Determining Poinsettia Nitrogen and Sulfur Fertilizer Application Rates Based on Chromometer and Sensory Panel Ratings

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Summary. 'Dark Red Annette Hegg' poinsettias (*Euphorbia pulcherrima* Willd. ex Klotzsch) were grown in a 1 peat : 1 perlite : 1 vermiculite medium using a pinched production schedule with varying N and S fertilizer application rates. Fifty-six treatments consisting of eight N levels (100 to 275 mg·L^{-1} in 25-mg·L^{-1} increments) and seven S levels (0 to 75 mg·L^{-1} in 12.5-mg·L^{-1} increments) were supplied. Other required nutrients were supplied at commercial recommendations for all treatments. Foliage of each plant was evaluated quantitatively by chromometer readings every 3 weeks. Marketability was determined by sensory evaluations from commercial producers, retailers, and consumers. Results indicated distinct color differences (hue, chroma, value) between S levels of 0 and 12.5 mg·L^{-1} and a slight difference between S at 12.5 and 25 mg·L^{-1}. The foliage of plants receiving 0 S was lighter, more vivid, and more yellow-green in color. As N levels increased, there was a linear response; foliage became more green, darker, and more dull. Commercial and consumer evaluators rated plants that received S at 0 or 12.5 mg·L^{-1} at all N levels and plants receiving N at 100 mg·L^{-1} as unmarketable. This research indicates that 'Annette Hegg' poinsettia requires S at a minimum of 25 mg·L^{-1} and N at a minimum of 125 mg·L^{-1} for commercial acceptance, and commercial N application rates may be greatly reduced when adequate S is supplied.

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The agricultural industry uses fertilizers as a major production tool in which excessive rates are sometimes supplied to ensure maximum yields (Pyle, 1991). Nitrate contamination in groundwater has prompted state and local governments to develop strict runoff regulations from agricultural production areas (Pyle, 1991). The greenhouse industry is a highly visible source of pollution; thus, growers need to improve their production techniques continually to minimize environmentally detrimental growing practices. Basic improvements in fertigation techniques (methods, types, and rates) can reduce input costs and nutrient contamination.

Sulfur deficiencies in container-grown ornamentals have become apparent in some geographical areas due to low-S-containing soilless potting media and irrigation water (Reddy and King, 1992). This is because, until recently, S was available through atmospheric sulfur dioxide pollution, S-based or contaminated pesticides and fertilizers (e.g., superphosphate), and some groundwater sources (Mortvedt, 1981; Reneau, 1983). Currently, general recommendations for S fertilization are being provided without research on specific crops.

Previous hydroponic poinsettia research by Dale et al. (1991) and Paparozzi et al. (1994) found S to be required and, by supplying S in adequate levels, it was suggested that applied N may be reduced to half of commercial recommendations. If these results are applicable to poinsettias grown under typical cropping practices, it could reduce grower fertilizer costs and contamination in greenhouse effluent.

The purpose of this project was to identify the lowest N and S fertilizer application rates required to produce a commercial-quality poinsettia grown in a soilless medium. These levels were identified by determining the following.

1) Can visual S deficiencies occur in a peat-based medium?
2) What is the minimum S application rate required for poinsettias grown in a peat-based medium?
3) Will adequate S nutrition allow for a reduction in applied N from commercial recommendations without affecting foliage color and marketability?

Materials and methods

'Dark Red Annette Hegg' poinsettias were chosen as the experimental genotype so that results could be directly compared to work completed by Dale et al. (1991) and Paparozzi et al. (1994). The medium was composed of equal amounts (by volume) of peat, perlite, and vermiculite and amended with 74 mg·L^{-1} fritted trace elements (Peter's Fritted Trace Element Mix 555; Scotts-Sierra Horticultural Products Co., Marysville, Ohio). Dolomitic lime was added to obtain an initial pH of ≈6.3. Rooted cuttings were planted in 15-cm black plastic azalea pots, randomly assigned a treatment number, and placed in the greenhouse in a randomized complete-block design.

