.5ab</td>
<td>75ab</td>
</tr>
<tr>
<td>Row Cover/Bare Ground</td>
<td>40.0</td>
<td>12.9</td>
<td>50.3a</td>
<td>92a</td>
</tr>
<tr>
<td>Black Plastic Mulch</td>
<td>41.0</td>
<td>12.0</td>
<td>42.0ab</td>
<td>50b</td>
</tr>
<tr>
<td>Bare Ground</td>
<td>41.0</td>
<td>12.0</td>
<td>36.4b</td>
<td>42b</td>
</tr>
<tr>
<td>LSD (p ≥ 0.05)</td>
<td>NS</td>
<td>NS</td>
<td>8.4</td>
<td>36.5</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different.

Table 2. Effect of Row Cover/Mulch Treatment on Days to First Flower (DFF) After Transplanting, Terminal Bloom Diameter (TBD), Mean Stem Length (SL), and Percent Blooms Harvested for *Rudbeckia hirta* L. ‘Irish Spring’ at Mayhew, MS.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>DFF</th>
<th>TBD (cm)</th>
<th>SL (cm)</th>
<th>BH (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Cover/Black Mulch</td>
<td>34.7</td>
<td>11.9ab</td>
<td>44.1</td>
<td>100a</td>
</tr>
<tr>
<td>Row Cover/Bare Ground</td>
<td>31.4</td>
<td>11.7b</td>
<td>39.3</td>
<td>92a</td>
</tr>
<tr>
<td>Black Plastic Mulch</td>
<td>34.8</td>
<td>10.4c</td>
<td>40.2</td>
<td>58b</td>
</tr>
<tr>
<td>Bare Ground</td>
<td>34.8</td>
<td>12.7a</td>
<td>38.8</td>
<td>33b</td>
</tr>
<tr>
<td>LSD (p ≥ 0.05)</td>
<td>NS</td>
<td>0.86</td>
<td>NS</td>
<td>32</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different.

Table 3. Effect of Row Cover/Mulch Treatment on Maximum Air Temperature (MXAT) and Mean Air Temperature (MAT) on *Rudbeckia hirta* L. ‘Irish Spring’ at Mayhew, MS.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>MXAT (°C)</th>
<th>MXAT (°F)</th>
<th>MAT (°C)</th>
<th>MAT (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Cover/Black Mulch</td>
<td>43.3a</td>
<td>110.0a</td>
<td>19.8a</td>
<td>68.0a</td>
</tr>
<tr>
<td>Row Cover/Bare Ground</td>
<td>42.4a</td>
<td>108.0a</td>
<td>19.3a</td>
<td>67.0a</td>
</tr>
<tr>
<td>Black Plastic Mulch</td>
<td>37.4ab</td>
<td>99.0ab</td>
<td>17.4b</td>
<td>63.0b</td>
</tr>
<tr>
<td>Bare Ground</td>
<td>31.5b</td>
<td>89.0b</td>
<td>17.0b</td>
<td>63.0b</td>
</tr>
<tr>
<td>LSD (p ≥ 0.05)</td>
<td>7.8</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different.
**Hydrangea macrophylla Cultivar Potential for Floral Cut Stems**

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**Index Words:** Hydrangea macrophylla, cut stems, overwintering, stem counts

**Significance to Industry:** Hydrangea macrophylla can be protected during production in order to keep all potential flower buds viable. Either container production or field tunnel production in Kentucky will create product that is salable to the floral industry. Cultivar differences do occur and specific cultivars may move better in certain markets. Additional benefits will result from this experiment as plants age in the production system.

**Nature of Work:** Hydrangea macrophylla cultivars were evaluated for feasibility of Kentucky farms growing the crop for floral cut stems. Hydrangea cut flowers are currently being shipped from the West coast, Canada or Europe into Kentucky. Hydrangea macrophylla growing in Kentucky’s landscapes are not dependable to always flower in all locations. Nurseries have been able to market the species as container grown flowering plants. Nursery grown container plants receive winter protection that protects flower buds. Nursery production techniques were used to produce plants which could yield cut stems for the floral industry.

Four cultivars (Table 1) were placed in five gallon containers during summer 2003. These plants were overwintered in an unheated overwintering house covered with white opaque poly. Inside the house the plants were covered directly with another sheet of poly during the coldest months. Every bud produced a stem and flower during the summer of 2004. The evaluations of these stems included a stem count, stem length, flower diameter, and flower quality.

During the summer of 2004 an additional seven cultivars were containerized. All eleven cultivars were again evaluated for the same four characteristics during 2005.

If flower buds are protected using the overwintering practices of the container industry, can plants grown in the ground be protected in a similar manner. During the summer of 2004 ten cultivars (Table 2) were planting in the ground and the site was covered by an overwintering house. These plants were also covered by an additional direct covering during the coldest months. During 2005 the plants were evaluated for stem count, stem length, flower diameter, and flower quality.

**Results and Discussion:** Two growth types were represented in the four cultivars grown in containers and evaluated in 2004. The stiff growth of Masja produced fewer stems during its first full year of growth compared to the other growth type represented by Nikko Blue, Dooley and All Summer Beauty (Table 1). During 2005 Masja was comparable to the three other cultivars in stem count. Nikko Blue had the highest stem count in both years. Decauter Blue was injured...
and thus a reduced number of stems. Stem length was acceptable for each of the original four cultivars during both years. The additional seven cultivars were not as long as expected except for Mme. Emily Mouillere during this first year. Flower diameter during both years averaged between 4.8 inch and 6.1 inches depending upon cultivar. This is an acceptable size for the floral market. Floral rating is based on a scale of 0-5. Irregular flower were common during 2004’s evaluation as three of the cultivars were no better than 2.5. Masja was definitely the best of these cultivars for floral use. During 2005, all cultivars had a floral rating above 4 except for All Summer Beauty, Nikko Blue, and Decatur Blue. Acceptable product was produced on container grown plants. However, the plants cannot remain in production over an extended time and will have to be replaced.

The plants grown in the ground and covered by an overwintering house were also evaluated during 2005. Stem count in the ground did not match the production of plants in containers. Stem production by Mme. Emily Mouillere, Westfalen and Harlequin did not make double figures (Table 2). The average stem length tended to be short for industry standards across most cultivars. This may be a result of being in their first year of full growth. Average Floral diameter was acceptable for all cultivars as they averaged between 5.4 inches and 7.8 inches. All cultivars had an average floral rating above 4. We feel flowers with a 4 or 5 rating are acceptable for wholesale sales to wholesale or retail florists.

Table 1. Cut Stem characteristics from container grown *Hydrangea macrophylla* cultivars

<table>
<thead>
<tr>
<th>Name</th>
<th>Stem Count</th>
<th>Stem Length</th>
<th>Floral Diameter</th>
<th>Floral Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Summer Beauty</td>
<td>19.2 b</td>
<td>19.0</td>
<td>15.9</td>
<td>15.6</td>
</tr>
<tr>
<td>Masja</td>
<td>7.8 c</td>
<td>19.6</td>
<td>14.3</td>
<td>16.3</td>
</tr>
<tr>
<td>Dooley</td>
<td>21.8 ab</td>
<td>19.8</td>
<td>13.9</td>
<td>13.7</td>
</tr>
<tr>
<td>Nikko Blue</td>
<td>25.1 a</td>
<td>25.8</td>
<td>12.8</td>
<td>14.4</td>
</tr>
<tr>
<td>Fasan</td>
<td>15.3</td>
<td>12.2</td>
<td></td>
<td>6.2</td>
</tr>
<tr>
<td>Gen. Vic. DeVibrayé</td>
<td>15.9</td>
<td>13.0</td>
<td></td>
<td>6.1</td>
</tr>
<tr>
<td>Matilda G†teges</td>
<td>17.0</td>
<td>11.1</td>
<td></td>
<td>6.0</td>
</tr>
<tr>
<td>Mme. Emily Mouillère</td>
<td>18.3</td>
<td>14.3</td>
<td></td>
<td>5.9</td>
</tr>
<tr>
<td>Harlequin</td>
<td>24.0</td>
<td>11.6</td>
<td></td>
<td>5.6</td>
</tr>
<tr>
<td>Parzifal</td>
<td>29.2</td>
<td>13.5</td>
<td></td>
<td>5.6</td>
</tr>
<tr>
<td>Decatur Blue</td>
<td>8.2</td>
<td>9.0</td>
<td></td>
<td>5.4</td>
</tr>
</tbody>
</table>
Table 2. Cut stem characteristics from tunnel grown *Hydrangea macrophylla* cultivars.

<table>
<thead>
<tr>
<th>Name</th>
<th>Stem Count 2005 (No.)</th>
<th>Stem Length 2005 (in.)</th>
<th>Floral Diameter 2005 (in.)</th>
<th>Floral Rating 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nikko Blue</td>
<td>16.3</td>
<td>13.3</td>
<td>7.4</td>
<td>4.6</td>
</tr>
<tr>
<td>All Summer Beauty</td>
<td>16.0</td>
<td>13.0</td>
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<td>13.0</td>
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<td>7.3</td>
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<td>4.7</td>
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<td>9.9</td>
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</tr>
</tbody>
</table>
Evaluation of an Alternative, Sustainable Substrate for Use in Greenhouse Crops

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Index Words: peat moss, pine bark, whole pine tree, greenhouse crops, marigold, petunia, lantana

Significance to Industry: This study evaluated a new substrate for greenhouse production of herbaceous annual crops. Results varied with crop produced but indicated a potential for an alternative substrate composed of processed whole pine trees. This product could prove to be an acceptable and highly economical alternative to traditional peat moss based substrates.