The production schedule was as follows. Rooted poinsettias were potted, grown for 2 weeks, and then pinched back to 5 nodes. Long days were supplied by night break lighting (2200 to 0200 HR) from potting until 2 weeks after pinch. Short days were initiated 4 weeks after potting and continued for 9 weeks. The research was conducted in glass covered greenhouses using computer-controlled heating and cooling systems set at 26/23 °C days/nights until 6 weeks after potting, then reduced to 20°/17 °C days/nights until experiment termination (12-week production cycle). Three experiments were conducted. Two were completed during the typical production period of August to December, and the third experiment was conducted during February to June.

The experiment was replicated three times in a randomized complete-block design using an 8 × 7 factorial treatment design. Nitrogen was applied at 100 to 275 mg·L^{-1} in 25-mg·L^{-1} increments. These N rates fell at or below commercial recommendations, which are 275 to 375 mg·L^{-1} (Ecke

Table 1. Nutrient concentrations supplied to all treatments.

Element	Concn ($mg \cdot L^{-1}$)
P	60
K	228
Mg	2.06
B	0.275
Cu	0.138
Fe	1.375
Mn	0.770
Mo	0.138
Zn	0.223

and Matkin, 1976) with constant fertigation. Optimal and deficient S levels have not been identified (Handreck, 1986), so S was applied at 0 to 75 $mg \cdot L^{-1}$ in 12.5-$mg \cdot L^{-1}$ increments. Small N and S fertilizer increments were used to pinpoint where deficiency symptoms began to appear.

The formulation of all treatments was composed using the same chemicals as in Peter's Professional Fertilizer 20–10–20 Peat-lite Special, (Scotts-Sierra Horticultural Products Co.). Thus, the following compounds were used: $NH_4H_2PO_4$, KNO_3, NH_4NO_3, $MgCl_2$, $MgSO_4 \cdot 7H_2O$, KCl, and K_2SO_4. The 56 nutrient solutions were calculated, maintaining equal concentrations for all nutrients except for N and S (Table 1). The NH_4NO_3 and KNO_3 were the main sources of N used to adjust the N levels applied. The K_2SO_4 was the primary nutrient used to adjust S levels. In treatments receiving 0 S, $MgSO_4$ was replaced with $MgCl_2$.

To ensure against chemical interactions, chemicals were weighed dry and put into 125-mL glass containers by treatment, except for the following micronutrients: H_3BO_3, CuEDTA, FeEDTA, MnEDTA, ZnEDTA, and Na_2MoO_4. Distilled-deionized water was put into each of the 125-mL glass containers to dissolve the chemicals completely before pouring into all 56 of the 19-L treatment buckets. The micronutrients were mixed in a stock solution and added to each treatment after the previous nutrients were mixed.

Nutrient solution was applied to all treatments when weight of a representative sample of plants was half of the weight at field capacity. Each pot received 400 mL of solution per watering and, depending on individual pot moisture status, a maximum of 100 mL would leach out (leaching fraction ≤0.25). Electrical conductivity (EC) and pH were monitored in the medium at planting and 3, 6, and 9 weeks after planting.

Quantitative data were obtained through the use of a CR-200 Chromameter (Minolta). Visual observations of growth (leaf size, break number, and color–floral development) and chromometer readings were taken at 3, 6, and 9 weeks after short-day initiation (SDI) on the first mature leaf of the lowest break. This leaf was marked and all readings were taken on this same leaf throughout the project. Output was collected in the Commission Internationale de l'Eclairage (CIELAB) color system (McLaren, 1976) and later manipulated using SAS (SAS Institute, 1987) to determine the interpretable data of value (L^*), chroma (C^*), and hue angle (h°) as explained by McGuire (1992).

Color is three-dimensional and can be more easily understood in the $L^* C^*$, h° color space. L^* is the measure of color value or lightness from black (numerically 0) to white (100). C^* is the degree of color from gray (0) to pure color (100). Finally, the actual color perceived is determined by h°, i.e., red, orange, yellow. With this understanding of three-dimensional color, analysis of variance could be performed and understood using Proc GLM (SAS Institute, 1987).