Nature of Work: Peat moss and pine bark are the primary components of growth substrates in the production of greenhouse grown herbaceous annual crops. However, there is concern that the availability of bark for horticultural usage might be limited due to alternative demands (e.g. industrial fuel) and reduced timber production (1, 4). Other factors affecting the future availability of pine bark are reduced forestry production, and increased importation of logs already debarked (5). Also the rising transportation cost of peat moss is negatively affecting the bottom line of many greenhouse operators. A cost effective sustainable alternative substrate is processed whole pine trees. A study by Gruda and Schnitzler (3) demonstrated the suitability of wood fiber substrates as an alternative for peat-based substrates in cultivation of greenhouse tomato plants. A study conducted by Wright and Browder (6) showed that whole chipped pine logs (“clean chips”) could be used successfully for nursery crop production with attention to nutrition and irrigation. A study by Fain and Gilliam (2) successfully used substrates composed of whole pine trees to produce container-grown vinca (Catharanthus roseus). Use of these substrates resulted in plants that were similar in size to plants grown in pine bark alone. The objective of our research was to evaluate processed whole pine trees as an alternative growth substrate for greenhouse crops.

Studies were conducted at the Southern Horticultural Laboratory (SHL) in Poplarville, MS and Young’s Plant Farm (YPF) in Auburn, AL. Six to eight inch diameter loblolly pine (Pinus taeda L.) were harvested from a 10 year old planted pine plantation in south Mississippi. The entire tree including needles was fed through a drum chipper (Vermeer BC1000XL). Resulting chips were then further processed using a swinging hammer mill (C.S. Bell No. 30) to pass a 3/16”, 1/4”, or 3/8” screen. Substrates (Table 1) were amended per yd³ with 7 lbs dolomitic lime, 0.75 lbs micromax and 6 lbs Osmocote 15-9-12 Plus (3-4 month formulation). On 14 April 2006 (20 April 2006 for YPF) six inch containers (ITML AZF 0600) were filled with substrates and 4 plugs (288 cell) were planted into each container for begonia (Begonia x semperflorens-cultorum ‘Prelude Scarlet’), marigold (Tagetes patula ‘Little Hero Yellow’), petunia (Petunia x hybrida ‘Dreams...
Pink’ and vinca (*Catharanthus roseus* ‘Peppermint Cooler’), and 2 plugs (50 cell) for lantana (*Lantana camera* ‘Lucky Red Hot Improved’).

Containers were placed on a greenhouse bench and watered as needed. All treatments received supplemental liquid fertilization weekly for three weeks at 200 ppm nitrogen the first week and 300 ppm thereafter using 20-10-20 (Peters Peatlite). Data collected included substrate electrical conductivity and pH at 1 and 34 days after potting (DAP) (28 DAP for petunia), plant growth indices, leaf chlorophyll content (SPAD-502 chlorophyll meter), flower number and root rating (0 – 5 scale, 0 = no roots present at substrate container interface to 5 = roots present at all areas of the substrate container interface) at 34 DAT (28 DAP for petunia).

**Results and Discussion:** Due to publication space constraints, only the data for lantana, marigold and petunia from the SHL tests will be presented. Plants exhibited similar results at both test locations. At 34 DAP there were no differences in flower number for marigold; however, lantana grown in 100% whole tree substrates (1-3) had the fewest flowers (Table 1). Petunias grown in substrate 10, an industry standard peat blend substrate, had over twice the number of flowers than observed on plants grown in other substrates. Leaf chlorophyll content was similar for petunia, but marigold and lantana plants had a general trend of an increase in chlorophyll content with an increase in substrate peat moss content. In general, plants grown in whole tree substrates were smaller than plants in other blends, but plants increased in size with increasing peat moss percentage. At 34 DAP, all marigold plants were considered salable. However, at 28 DAP, petunias grown in substrates 1-6 were significantly smaller and considered un-salable than plants in substrates 7-10. There were no differences for root ratings with any species among treatments with the exception of lantana, which in substrate 1 had a lower root rating than substrates 7-10.

In conclusion the results of this experiment indicate that whole tree substrates, especially when combined with peatmoss are a potential alternative to conventional greenhouse substrates. More research is needed to establish fertilizer practices to address possible N immobilization that might occur with the whole tree substrates. Although there were no differences in tissue N concentration with petunias for any substrate at 28 DAP (data not shown) a nitrogen sink in the whole tree substrates early in the crop cycle could explain the differences in final growth.

**Literature Cited:**


### Table 1. Effects of processed whole tree substrates on growth of greenhouse grown herbaceous annuals.

<table>
<thead>
<tr>
<th>Substrate treatments</th>
<th>Marigold (34 DAP)</th>
<th>Lantana (34 DAP)</th>
<th>Petunia (28 DAP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPAD</td>
<td>Flower #</td>
<td>GI</td>
</tr>
<tr>
<td>1 - 100% 3/16&quot; whole pine tree</td>
<td>41.3</td>
<td>13.7</td>
<td>18.6</td>
</tr>
<tr>
<td>2 - 100% 1/4&quot; whole pine tree</td>
<td>41.1</td>
<td>15.0</td>
<td>18.0</td>
</tr>
<tr>
<td>3 - 100% 3/8&quot; whole pine tree</td>
<td>42.3</td>
<td>12.2</td>
<td>18.3</td>
</tr>
<tr>
<td>4 - 4:1 (v:v) 3/16&quot; whole pine tree:peatmoss</td>
<td>42.8</td>
<td>13.0</td>
<td>19.5</td>
</tr>
<tr>
<td>5 - 4:1 (v:v) 1/4&quot; whole pine tree:peatmoss</td>
<td>41.9</td>
<td>14.2</td>
<td>20.1</td>
</tr>
<tr>
<td>6 - 4:1 (v:v) 3/8&quot; whole pine tree:peatmoss</td>
<td>43.8</td>
<td>14.8</td>
<td>19.7</td>
</tr>
<tr>
<td>7 - 1:1 (v:v) 3/16&quot; whole pine tree:peatmoss</td>
<td>42.8</td>
<td>14.2</td>
<td>20.1</td>
</tr>
<tr>
<td>8 - 1:1 (v:v) 1/4&quot; whole pine tree:peatmoss</td>
<td>46.2</td>
<td>15.2</td>
<td>21.7</td>
</tr>
<tr>
<td>9 - 1:1 (v:v) 3/8&quot; whole pine tree:peatmoss</td>
<td>43.7</td>
<td>14.3</td>
<td>22.5</td>
</tr>
<tr>
<td>10 - 8:1:1 (v:v) peatmoss:perlite:vermiculite</td>
<td>49.6</td>
<td>15.3</td>
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</tr>
</tbody>
</table>

HSD\[^v\] = 4.2 5.5 2.3 0.6 6.8 6.7 7.1 0.71 7.0 4.7 3.8 1.2

\[^a\]Days after potting.

\[^b\]Leaf chlorophyll content determined using a SPAD-502 chlorophyll meter (average of 4 leaves per rep).

\[^c\]Growth Index = (width 1 + width 2 + height)/3.

\[^d\]Root rating 0 - 5 scale where 0 = no roots visible at substrate container interface and 5 = roots present in all portions of substrate/container interface.

\[^e\]Tukey’s honest significant difference (\(\alpha = 0.05\)).
Nutrient Deficiencies of Lantana ‘Athens Rose’

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Index Words: Nutritional Disorders, Hydroponics, Shrub Verbena

Nature of Work: Perennials are profitable crops to grow because of their popularity among consumers, and have subsequently become an important component of an ornamental plant producer’s inventory. In 2004 production totals of perennials were reported at $689 million, up 8% from the previous year, and are one of the fastest-growing segments of floriculture (7). With the popularity of perennials has come an increased demand for production information. Little information has been published regarding their mineral nutrition requirements, specifically nutrient foliar standards and nutrient deficiency symptoms. Most research in these areas has focused on annual floriculture crops (3, 8), leaving plant producers, researchers, and commercial laboratories to rely on experience or adapt recommendations from other floriculture crops.

Shrub verbena (Lantana hybrida) is a semi-woody shrub hardy to USDA Zones 8 through 11 and can be used as a containerized ornamental, hedge or groundcover. Lantana performs best in well drained slightly acidic soils, full sun conditions, and is sensitive to insect pests such as mites and whiteflies (4). Nutrient requirements for lantana vary by source. Tanaka (5) fertilized lantana in sand culture at 224, 672, 896, or 1120 mg•L^{-1} and produced the highest quality plants at 896 mg•L^{-1}, although producers should never grow lantana in 100% sand because of low cation exchange capacity and high bulk density. Fertilizer recommendations suggest N at 125 to 150 mg•L^{-1} for constant liquid fertilization or weekly applications of N at 175 to 200 mg•L^{-1} (1). Even at a moderate fertility level, nutrient deficiencies can occur during production, the symptoms of which have been reported as chlorosis of the lower leaves (N or Mg deficiency) (R. Schoellhorn, personal communication). Therefore, our research will generate visual symptoms of nutrient deficiencies in the chronological order in which they appear from incipient to advanced stages for N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, and B in Lantana ‘Athens Rose’.