After a successful first experiment (in terms of identifying deficiency and color criteria), qualitative evaluations were made on the second experiment by a sensory panel composed of 24 commercial growers and 42 consumers. Commercial growers from the Lincoln and Omaha, Nebr., areas were formally invited by letter to participate in the evaluations, which took place 8 weeks after SDI. One plant from each treatment was selected and randomly assigned a number. These plants were placed in a row on evaluation tables in a greenhouse. Evaluators were given written instructions that they would be evaluating 56 pinched single-stem poinsettias. They were instructed to check off whether plants were of exceptional quality (florist grade), salable (average grade), or unsalable. For each plant, they were given the opportunity to check off the reasons for the evaluation, including bract color, bract quantity, foliage color, plant form, cyathia maturity, or other. A space for comments was also included.

Consumer evaluators were obtained by posting a notice in the university newspaper. They received a free poinsettia for their time. The instructions were similar; however, the plants were evaluated based on the terms florist quality, discount store quality, or would not buy. They also could check the reason(s) for the evaluation as in the commercial evaluation form.

Evaluator fatigue was a concern when designing the evaluation procedure. Thus, only one plant per treatment combination (56 plants) was rated and the evaluation took ≈30 min. Nonreplicated data calls for a special analysis that required the use of half-normal plots, a method proven appropriate for nonreplicated experiments (Stroup et al., 1998). Proc GLM (SAS Institute, 1987) was used to compute the half-normal plot analysis, which identified an estimated error term. ANOVA could then be completed by using this estimated error term (Stroup et al., 1998). Profile or trend analysis was then performed on the sensory panel evaluations (Huang et al., 1997). This allowed for a comparison between known satisfactory nutrient levels and the reduced levels. For example, since 275 $mg \cdot L^{-1}$ is a commercial N recommendation, the

Table 2. Partial analysis of variance for L* value taken at 6 weeks after the pinch in Expt. 2.

	Dependent variable L*			
Source	df	Mean square	F	P > F
Block	2	6.36	0.99	0.3743
NLIN	1	122.75	20.16	0.0001
N	6	7.10	1.17	0.3298
0 S vs. others	1	1202.04	197.46	0.0001
S	6	4.81	0.79	0.5795
NLIN × 0 S vs. others	1	4.47	0.73	0.3933
N × S	41	4.14	0.68	0.9181
Error	110	6.09		

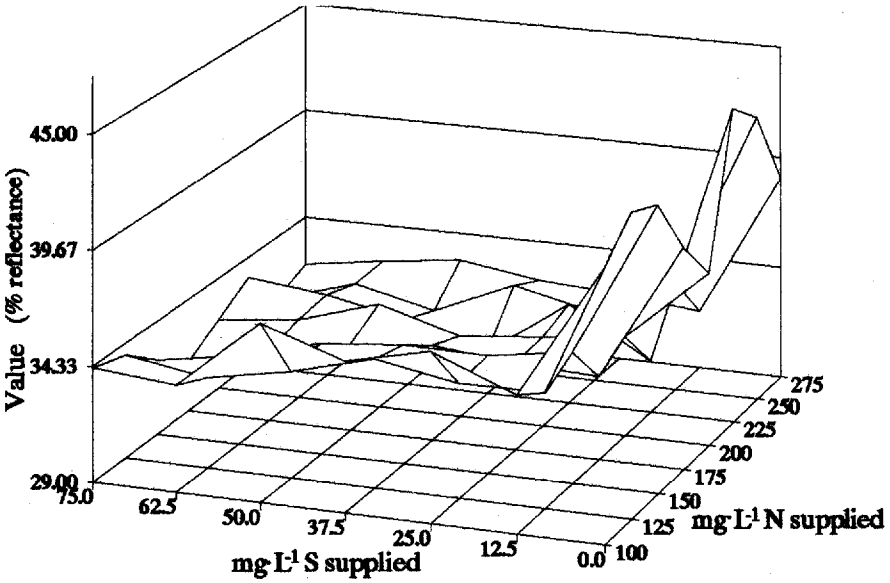

Fig. 1. Value (percent reflectance) of poinsettia foliage when varying levels of N and S are applied. Data from 6 weeks after the pinch in Expt. 1.

sensory evaluations for this level are contrasted to those at the next level lower, or 250 mg·L^{-1}. Next the average of the 275- and 250-mg·L^{-1} treatments are compared to plants receiving N at 225 mg·L^{-1} and so on.