Unrooted stem cuttings of Lantana ‘Athens Rose’ were inserted in Oasis horticultural foam (3.7 x 3.0 x 1.8 cm) (Smithers Oasis, Kent, Ohio) containing only Ca and Mg from dolomitie limestone on October 17, 2005. Cuttings were fertilized at each watering with N at 200 mg•L^{-1} using 13N-0.88P-10.8K (13-2-13 (TotalGro, Winnsboro, La.) until roots were visible at the edges of the rooting cube. On November 19 cuttings were pinched by removing 2 cm of growth from the terminal tip. After establishment, plants were transplanted on December 15 into 4.87-L aluminum painted plastic tubs containing a complete nutrient formula. Plants were subjected to a complete nutrient formula for approximately two weeks in order to have sufficient biomass for tissue sampling. On January 5, 2006 all treatments were induced that included a complete nutrient formula and complete minus one of the nutrients N, P, K, Ca, Mg, S, B, Cu, Fe, Mn and Zn (2). Six replications, each consisting of one tub with six rooted cuttings, were assigned to 12 treatments.
Plants were monitored daily to document and photograph sequential series of symptoms on youngest, young, recently mature, and mature leaves as they developed. Plants within each deficiency treatment were grown until the first symptom appeared relative to the control. At that point, recently fully expanded leaves were sampled from the deficient treatment and from the control treatment (three replications of each experimental unit). Once symptoms advanced, a second set of leaf samples were collected. Plant tissue was dried for shoot dry weight and foliar analysis.

All the data were subjected to ANOVA using PROC GLM SAS program (SAS Inst., Cary, N.C.). Where the F test indicated evidence of significant difference among the means, LSD ($P \leq 0.05$) was used to establish differences between means.

**Results and Discussion:** The number of days to each symptom refers to time from the start of deficiency treatments (Fig. 1). Initial and advanced shoot dry weight comparisons to the control are indicated in Figure 2. *Lantana* ‘Athens Rose’ appears to be most sensitive to Fe deficiency due to the rapid appearance of symptoms 6 days after the initiation of treatment. Plants were moderately sensitive to N, Mg and Ca that followed at day 7 and K, P and S at day 10. Plants were fairly resistant to Mn, Zn and B (day 18) and Cu was the slowest at day 20. After initial symptoms appeared on K and P deficient plants, advanced symptoms did not appear until days 54 and 56, respectively. Similar related results occurred when Tanaka and Sano (6) did not provide P and K to lantana plants grown in sand and reported that K deficiency had no effect on growth and P deficiency was not observed. During the initial stage, B, Ca, Fe, N, P, and S deficiencies resulted in lighter plants when compared to the control, and Cu, Fe, and S deficiencies resulted in notable plant weight loss as an advanced symptom (Figure 2).

Synoptic and unique visual symptoms for *Lantana* ‘Athens Rose’ plant were as follows: N- compressed axillary shoots with dull, uniform yellow mature leaves; P- recently mature leaves had a band of interveinal chlorosis along margin with a glossy sheen; K- mature leaves expressed interveinal chlorosis along margins; Ca- young and youngest leaves were curled downward; Mg- recently mature leaves had splotchy chlorosis with a concave leaf structure; S- older leaves were cupped inward at the midrib; B- all leaves had a glossy sheen with necrotic tips on young leaves; Cu- mature leaves had bands of chlorosis and young leaves were contorted; Fe- recently mature leaves expressed splotchy interveinal chlorosis while the young and youngest leaves had yellow chlorosis with green tips; Mn- all leaves were a lighter shade of green compared to the control; Z- mature and recently mature leaves had intermeinal chlorosis forming along the margins and young leaves were strap-like

**Significance to the Industry:** Fertility monitoring and management for lantana requires a balancing of the plant’s needs. Growers must be aware and manage the root substrate pH, electrical conductivity (EC) and provide adequate, but not excessive, levels of all essential elements. Nutrient deficiency descriptions are unavailable for most floriculture crops, yet growers must often make quick diagnoses. This study determined and discussed the progression of visual
symptoms of nutrient deficiencies in lantana. For actually growing young plants lantana appears to be most sensitive to Ca, Fe, N and Mg. Using a plant diagnostic lab to identify the source of problems is still the best way to ensure accurate diagnoses, since many nutritional, physiological, insect and disease problems can mimic each other. In order to help prevent the development of deficiencies, minimal critical tissue levels have to be determined for adaptation by the greenhouse industry for nutritional monitoring.

Acknowledgements: The authors gratefully acknowledge Maryah Williams for her technical assistance and plant material from Emerald Coast Growers, Pensacola, FL. Appreciation is also expressed to Smithers-Oasis for providing the rooting substrate.

Literature Cited:
Figure 1. Days to develop specific initial nutrient deficiency symptoms or necrosis for *Lantana* ‘Athens Rose’.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Days to Develop Symptoms</th>
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<td>Ca</td>
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<td>Mn</td>
<td></td>
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<tr>
<td>Cu</td>
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</tr>
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</table>

Figure 2. Shoot dry weight of nutrient deficient plants of *Lantana* ‘Athens Rose’ expressed as a percentage of control plants at initial and advanced stages. NS, *, ** denotes not significant at $P \leq 0.05$, significant at $P \leq 0.05$ and $P \leq 0.01$, respectively.
Nutrient Deficiencies of Yellow Shrimp Plant

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Index Words: Nutritional Disorders, Pachystachys lutea, Lollipop Plant

Nature of Work: Perennials are profitable crops to grow because of their popularity among consumers, and have subsequently become an important component of an ornamental plant producer’s inventory. In 2004 production totals of perennials were reported at $689 million, up 8% from the previous year, and are one of the fastest-growing segments of floriculture (6). With the popularity of perennials has come an increased demand for production information. Little information has been published regarding their mineral nutrition requirements, specifically nutrient foliar standards and nutrient deficiency symptoms. Most research in these areas has focused on annual floriculture crops (5, 7), leaving plant producers, researchers, and commercial laboratories to rely on experience or adapt recommendations from other floriculture crops.

Yellow shrimp plant (Pachystachys lutea Nees.) is a versatile tropical perennial hardy to USDA Zones 9 through 11 and can be used as a containerized ornamental or as a landscape item in mass, borders, hedges, or as a specimen plant. Yellow shrimp plant performs best in moist, acidic to slightly alkaline soils, full to part sun conditions, and is sensitive to insect pests such as aphids, mealybugs, mites, scale, and whiteflies (1).

Fertilizer recommendations are limited for this herbaceous plant, however studies have shown it to perform best in substrates low in organic matter. Yellow shrimp plants grown in substrates containing ≥ 70% compost had a smaller leaf area with a lower plant dry weight when compared to plants grown in substrates containing no compost (9). Will (8) showed that high rates of fertilizer increased growth of yellow shrimp plants in peat-based substrates. Pederson (4) reported that more flowers were produced with the darkest leaves when the nirogen (N) concentration was doubled (Pederson, 1975). Form of N also had an impact on growth. When ammoniacal nitrogen was greater than 30% of the total N, leaf number was reduced, while low concentrations of fertilizer with 60% nitrate nitrogen produced the greatest number of flowers and the longest flower length (3).

Nutrient deficiencies can also occur during production, especially during winter months when greenhouse night temperatures are below 60 F. Common symptoms include intervenal chlorosis of the young leaves and lower leaf yellowing (R. Schoellhorn, personal communication). Therefore, our research will generate visual symptoms of nutrient deficiencies in the chronological order in which they appear from incipient to advanced stages for N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, and B in yellow shrimp plants.

Unrooted stem cuttings of yellow shrimp plants were inserted in Oasis horticultural foam (3.7 x 3.0 x 1.8 cm) (Smithers Oasis, Kent, Ohio) containing
only Ca and Mg from dolimitic limestone on December 16, 2005. Cuttings were fertilized at each watering with N at 200 mg•L\(^{-1}\) using 13N-0.88P-10.8K (13-2-13 (TotalGro, Winnsboro, La.) until roots were visible at the edges of the rooting cube. On January 18, 2006 cuttings were pinched by removing 2 cm of growth from the terminal tip. After establishment, plants were transplanted on February 15 into 4.87-L aluminum painted plastic tubs containing a complete nutrient formula. Plants were subjected to a complete nutrient formula for approximately two weeks in order to have sufficient biomass for tissue sampling. On March 9 all treatments were induced that included a complete nutrient formula and complete minus one of the nutrients N, P, K, Ca, Mg, S, B, Cu, Fe, Mn and Zn (2). Six replications, each consisting of one tub with six rooted cuttings, were assigned to 12 treatments.

Plants were monitored daily to document and photograph sequential series of symptoms on youngest, young, recently mature, and mature leaves as they developed. Plants within each deficiency treatment were grown until the first symptom appeared relative to the control. At that point, recently fully expanded leaves were sampled from the deficient treatment and from the control treatment (three replications of each experimental unit). Once symptoms advanced, a second set of leaf samples were collected. Plant tissue was dried for shoot dry weight and foliar analysis.

All the data were subjected to ANOVA using PROC GLM SAS program (SAS Inst., Cary, N.C.). Where the F test indicated evidence of significant difference among the means, LSD (\(P \leq 0.05\)) was used to establish differences between means.

**Results and Discussion:** The number of days to each symptom refers to time from the start of deficiency treatments (Fig. 1). Initial and advanced shoot dry weight comparisons to the control are indicated in Figure 2. Yellow shrimp plants appear to be most sensitive to N deficiency due to the rapid appearance of symptoms 5 days after the initiation of treatment. Plants were moderately sensitive to Fe and Zn with symptoms that followed at day 7 and Ca and S at day 9. Plants were fairly resistant to K and Cu (day 11), Mn (day 12), and Mg and P on day 13. Boron was the slowest at day 21. During the initial stage, all nutrient deficiencies resulted in similar dry weights when compared to the control except potassium-deficient plants which were heavier, while Cu deficiency resulted in notable plant weight loss as an advanced symptom (Figure 2).

Synoptic and unique visual symptoms for yellow shrimp plant were as follows: N- young leaves were a uniform bright yellow with necrotic brown spots between veins; P- recently mature leaves were curled inward with interveinal chlorosis along the margins and young leaves had wavy margins that curled at the tip; K- internodes were stretched with upward angled young and youngest leaves, Ca- young and youngest leaves were cupped downward; Mg- young and recently mature leaves had interveinal chlorosis with puckered mature leaves; S- recently mature leaves had patches of yellowish-green chlorosis; B- swollen brown root tips with downward cupped young and recently mature leaves; Cu- young leaves with bright yellow tips and slender leaves; Fe- youngest leaves had lime-green interveinal chlorosis along the margins; Mn- recently mature leaves were curled...
at the tips; Zn- young and recently mature leaves exhibited patchy chlorosis and interveinal chlorosis along the margins

Significance to the Industry: Fertility monitoring and management for yellow shrimp plant requires a balancing of the plant’s needs. Growers must be aware and manage the root substrate pH, electrical conductivity (EC) and provide adequate, but not excessive, levels of all essential elements. Nutrient deficiency descriptions are unavailable for most floriculture crops, yet growers must often make quick diagnoses. This study determined and discussed the progression of visual symptoms of nutrient deficiencies in yellow shrimp plant. For actually growing young plants yellow shrimp plant appears to be most sensitive to N, Ca, Fe, S and Zn. Using a plant diagnostic lab to identify the source of problems is still the best way to ensure accurate diagnoses, since many nutritional, physiological, insect and disease problems can mimic each other. In order to help prevent the development of deficiencies, minimal critical tissue levels have to be determined for adaptation by the greenhouse industry for nutritional monitoring.

Acknowledgements: The authors gratefully acknowledge Maryah Williams for her technical assistance and plant material from Hachett Creek Farms, Gainesville, FL. Appreciation is also expressed to Smithers-Oasis for providing the rooting substrate.

Literature Cited:
**Figure 1.** Days to develop specific initial nutrient deficiency symptoms or necrosis for yellow shrimp plants.

**Figure 2.** Shoot dry weight of nutrient deficient yellow shrimp plants expressed as a percentage of control plants at initial and advanced stages. NS, * denotes not significant at $P \leq 0.05$ and significant at $P \leq 0.05$, respectively.
Florida Coreopsis (*Coreopsis floridana*): A New Fall-flowering Perennial

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**Index Words:** native plant, wildflower, landscape, restoration

**Significance to Industry:** Native wildflowers are being increasingly used in European-style and low input gardens as well as for large and small scale restoration of habitats and natural areas. One candidate for these uses is Florida coreopsis. Florida coreopsis can be started from seed under greenhouse conditions in January in north Florida and result in a #1 container ready for fall shipment as the flower stems begin to bolt and set buds. Divisions of larger plants are a viable form of vegetative propagation as well.

**Nature of Work:** The growing demand for new landscape crops fuels the need to consider various sources for potential plant material. Native plants are being used in an ever increasing manner in European-style gardens and for restoration action (4). McMahan states that there are historical, cultural, and horticultural reasons for renewed interest in the use of natives in gardening to recapture ‘wild areas’ focusing on wildlife habitats.

Various organizations are working to release new cultivars of native plant material. The USDA Plant Materials Centers recently initiated three ‘pre-varietal’ release stages of native plants to provide germplasm with landscape potential before completing the formal evaluation resulting in a varietal release (2). Selection of various native perennials and short-lived perennials in the “Raider Wildflower Collection” program from Texas have been evaluated and formally released or targeted for release and include *Oenothera speciosa* (‘Raider Rose’), *Oenothera elata* (‘Matador’s Gold’), *Salvia farinacea* (‘Texas Storm’), *Zinnia angustifolia* (‘Raider Sunrise’), and *Melampodium leucanthum* (‘Plains’) (3). At the North Florida Research and Education Center in Quincy, Florida coreopsis has been seed propagated for use in field plantings and in containers since 2004. Information and observations about propagation, production, landscape use, and pests of Florida coreopsis are discussed below.

**Results and Discussion:** Florida coreopsis, (*Coreopsis floridana*, E.B. Smith), also known as Florida tickseed, is an endemic species found mainly in the Florida peninsula and Gulf-bound counties of the Big Bend. It naturally occurs in sunny, moist habitats such as wet flatwoods, moist prairies, cypress bogs, and roadside ditches and swales (5, 7). Plants do not tolerate salt or brackish water, and may be burned by salt-laden wind (1).

Florida coreopsis is known to be hardy in USDA Cold Hardiness Zones 8 to 10 (8). Work by Smith (6) states that *C. floridana* almost certainly was derived from *C. linifolia* (Texas tickseed) and perhaps *C. gladiata* (Coastalplain...
coreopsis), both of which are hardy into USDA Cold Hardiness Zone 7 (7). Survival of Florida coreopsis north of Zone 8 will be investigated.

Florida coreopsis has long, narrow leaves (up to 9 inches long and 0.875 inches wide) that emerge in spring to form a low-growing clump. Leaves are medium green in color and somewhat thick and leathery. Linear to slightly oblanceolate leaves alternate and are principally on the lower portion of the plant (8). Upper leaves on the long flower stalks are small and closely attached to the stem (5). Clumps of foliage do not spread aggressively even though most plants are perennial.

Florida coreopsis blooms over a 6- to 8-week period starting in early October. The airy “panicles” of bright orange-yellow flowers are produced on stout stems over 3-feet tall. Each stem typically produces 6 to 12 flowers but as many as 23 flowers have been noted on a single stem. Up to 15 flower stems form on a typical plant growing in a #3 container. Flowers are 1.5 to 2.5 inches in diameter with 8 symmetrical orange-yellow ray flowers (petals) surrounding the dark purple disc flowers (5). The prominent flower buds are burgundy to purple, with each about 0.4 inches long and wide, adding ornamental interest even before the flowers open. After petals drop, the developing seed head, generally 0.4 inches wide and 0.6 inches long, is also burgundy to purple, thus extending the plant’s attractiveness. Seeds, 0.035 inches wide by 0.07 inches long, with a seed weight of 1 oz = 30,500 seed; are highly viable (about 90% pure live seed). Although fresh seed is highly viable, reseeding in field plots is almost nonexistent.

**Propagation and production.** Seed heads can be harvested when mature in late fall, and seeds removed and stored. Seed heads are mature when they turn dark brown and appear dry. Soon after that, they open and seed are easily dispersed. Seed should be dried fairly quickly after harvest as moisture deteriorates seed quality. Unless seed will be sown soon after harvest, store seed in a cool, dry place. Plant seed in plug trays or cell packs using any standard germination substrate. Divisions of larger plants are a viable form of vegetative propagation as well. Two months after dividing the crowns of two-yr-old plants in #3 containers into quarters and repotting the divisions in #1 containers, 83% had survived. During the same period six of seven, or 86%, undivided #3 containers survived.

Full sun and a moderate fertilization level are indicated for production of Florida coreopsis. Use a well-drained substrate, and irrigate the plants often enough so that the substrate remains moist. Developing flower stems may be sheared at 6 to 12 inches, and a second group of flower stems will develop and mature at a lower height. Florida coreopsis response to plant growth regulators is unknown.

Seeds sown in January in the greenhouse, with liners transplanted to #1 containers in mid-late March, will yield full #1 plants by fall. Later seeding should result in smaller mature plants while also reducing production time. Florida coreopsis should be marketed in fall, and shipped as flower stems develop.
Landscape use. Florida coreopsis should be grown in full sun in any good garden soil. Avoid planting it in dry soils, or provide irrigation, especially during drought. This plant will be an unobtrusive part of the garden from spring through early fall, when flower stems emerge.

Pests. Alternaria leaf spot occurs periodically. Use an appropriate fungicide according to label recommendations to control this disease. Deer might feed on foliage and flowers.

Availability. Florida coreopsis currently is available from a few wholesale nurseries specializing in native plants. To trial small numbers of plants under production conditions or in demonstration gardens, please contact the authors.

Literature Cited:
4. McMahan, L.R. 2006. Understanding cultural reasons for the increase in both restoration efforts and gardening with native plants. Native Plants J. 7:31-34.
Hybrid Lily Cut Flower Research in Mississippi

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Index Words: Cut flower, field production, fresh flower, hybrid lily, Asiatic lily, Oriental lily

Significance to Industry: A survey of Mississippi consumers reported that they would pay a premium to purchase fresh, cut flowers that were grown in Mississippi (4). The survey indicated that the flowers that Mississippi consumers most often purchased are roses, followed by daisies, carnations, irises, lilies, and gladiolas. They also reported that Mississippi consumers would pay a premium price for flowers with fragrance. Hybrid lilies have become an important cut flower crop in the United States, and high quality, fragrant hybrid lilies can be grown in Mississippi (5). The USDA reports a wholesale value of $78,169,000 for cut flower hybrid lilies produced in the U.S. in 2004 (2). Asiatic and Oriental hybrids are popular in the market due to their large, colorful, fragrant blooms. Other hybrids such as the LA (longiflorum x asiatic) and OT (oriental x trumpet) are becoming more readily available to growers. The rapid introduction of new cultivars by breeders offers many promising but unknown cultivars for growers to produce.