Results

Chromometer. Results of chromometer readings for all three experiments were similar. Analysis of chromometer readings for Expt. 2 indicated a significant linear effect on L* at 3, 6, and 9 weeks SDI (Table 2). The response surface is highest at N at 100 mg·L^{-1} and drops in L* as N level increases (Fig. 1). The higher the reflectance, the lighter the color; thus, this indicates that, as N level increased from 100 to 275 mg·L^{-1}, the plants became darker. This N effect on value was most visually evident at weeks 6 and 9 in all experiments (Adams, 1995).

Plants receiving 0 S were also significantly different to those that received S at ≥12.5 mg·L^{-1} for L* at 3, 6, and 9 weeks SDI (Table 2). At week 6, the response surface was highest (more light in color) at S at 0 mg·L^{-1} and dropped in value once S was applied at 12.5 mg·L^{-1}. There were no significant differences between plants that received S at 12.5 to 75 mg·L^{-1} (Table 2, Fig. 1). This response was true for weeks 3 and 9, with the differences between S at 0 and 12.5 mg·L^{-1} very pronounced.

There was also a significant linear effect on C* by N at weeks 3, 6, and 9 (Table 3). At week 6 (Fig. 2), the response surface tilts downward from N at 100 to 275 mg·L^{-1}. This means the plants became more dull or gray in color as N level increased. The response surface was similar for weeks 3 and 9 for all experiments. The S effects were identical to those reported for value. Plants receiving 0 S were more vivid (bright and true in color) than plants that received ≥12.5 mg·L^{-1}. Once S was applied, there were no significant differences between plants (Fig. 2).

The h° value also responded linearly as N application rates increased (Table 4). In Fig. 3, the response surface became higher in degrees as the level of N increases from 100 to 275 mg·L^{-1}. This means that, as N level increased, the plants became increasingly more green in color. Again, this was also true for weeks 3 and 9 for all three experiments. Plants receiving 0 S

Table 3. Partial analysis of variance for chroma (C*) taken at 6 weeks after the pinch in Expt. 2.

	Dependent variable C*			
Source	df	Mean square	F	P > F
Block	2	43.30	3.21	0.0443
NLIN	1	317.37	23.52	0.0001
N	6	18.51	1.37	0.2325
0 S vs. others	1	3379.30	250.4	0.0001
S	6	23.15	1.72	0.1243
NLIN × 0 S vs. others	1	38.12	2.82	0.0957
N × S	41	7.32	0.54	0.9860
Error	110	13.50		

Fig. 2. Chroma (relative intensity units) of poinsettia foliage when varying levels of N and S are applied. Data from 6 weeks after the pinch in Expt. 1.

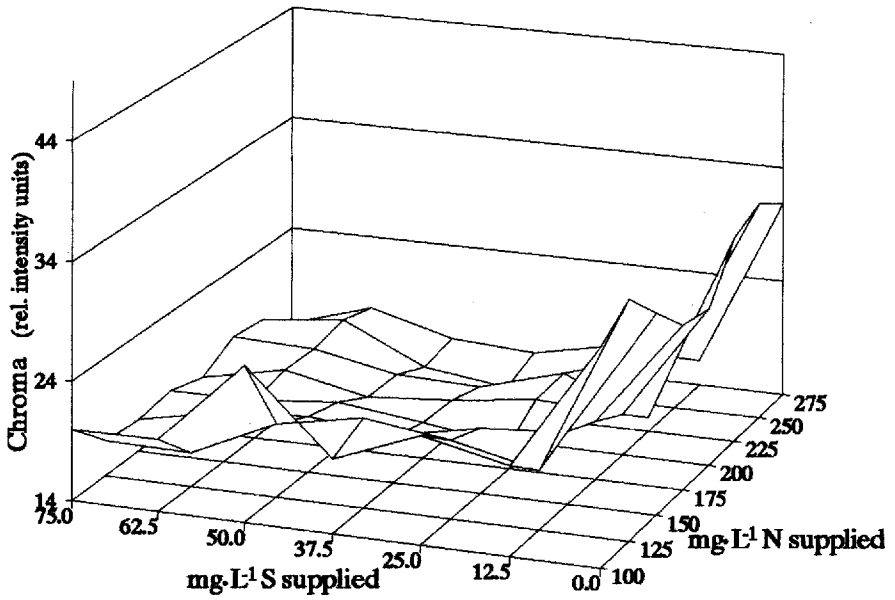

Table 4. Partial analysis of variance for hue angle (h°) taken at 6 weeks after the pinch in Expt. 2.