Nature of Work: In 2003 the United States imported cut flowers valued at more than $611 million while U. S. production of cut flowers was estimated to be valued at $421 million (3). The value of cut flower production in Mississippi accounts for 0.2% of the value of all floriculture and nursery crops grown in the state (1). The objective of this trial was to evaluate the plant growth parameters of stem length and diameter, number of blooms per stem, and time required for harvest of 10 OT hybrid, 26 Oriental, 12 LA hybrid, and four Asiatic lily cultivars. The trial was conducted at the North Mississippi Research & Extension Center in Verona, Mississippi. Verona is in hardness zone 7b and AHS heat zone 8. In 2005 the average maximum and minimum temperatures from May 11-20 were 83.8 and 59.3 °F, respectively, and from June 11-20 they were 85.4 and 65.6 °F. The bulbs, obtained from Zabo Plants, were planted in bulb crates (14.5 x 22 x 8 inches) on March 30, 2005, and grown in a shade house. Lily stems were harvested as soon as color appeared on the first bloom. Stems were cut at the soil line, and stem diameters were measured at the base of the stem. The stem length was measured from the base of the stem to the upper edge of the bloom.

Results and Discussion: The harvest period for the lilies in this trial that were planted on March 30 started on June 8 and ended July 8, 2006. The LA and Asiatic hybrid cultivars plus the OT hybrids, ‘Ohara’ and ‘Go for Gold’, were the cultivars in this trial required the fewest days from planting the bulbs in the crates until harvest, 70.0 – 76.5 days. The Oriental hybrids required the longest time to grow to harvest, 82.0 - 97.5 days. Among the Oriental cultivars, ‘Armonia’ and ‘Valdemar’ required the fewest days to harvest. The Asiatic and LA hybrids were harvested from June 8 – 14. The Oriental hybrids were harvested from June 20 – July 8 and the OT hybrids were harvested from June 8 – 28.
The Oriental cultivar, ‘Pranese’, produced stems statistically longer than all other cultivars except ‘Natal’. The stem length of cultivars ‘May Tay’, ‘Lucera’, and ‘Caruso’, at 26 inches, were the shortest Oriental cultivars in the trial. The stem length of ‘Tinos’, an Asiatic hybrid, averaged 23 inches and was the shortest lily in the trial.

In general, the stem diameters of the OT hybrid cultivars were greater than the other lilies in this trial. The basal stem diameter of ‘Alusta’ was the largest in the trial at 0.77 inches. ‘Caruso’, ‘May Tay’, and ‘Cornas’, Oriental hybrids, produced the smallest stem diameters in the trial, 0.32 inches.

The OT hybrid ‘Alusta’ produced ten blooms per stem, which was the highest number of blooms of all the cultivars in this trial. The cultivars ‘Soprano’ and ‘Belladonna’ had the fewest blooms per stem in the OT hybrid group. The Asiatic cultivars averaged 4 blooms per stem. The number of blooms among the LA hybrid cultivars ranged from 7 – 2.8 blooms per stem. ‘Pantanal’ produced the most blooms of the LA hybrid cultivars at 7 per stem. The number of blooms for the Oriental hybrids ranged from 7.5 to 1.7.

All of the hybrid lilies in this trial produced acceptable stem lengths and diameters. ‘Brenta’ was the only cultivar planted that did not produce blooms. Considerations of bloom color, number of blooms per stem, and harvest timing will guide growers in cultivar selection. This trial was conducted during the spring before the summer heat could affect plant growth. Bulbs stored in a cooler for a later planting date could well be affected by longer day lengths and higher temperatures.

**Literature Cited:**

Table 1. Bloom description, bloom number per stem, and days required from planting to harvest of hybrid lily cultivar grown at the North Mississippi Research & Extension Center in Verona, Mississippi, 2005.

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<th>Cultivar</th>
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<th>Bloom description</th>
<th>Blooms per stem</th>
<th>Days required to harvest</th>
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<tr>
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<td>4.1 h-l</td>
<td>76.0 mn</td>
</tr>
<tr>
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<td>Red</td>
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<td>73.3 op</td>
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<td>Salmon</td>
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<td>74.0 n-p</td>
</tr>
<tr>
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<td>Asiatic</td>
<td>Red/yellow/white</td>
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<td>70.6 rs</td>
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<td>LA Hybrid</td>
<td>Pink</td>
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<td>75.0 m-p</td>
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<tr>
<td>Cevennes</td>
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<td>4.6 f-k</td>
<td>73.1 o-q</td>
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<tr>
<td>Courier</td>
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<td>Creme</td>
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<td>70.2 s</td>
</tr>
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<td>93.0 c-e</td>
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<td>97.0 ab</td>
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### Table 2. Average stem length and diameter of hybrid lily cultivars grown at the North Mississippi Research & Extension Center in Verona, Mississippi, 2005.

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<td>0.40 i-o</td>
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<td>0.40 i-o</td>
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*Mean comparison within columns by Fisher’s Protected LSD at P=0.05. Means with the same letter do not differ at the 5% significance level.*
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<th>Container</th>
<th>Type</th>
<th>Value</th>
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Effects of Fertilization on Productivity and Vase Life of Greenhouse Cut Roses

Amanda Chau and Kevin M. Heinz
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Index Words: Fertilizer, Rosa hybrida, Plant Productivity, Leaf Greenness, Vase Life

Significance to Industry: Reduction of fertilizer input during production can address both water quality and pest management issues only if it does not adversely affect crop growth and productivity. In this study, we evaluated the effects of fertilization on rose [Rosa hybrida cv. ‘Tropicana’ on ‘Dr. Huey’ rootstock] yield, quality, and post-harvest longevity (vase life). We measured the effect of fertilization level on number of flowering shoots produced, length of flowering shoots, number of petals per flower, leaf greenness, and vase life. By lowering fertilization to 75 ppm N, 50% of the recommended level, we were still able to maintain crop productivity or quality. Reducing fertilization would significantly reduce fertilizer input into the production system and could also be a useful tactic in an integrated pest management program for managing twospotted spider mite (TSSM) on greenhouse cut roses.

Nature of Work: Fertilizers are extensively used to ensure production of high quality crops in greenhouse ornamental production. In response to environmental concerns and governmental regulations, best management practices seek to reduce fertilizer input and minimize runoff from agricultural crops (6, 7). On potted chrysanthemum, we demonstrated that fertilization could be lowered to a level that reduces WFT population growth, but still maintains plant productivity (2). On cut roses, we showed that lowering fertilization to 50% of the recommended level reduces the number of TSSM eggs by 26.8% (3). A previous study showed that yield and leaf nitrogen content of roses, Rosa hybrida L. cv. ‘Royalty’, do not increase beyond 90 ppm N (1). The author suggested that fertilization could be lowered to 90 ppm N, below the recommended range (150 to 250 ppm N) for commercial cut rose production (4), without adversely affecting rose yield.

In our study, we treated roses with four fertilization levels: 50, 75, 100, and 125% of the recommended level (150 ppm N). Reverse-osmosis-filtered tap water (RO water) was used to make the fertilizer solutions and water the plants. We grew our roses as a cut flower crop in the greenhouse following conventional practices (5). Individual bare-root rose plants (R. hybrida cv. ‘Tropicana’ on ‘Dr. Huey’ rootstock, grade #1) were grown in 14-L, plastic nursery-containers in soilless potting mix, pine bark, and sand (3:1:1, by volume). Containers were placed on raised greenhouse benches, 3 abreast and spaced 45-cm apart. Twenty-four rose plants were used for the experiment and each plant was a replicate. We used a randomized design with three replicates per fertilization level per bench, totalling 6 replicates per fertilization level. A water soluble, complete and commercially available fertilizer (Peters Excel 15-5-15 Cal-Mag,
The Scotts Co., Marysville, OH) was used to maximize the applicability to rose growers. Each plant was fertilized three times a week with 1 L of fertilizer solution. To reduce salt accumulation in the growing medium, plants were watered with 1.5 L of RO water once a week, two days after the third feeding.

To keep the plants free of thrips and spider mites, abamectin (Avid® 0.15 EC, Syngenta Crop Protection, Inc., Greensboro, NC, USA) was applied at the recommended rate of 0.62 ml/l to each plant at the start of the experiment. The plants were monitored for thrips and spider mites throughout the experiment to determine if additional insecticide applications were needed. We harvested and pruned the roses following conventional practices (4, 5) to produce synchronized flushes of growth and flowering. We began to harvest flowering shoots when the flowers were fully open. We measured the length of the harvested shoots and counted the number of flowering shoots produced per plant, and the number of petals per flower. To detect changes in leaf greenness, relative leaf chlorophyll levels of 5-leaflet leaves from individual harvested shoots were measured with a SPAD-502 portable chlorophyll meter. Two flushes were produced during the experiment and each flush occurred on average every 38.5 days. All flowering shoots were harvested within a two-week period. Average temperature and relative humidity inside the greenhouse during the experiment were 29.8 °C and 73.1% RH.

To evaluate the effect of fertilization on vase life of cut roses, two flowering shoots were randomly harvested from each plant and these cut roses were moved from the greenhouse to an indoor environment. We harvested each flowering shoot when the sepals of the flower began to separate from the petals and were horizontal to the stem, a stage when cut roses are usually harvested for local market (4). We re-cut each shoot to a length of 25 cm and stripped all leaves from the shoot leaving only the upper three leaves. Cut roses were transferred to a 450 ml plastic cup with 400 ml of RO water (4 stems per cup) and kept under fluorescent lighting within an office environment. Average temperature and relative humidity inside the office were 22.8 °C and 50.8% RH. The vase life was the total number of days the flowers were kept in the office until they were judged to be unattractive. A cut rose was considered unattractive when the petals began to lose turgidity and turn brown, the petals began to drop, or the flower developed a bent neck, whichever came first. All plant measurements were analysed using repeated measures one-way ANOVA with fertilization level as the main factor.

**Results and Discussion:** We found no significant fertilization effects on the yield of cut roses. There were also no significant differences in the number of flowering shoots produced per plant, length of flower shoots, and number of petals per flowers among fertilization levels (all P values > 0.05). Numbers of flowering shoots produced per plant did not differ between harvests (Table 1). Although the number of petals per flower and flowering shoot length from the 2nd harvest were greater than those of the 1st harvest (Table 1), these parameters were not influenced by fertilization level and there were no significant interactions between harvest and fertilization level (all P values > 0.05). The effect of fertilization on relative leaf chlorophyll levels was not consistent. Lowering fertilization to 50% of the recommended level did not affect leaf chlorophyll level in one harvest.
but did slightly reduce leaf chlorophyll level in another (Figure 1). Vase life was about 11.7 ± 0.1 days (mean ± SE, n = 48) and did not differ among fertilization levels or harvests and no significant interaction was found between harvest and fertilization level (all P values > 0.05). Lowering fertilization to 75 ppm N, 50% of the recommended level did not adversely affect rose productivity, quality, or vase life and would significantly reduce fertilizer input into the production system. Reducing fertilization could be a useful tactic in an integrated pest management program for managing twospotted spider mites (TSSM) on roses.

Acknowledgements: The authors would like to thank the USDA-ARS Floriculture and Nursery Research Initiative and the Texas Department of Agriculture- Texas-Israeli Exchange and U.S./Israel Binational Agricultural Research and Development Program for providing financial support and Ran-Pro Farms, Inc. for donating bare-root rose plants.

Literature Cited:

Table 1. Differences in yield and quality of cut roses among harvests.

<table>
<thead>
<tr>
<th>Yield and Quality of Cut Roses</th>
<th>First Harvest</th>
<th>Second Harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of flowers per plant</td>
<td>7.2 ± 0.5 a</td>
<td>6.3 ± 0.5 a</td>
</tr>
<tr>
<td>Number of petals per flower</td>
<td>16.5 ± 0.4 a</td>
<td>19.8 ± 0.5 b</td>
</tr>
<tr>
<td>Length of flowering shoot (cm)</td>
<td>29.0 ± 0.8 a</td>
<td>38.7 ± 1.2 b</td>
</tr>
</tbody>
</table>

¹Differences between means (n = 24) within row sharing the same letter(s) are not significantly different (P > 0.05).
Figure 1. Relative leaf chlorophyll level (Mean + SE) of 5-leaflet leaves taken from individual harvested shoots from plants fertilized with 50, 75, 100 or 125% of the recommended fertilization level (150 ppm N). Different letter(s) above bars indicate significant differences among fertilization treatments at $P \leq 0.05$ ($n = 6$).
Viability of Reducing Fertilization in Potted Mums Production

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Index Words: Fertilizer, Dendranthema grandiflora, EC, Leaf Nitrogen Content, Plant Height, Flower Production, Flower Size

Significance to Industry: Lowering fertilization can be a useful pest management tactic for western flower thrips (WFT) on potted mums [Dendranthema grandiflora (Tzvelev) cv. Charm] if it does not adversely affect mums growth and productivity. In this study, we present results that show the effects of lowering fertilization on potted mums in terms of plant height, number of flowers produced, flower size, leaf nitrogen content, and electrical conductivity (EC) of root substrate. We demonstrated that fertilization could be lowered to a level that reduced thrips population growth, but still maintained plant productivity. Reduction of fertilizer input during production will also help to reduce non-point source runoff and contamination of surface and ground water.

Nature of Work: Best management practices that reduce inputs and minimize non-point source runoff are becoming a necessity for commercial operations in the United States due to environmental concerns and governmental regulation such as the Federal Clean Water Act (4, 8). Fertilization during production influences not only chrysanthemum growth and productivity but also WFT population growth (2, 3). Manipulating fertilization to control WFT, possibly the most severe pest of floricultural crops (5), has been demonstrated to be a useful management tactic (3). Lowering fertilization to 188 ppm N (50% of the recommended level) results in a 44% reduction in mean WFT abundance on chrysanthemum (3). If fertilization could be manipulated to slow pest population growth while maintaining crop productivity, this tactic may be used with other control measures for WFT.

In our study, we tested four fertilization levels: 20, 50, 75, and 100% of the recommended rate (375 ppm N for constant liquid feeding of potted chrysanthemum). Reverse-osmosis-filtered tap water (RO water) was used to make the fertilizer solutions and water the plants. The strength of a water-soluble, complete fertilizer [Peters Professional Peat-lite special, 15-16-17 (15N-6.7P-14.1K)] was varied to the levels specified above but the ratio of all macro- and micro- nutrients was kept the same. A commercially available fertilizer was used to maximize application of research results for crop management practices. Potted mums were produced using standard commercial guidelines (9). Plants were fertilized with 200 ml of fertilizer solution twice a week right after transplantation. Fertilization was terminated before anthesis and plants were watered with 200 ml of RO water until harvest. Single rooted cuttings of chrysanthemum were transplanted to individual 6-in (16 cm diameter, 11 cm deep) Azalea pots, and placed on two greenhouse benches. A randomized
design with five replicates per fertilization level per bench was used, totalling ten replicates per fertilization level. Individual pots served as replicates. The average daily temperature and relative humidity inside the greenhouse during the experiment were 76 °F (25 °C) and 65%. Average day length during this period was 11.2 hours.

We measured plant height and counted the number of flowers produced at harvest. We decided to use leaf total nitrogen content as indicators of varying plant quality. We randomly selected five replicates per fertilization level and collected five physiologically mature leaves from each replicate. Leaves were analyzed for total nitrogen content by the Analytical Chemistry Laboratory (Institute of Ecology, University of Georgia, Athens, GA) using Micro-Dumas Combustion Analysis. To measure flower size, we also collected five fully open terminal flowers from each of these plants and recorded the largest diameter of each open flower. Salt accumulation due to fertilization in the root system may influence plant growth and productivity. To estimate the level of salt accumulation in the growing medium, we randomly selected five replicates per fertilization level and measured the electrical conductivity (EC) of root substrate using the PourThru Extraction method (7). We added 75 ml of RO water to each pot and collected 50 ml of leachate at weekly intervals from week 7 to harvest. Three EC readings were taken from each sample and the average of the three readings was used.

Plant height and number of flowers were analysed by one-way ANOVA with fertilization level as the main factors. Flower size and leaf total nitrogen content were analyzed using the Kruskal-Wallis test. Substrate EC was first In-transformed and analyzed using one-way repeated-measures ANOVA. Tukey’s honestly significant difference test (Tukey’s HSD) was used to determine significant differences between pairs of mean values following parametric tests and the Games and Howell method was used following non-parametric tests.

**Results and Discussion:** Plants were similar in height regardless of fertilization levels (Table 1). However, number of flowers produced increased with fertilization from 20 to 50% but remained the same when fertilization level was greater than 50% (Table 1). Flower size was also influenced by fertilization level. Flower size increased with fertilization from 20 to 75% and remained the same beyond 75% (Table 1). Our results showed that total nitrogen content of leaf tissues increased with higher fertilization (Figure 1). Lowering fertilization level to 50% of the recommended level would still provide plants with leaf nitrogen within an acceptable range (40 to 60 g kg\(^{-1}\)) (6). When fertilization level was reduced to 20%, the plants were considered to be moderately deficient in leaf nitrogen and produced fewer and smaller flowers than other fertilization levels.

We found a significant fertilization effect on substrate EC (P < 0.001) (Figure 2). Average substrate EC from plants fertilized with the recommended fertilization level was 3.8 mS/cm. Lowering fertilization level by 50% reduced substrate EC to 0.7 mS/cm, below the recommended range of substrate EC for chrysanthemum (1.7 to 4.6 mS/cm) (1), but did not adverse affect plant height and flower production. In this study, we showed that fertilization level could be lowered to 188 ppm N (50% of the recommended level) and still maintained chrysanthemum growth and flower production. We propose that reducing fertilization for potted
mums will facilitate thrips management and greatly reduce fertilizer input into the production system.

Acknowledgements: The authors would like to thank the American Floral Endowment and the USDA-ARS Floriculture and Nursery Research Initiative for providing financial support and Yoder Brother, Inc. for donating chrysanthemum cuttings.

Literature Cited:

Table 1. Effect of fertilization level on plant height, number of flowers produced, and flower size of chrysanthemum at harvest.