	Dependent variable h°			
Source	df	Mean square	F	P > F
Block	2	1.27	0.17	0.8442
NLIN	1	104.32	13.92	0.0003
N	6	9.67	1.29	0.2675
0 S vs. others	1	1525.21	203.51	0.0001
S	6	11.26	1.50	0.1842
NLIN × S 0 vs. others	1	3.38	0.45	0.5033
N × S	41	5.28	0.70	0.8981
Error	110	7.49		

were found to be significantly different to those that received ≥12.5 mg·L^{-1}. These plants were more yellow-green in color. Once S was received, no significance was detected between treatments receiving any level of S at weeks 3, 6, and 9 (Fig. 3).

SENSORY PANEL EVALUATIONS. Plant evaluators, whether commercial or consumer, did not identify any specific treatment combination as florist grade. However, the sensory panels differentiated between plants that were saleable and those that were not. From the profile analysis in Table 5, commercial evaluators identified plants given N at 100 mg·L^{-1} to be significantly different to those that received ≥125 mg·L^{-1}. This indicates that plants that received N at 100 mg·L^{-1} were not salable. Comments from the evaluators indicated that plant form and bract quantity were the reasons for their selection. Commercial evaluators also identified plants given S at 0 and 12.5 mg·L^{-1} at all N levels to be significantly different (not salable) to those receiving S at ≥25 mg·L^{-1} (Table 5). Evaluators indicated that bract and foliage color were their primary reasons. If we compare the mean square values, it appears most of the variation is with plants receiving S at 0 and 12.5 mg·L^{-1} (MS = 164.024) followed by plants receiving N at 100 mg·L^{-1} (MS = 26.623) and S at 12.5 mg·L^{-1} (MS = 12.152). As explained in the materials and methods, a profile analysis contrasts each treatment level to the next higher level. Since there was no significant difference from N at 125 to 275 mg·L^{-1} and S at 25 to 75 mg·L^{-1}, these plants were all evaluated as equally salable.

Consumer evaluators identified only plants that received S at 0 mg·L^{-1} or N at 100 mg·L^{-1} as unmarketable. This confirms the results obtained by the commercial panel and also indicates that the commercial evaluators are more sensitive to color and quality differences.

Discussion

Sulfur is available in most groundwater in varying amounts; however, it is highly dependent on the organic matter in the substrate components (Reddy and Madore, 1995). Yeager and Barrett (1985) suggested that S would be deficient in coarse soilless potting media since sulfur is an easily leached nutrient and any available S would be lost via water percolation. From this research, we have confirmed that S must be applied to poinsettias grown in a peat-based potting medium. Plants grown with S at 0 mg·L^{-1} had foliage that the chromometer identified as light, more vivid, and yellow-green in color. The sensory panel also identified these plants as not salable, and comments indicated that color and form were their reasons for their evaluation. These results are comparable to the observations by Dale et al (1991), who identified S deficiency in poinsettias grown without S in hydroponic culture.

Chromometer results also indicated a linear response surface from N at 100 to 275 mg L^{-1}. As expected, adding N caused plants to become darker, more dull, and more green as amounts of N increased. No leveling or plateauing was detected, so a specific N level could not be suggested from these readings (Figs. 1–3). However, the sensory panel evaluations associated acceptable N and S application rates with acceptable color and quality (Table 5). Results indicate that color is greatly affected by S deficiency as detected by the chromometer and all sensory evaluators. Once S was applied at 12.5 mg·L^{-1}, plants receiving N at ≥125 mg·L^{-1} were acceptable to the consumer panel.