<table>
<thead>
<tr>
<th>Fertilization Level (% of recommended level)</th>
<th>Plant Height (cm)&lt;sup&gt;2&lt;/sup&gt;</th>
<th>No. of Flowers</th>
<th>Flower Size (cm)&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SE)</td>
<td></td>
<td>Mean (SE)</td>
<td>Mean (SE)</td>
</tr>
<tr>
<td>20                            25.1 (0.6)a</td>
<td>32.3 (2.2)a</td>
<td>6.8 (0.1)a</td>
<td></td>
</tr>
<tr>
<td>50                            27.3 (0.5)a</td>
<td>42.1 (0.9)b</td>
<td>7.3 (0.1)b</td>
<td></td>
</tr>
<tr>
<td>75                            26.5 (0.6)a</td>
<td>41.9 (1.9)b</td>
<td>7.3 (0.2)abc</td>
<td></td>
</tr>
<tr>
<td>100                           26.5 (0.8)a</td>
<td>43.0 (2.1)b</td>
<td>7.6 (0.0)c</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>The recommended rate for constant liquid feeding of potted chrysanthemum is 375 ppm N.
<sup>2</sup>Differences between means (n = 10) within column sharing the same letter(s) are not significantly different (P > 0.05).
<sup>3</sup>Differences between means (n = 5) within column sharing the same letter(s) are not significantly different (P > 0.05).
Figure 1. Mean total nitrogen content (g kg\(^{-1}\)) per sample (+ SD) of physiological mature leaves taken from plants fertilized with 20, 50, 75, or 100% of the recommended fertilization level (375 ppm N). Different letter(s) above bars indicate significant differences among fertilization treatments at P ≤ 0.05 (n = 5).

Figure 2. Mean electrical conductivity (EC) (mS/cm) of leachate per pot at weekly sampling intervals from plants fertilized with 20, 50, 75, or 100% of the recommended fertilization level (375 ppm N). Leachate was collected at weekly intervals from week 7 to harvest. Untransformed mean values were presented (n = 5).
Topflor Foliar Sprays Effective on Snapdragon

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Index Words: Flurprimidol, Plant Growth Regulation, Snapdragon

Significance to Industry: Flurprimidol foliar sprays of 10 to 100 ppm were applied to ‘Montego Red’ snapdragons for growth control. A 40 ppm flurprimidol application resulted in plants which were 18% shorter in height and 15% smaller in diameter, but flowering was delayed by five days, when compared to the untreated control.

Nature of Work: Snapdragons are popular bedding plants, but growth can be excessive and a plant growth regulator may be required to control growth. Plugs of ‘Montego Red’ snapdragons were transplanted into 1801 cell packs on 19 February using Fafard 4P root substrate (Fafard, Anderson, SC). Plants were fertigated with 150 ppm N from Excel 15-5-15 Cal-Mag (Scotts, Marysville, OH). Greenhouse temperature day/night set points were 75/64ºF and the plants were grown under natural daylength. The PGR foliar sprays were applied on 5 March using a volume of 0.5 gallons per 100 square feet: flurprimidol (0.38%) at 10, 20, 40, 60, 80, or 100 ppm and an untreated control. The experiment was a completely randomized design with 8 single-plant replications of the seven treatments. At flowering, total plant height (measured from the pot rim to the uppermost part of the inflorescence) and plant diameter (measured at the widest dimension and turned 90º, and averaged) were recorded. Plant height, diameter, and flowering date values for flurprimidol were regressed using the PROC REG procedure (SAS Inst., Cary, NC) to determine the best-fit linear or quadratic model. Terms of the model were judged to be significant or nonsignificant and included in the final model based on a comparison of F values at alpha = 0.05.

Results and Discussion: Plant height. ‘Montego Red’ snapdragon plants were 18% shorter when treated with 40 ppm, when compared to the untreated control (Fig.1). No further control of plant height was observed at concentrations higher than 60 ppm.

Plant diameter. There was a linear relationship between plant diameter and flurprimdol concentrations. ‘Montego Red’ snapdragon plant diameter was affected by flurprimidol foliar sprays ≥ 40 ppm, with the plants being 15% smaller in diameter than the untreated control (Fig. 2).

Flowering date. Flowering was delayed as flurprimidol concentrations increased (Fig. 3). Flurprimidol foliar sprays ≥ 40 ppm delayed flowering by 5 days as compared to the untreated control.
**Figure 1.** Flurprimidol (0.38% Topflor) foliar spray effects on ‘Montego Red’ snapdragon plant height. The regression line was generated from the best-fit model (n=8).

\[ y = 17.48 - 0.08x \]
\[ X_0 = 59.7, \ R^2 = 0.57 \]

**Figure 2.** Flurprimidol (0.38% Topflor) foliar spray effects on ‘Montego Red’ snapdragon plant diameter. The regression line was generated from the best-fit model (n=8).

\[ y = 14.017 - 0.0258x \]
\[ R^2 = 0.25 \]
Figure 3. Flurprimidol (0.38% Topflor) foliar spray effects on ‘Montego Red’ snapdragon flowering. The regression line was generated from the best-fit model (n=8).

\[ y = 31.94 + 0.134 - 0.0007x^2 \]

\[ R^2 = 0.48 \]
Topflor Foliar Sprays Effective on Dianthus

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Index Words: Dianathus, Flurprimidol, Plant Growth Regulation

Significance to Industry: Flurprimidol foliar sprays of 10 to 100 ppm were applied to ‘Telster Picotee Red’ dianthus for growth control. A 60 ppm flurprimidol application resulted in 13% shorter plants and did not delay flowering, but provided no control of plant diameter, when compared to the untreated control.

Nature of Work: Dianthus are popular bedding plants, but growth can be excessive and a plant growth regulator may be required to control growth. Plugs of ‘Telster Picotee Red’ dianthus were transplanted into 1801 cell packs on 19 February using Fafard 4P root substrate (Fafard, Anderson, SC). Plants were fertigated with 150 ppm N from Excel 15-5-15 Cal-Mag (Scotts, Marysville, OH). Greenhouse temperature day/night set points were 75/64ºF and the plants were grown under natural daylength. The PGR foliar sprays were applied on 5 March using a volume of 0.5 gallons per 100 square feet: flurprimidol at 10, 20, 40, 60, 80, or 100 ppm and an untreated control. The experiment was a completely randomized design with 8 single-plant replications of the seven treatments. At flowering, total plant height (measured from the pot rim to the uppermost part of the inflorescence) and plant diameter (measured at the widest dimension and turned 90º, and averaged) were recorded. Plant height values for flurprimidol were regressed using the PROC REG procedure (SAS Inst., Cary, NC) to determine the best-fit linear or quadratic model. Terms of the model were judged to be significant or nonsignificant and included in the final model based on a comparison of F values at alpha = 0.05.

Results and Discussion: Plant height. ‘Telster Picotee Red’ dianthus plants were only marginally affected by flurprimidol foliar sprays (Fig. 1). Sprays of 10 and 20 ppm resulted in plants taller than the untreated control. ‘Telster Picotee Red’ dianthus plants were 13% shorter when treated with 60 ppm and 19% shorter with 100 ppm, when compared to the untreated control plants.

Plant diameter. ‘Telster Picotee Red’ dianthus plant diameter was not affected by flurprimidol foliar sprays ≤ 100 ppm. The mean plant diameter for all concentrations was 16.5 cm.

Flowering date. Flowering was not delayed by any flurprimidol concentrations > 10 ppm. The average time to flowering was 51 days after transplanting.
Figure 1. Flurprimidol (0.38% Topflor) foliar spray effects on ‘Telster Picotee Red’ dianthus plant height. The regression line was generated from the best-fit model (n=8).

\[ y = 16.57 - 0.039x \]

\[ R^2 = 0.33 \]
Topflor Liner Soaks Effective on *Argyranthemum frutescens*

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Raleigh, NC, 27695-7609

**Index Words:** Argyranthemum, Flurprimidol, Plant Growth Regulation

**Significance to Industry:** Topflor liner soaks were used to determine their efficacy on vegetatively propagated *Argyranthemum frutescens* (‘Luna’). The plugs were thoroughly irrigated and allowed to drain for one hour and then the root substrate was soaked for 2 minutes in Topflor solutions ranging from 0 to 24 ppm. Topflor soak concentrations ≥4 ppm resulted in significantly smaller plant heights and concentrations ≥8 ppm resulted in significantly smaller plant diameters when compared to the untreated control. Plant height was affected more than plant diameter. Topflor concentrations of 4 ppm resulted in plants 26% shorter, but 5% wider in diameter than the control. Topflor at 8 ppm resulted in a 37% control of height and 4% control of diameter, when compared to the untreated control.

**Nature of Work:** *Argyranthemum frutescens* is a popular European pot plant. Plant growth can be excessive and a plant growth regulator may be required to control growth. Vegetatively propagated *Argyranthemum frutescens* cuttings of the cultivar ‘Luna’ [84 cell size (cell measured 4 cm deep x 2.9 cm x 2.9 cm)] were irrigated 1 h prior to the Topflor root substrate soak application. The cuttings were soaked in a Topflor (0.38% flurprimidol) solution of 0, 4, 8, 16, or 24 ppm for 2 min and then transplanted into 5-inch pots containing Fafard 4P (Fafard, Anderson, SC) on 5 March. Plants were grown at North Carolina State University, Raleigh, NC, in a glass-covered greenhouse set at 75/65ºF day/night temperatures. There were 6 replications of each treatment. The plants were fertilized with 150 ppm N from 13-2-13 Cal-Mag (Scotts Co., Marysville, OH). The plants were visually evaluated for phytotoxicity symptoms after Topflor was applied. Data for plant height (measured from the soil line to the highest growing point) and plant diameter (measured at the widest point and then turned 90º) were recorded on 14 April. Plant height and diameter values were regressed using the PROC REG procedure (SAS Inst., Cary, NC) to determine the best-fit linear or quadratic model. Terms of the model were judged to be significant or nonsignificant and included in the final model based on a comparison of F values at alpha = 0.05.

**Results and Discussion:** *Initial Observations After the PGR Applications.* Phytotoxicity did not occur with any of the concentrations used. The application of Topflor resulted in a darker leaf color when compared to the control. The lack of phytotoxicity is a positive development because in an earlier study with the European 1.5% Topflor formulation there was phytotoxicity when foliar sprays ≥100 ppm were applied to *Argyranthemum frutescens* ‘Pink Comet’ (1).
Final Observations. Plant height was significantly shorter (Fig 1) with liner soak concentrations ≥4 ppm. Plant height was best fit to a quadratic model. With 4 ppm Topflor, plants were 26% shorter in height compared to the non-treated control. This amount of control appeared to be adequate and limits inflorescence stretching, which makes shipping easier. This concentration is lower than the 75 ppm of Topflor required as a foliar spray to obtain 29% control of height when compared to the untreated control (1).

Plant diameter was 4% smaller with the application of Topflor at 8 ppm as compared to the untreated control (Fig 1). Plants treated with Topflor at 4 ppm were larger in diameter than the control. Plant diameter was also not affected with foliar sprays ≤75 ppm, and the use of 100 ppm Topflor was required to obtain a 7% smaller plant diameter when compared to the untreated control (1).

For Mid-Atlantic growers, concentrations of 4 to 8 ppm should be sufficient to control excessive stretch and still result in robust looking plants. Southern growers may want to use slightly higher concentrations to control growth under commercial settings. Northern growers may find concentrations of 1 to 2 ppm to be suitable for cooler climates. ‘Luna’ Argyranthemum frutescens appears to be a low vigor plant and concentrations may need to be modified for other cultivars. The rates used in this study were based on irrigating the plants 1 hour prior to soaking the liners and growers treating dry plugs will need to use lower concentrations, estimated to be only 20% of the amount stated above in the recommendations.

Literature Cited:
Figure 1. Response of *Argyranthemum frutescens* 'Luna' plant height and diameter to Topflor liner soaks.

\[
y = 22.4 - 1.07x; \quad r^2 = 0.72
\]

\[
y = 19.5 - 4.72x + 0.47x^2; \quad r^2 = 0.92
\]
Topflor Liner Soaks Effective on Strobilanthes

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Index Words: Flurprimidol, Persian Shield, Plant Growth Regulation, Strobilanthes

Significance to Industry: Topflor liner soaks were used to determine their efficacy on Strobilanthes (Persian Shield). The plugs were thoroughly irrigated and allowed to drain for one hour and then the root substrate was soaked for 2 minutes in Topflor solutions ranging from 0 to 32 ppm. Topflor soak concentrations ≥8 ppm resulted in significantly smaller plant plant heights and plant diameters when compared to the untreated control. Plant height was more drastically affected than the plant diameter. Topflor concentrations of 8 ppm resulted in plants 30% shorter and 22% smaller in diameter than the control.

Nature of Work: Strobilanthes are popular vegetatively propagated bedding plant, but growth can be excessive and a plant growth regulator may be required to control growth. Strobilanthes cuttings [50 cell size (cell measured 6 cm deep x 4.8 cm x 4.8 cm)] were irrigated 1 h prior to the root substrate soak application. The cuttings were soaked in a Topflor (0.38%) solution of 8, 16, 24, or 32 ppm for 2 minutes and then transplanted into 5-inch pots containing Fafard 4P (Fafard, Anderson, SC) on 2 April. Plants were grown at North Carolina State University, Raleigh, NC, in a glass-covered greenhouse set at 72/65ºF day/night temperatures. There were 6 replications of each treatment. The plants were fertilized with 150 ppm N from 13-2-13 Cal-Mag (Scotts, Marysville, OH). The plants were visually evaluated for phytotoxicity symptoms after the Topflor was applied. Data for plant height (measured from the soil line to the highest growing point) and plant diameter (measured at the widest point and then turned 90º) were recorded on 14 May. Plant height and diameter values were regressed using the PROC REG procedure (SAS Inst., Cary, NC) to determine the best-fit linear or quadratic model. Terms of the model were judged to be significant or nonsignificant and included in the final model based on a comparison of F values at alpha = 0.05.

Results and Discussion: Initial Observations After the PGR Applications.
Phytotoxicity did not occur with any of the application concentrations used. The application of Topflor resulted in a darker leaf color when compared to the control.

Final Observations. Plant height was significantly shorter (Fig 1) with liner soak concentrations ≥8 ppm. Plant height was best fit to a quadratic model. With 8 ppm Topflor, plants were 30% shorter in height compared to the non-treated control. This amount of control appeared to be adequate. Grower recommended concentrations for the Mid-Atlantic region should be around 8 ppm. Plant diameter was 22% smaller with the application of Topflor at 8 ppm as compared to the untreated control (Fig 1).
For Mid-Atlantic growers, concentrations of 8 ppm should be sufficient to control excessive stretch. Strobilanthes are very vigorous growing plants. Southern growers may want to use slightly higher concentrations to control growth under commercial settings. Northern growers may find concentrations of 2 to 4 ppm to be suitable for cooler climates. The rates used in this study were based on irrigating the plants 1 h prior to soaking the liner and growers treating dry plugs will need to use lower concentrations, estimated to be only 20% of the amount stated above in the recommendations.

**Figure 1.** Response of strobilanthes plant height and diameter to Topflor liner soaks.
Topflor Liner Soaks Effective on Vegetative Coleus

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Index Words: Coleus, Flurprimidol, Plant Growth Regulation

Significance to Industry: Topflor liner soaks were used to determine their efficacy on vegetatively propagated coleus ‘Skyfire’. The plugs were thoroughly irrigated and allowed to drain for one hour and then the root substrate was soaked for 2 minutes in Topflor solutions ranging from 0 to 24 ppm. Topflor soak concentrations ≥8 ppm resulted in significantly smaller plant heights and concentrations ≥4 ppm resulted in significantly smaller plant diameters when compared to the untreated control. Plant diameter was more drastically affected than plant height. Topflor concentrations of 8 ppm resulted in plants 13% shorter and 30% smaller in diameter than the control.

Nature of Work: Coleus (Solenostemon scutellarioides) are popular bedding plants, but plant growth can be excessive and a plant growth regulator may be required to control growth. Vegetatively propagated coleus cuttings of the cultivar ‘Skyfire’ [84 cell size (cell measured 4 cm deep x 2.9 cm x 2.9 cm)] were irrigated 1 h prior to the Topflor root substrate soak application. The cuttings were soaked in a Topflor (0.38% flurprimidol) solution of 4, 8, 16, or 24 ppm for 2 minutes and then transplanted into 5-inch pots containing Fafard 4P (Fafard, Anderson, SC) on 5 March. Plants were grown at North Carolina State University, Raleigh, NC, in a glass-covered greenhouse set at 72/65ºF day/night temperatures. There were 6 replications of each treatment. The plants were fertilized with 150 ppm N from 13-2-13 Cal-Mag (Scotts Marysville, OH). The plants were visually evaluated for phytotoxicity symptoms after the Topflor was applied. Data for plant height (measured from the soil line to the highest growing point) and plant diameter (measured at the widest point and then turned 90º) were recorded on 15 April. Plant height and diameter values were regressed using the PROC REG procedure (SAS Inst., Cary, NC) to determine the best-fit linear or quadratic model. Terms of the model were judged to be significant or nonsignificant and included in the final model based on a comparison of F values at alpha = 0.05.

Results and Discussion: Initial Observations After the PGR Applications. Phytotoxicity did not occur with any of the application concentrations used. The application of Topflor resulted in a darker leaf color when compared to the control.

Final Observations. Plant height was significantly shorter (Fig 1) with liner soak concentrations ≥8 ppm. Plant height was best fit to a linear model. With 8 ppm Topflor, plants were 13% shorter in height compared to the non-treated control. This amount of control appeared to be adequate. Grower recommended concentrations for the Mid-Atlantic region should be around 8 ppm. Plant diameter was 30% smaller with the application of Topflor at 8 ppm as compared to the untreated control (Fig 1).
Based on these results, Topflor liner soak concentrations of 8 ppm were effective on ‘Skyfire’ vegetatively propagated coleus grown under North Carolina conditions. ‘Skyfire’ coleus appears to be a moderately vigorous growing plant. Southern growers may want to use slightly higher concentrations to control growth under commercial settings. Northern growers may find concentrations of 2 to 4 ppm to be suitable for cooler climates. The rates used in this study were based on irrigating the plants 1 h prior to soaking the liners and growers treating dry plugs will need to use lower concentrations, estimated to be only 20% of the amount stated above in the recommendations.

**Figure 1.** Response of coleus plant height and diameter to Topflor liner soaks.