For N, the sensory panels and the chromometer identified plants receiving S at 0 mg·L^{-1} as unsalable; however, the commercial panel also rated plants receiving S at 12.5 mg·L^{-1} as unsalable. This difference between the chromometer and the commercial sensory panel indicated that some other attribute, such as plant size, structure, maturity, or fullness (Heintz and Kader, 1983), may have been responsible for the preference expressed by the commercial panel.

In conclusion, S is required by 'Dark Red Annette Hegg' poinsettias at a minimum of 12.5 mg·L^{-1} for con-

Fig. 3. Hue angle (degrees) of poinsettia foliage when varying levels of N and S are applied. Data from 6 weeks after the pinch in Expt. 1.

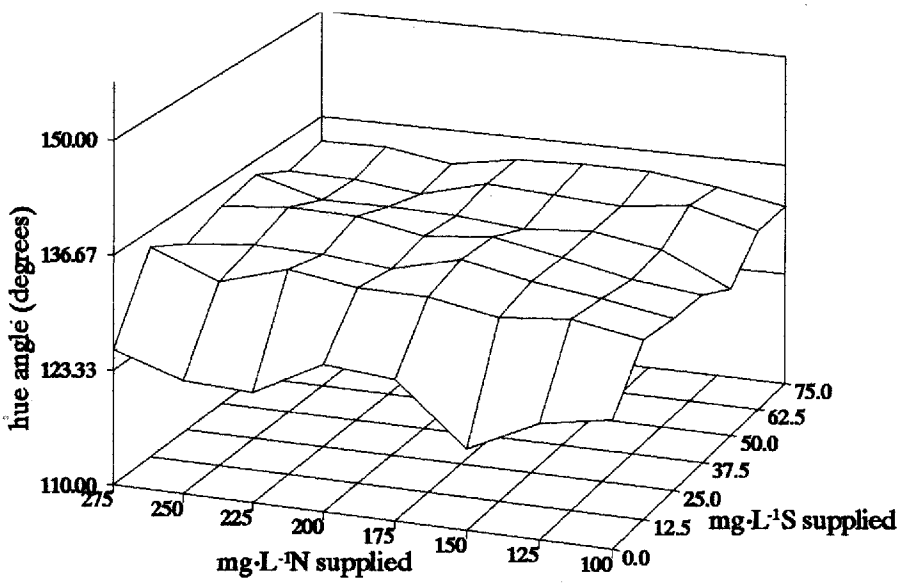

Table 5. Partial analysis of variance for ratings of poinsettia plants receiving varying amounts of N and S by commercial producers.

Source	df	Mean square	F	P > F
250 N vs. 275 N	1	0.078	0.03	0.8549
225 N vs. >225 N	1	0.175	0.08	0.7837
200 N vs. >200 N	1	0.002	0.00	0.9762
175 N vs. >175 N	1	0.011	0.00	0.9447
150 N vs. >150 N	1	2.337	1.02	0.3185
125 N vs. >125 N	1	0.723	0.32	0.5775
100 N vs. >100 N	1	26.623	11.61	0.0015
62.5 S vs. 75 S	1	1.837	0.80	0.3758
50 S vs. >50 S	1	4.188	1.83	0.1837
37.5 S vs. >37.5 S	1	5.990	2.61	0.1135
25 S vs. >25 S	1	0.457	0.20	0.6576
12.5 S vs. >12.5 S	1	12.152	5.30	0.0263
0 S vs. >0 S	1	164.024	71.55	0.0001
Error (estimated by N × S)	42	2.292		

sumer acceptance. However, S at 25 $mg \cdot L^{-1}$ is preferable for commercial application, as this correlates to the general commercial recommendations that suggest adding S at 20 to 30 $mg \cdot L^{-1}$ if it is not available through irrigation sources (Handreck, 1986; Reddy and King, 1992). With adequate S available, N may be reduced from commercial recommendations of 275 $mg \cdot L^{-1}$ (Ecke and Matkin, 1976) to 125 $mg \cdot L^{-1}$ with no reduction in plant quality. This is a reduction in N application of 55% from commercial recommendations and is supported by the research results obtained by Dale et al. (1991) and Paparozzi et al. (1994). Further studies should be completed to determine the applicability of this research to the new, dark-leaved, and potentially less-nutrient-requiring genotypes currently available (Hammer, 1996).

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Selecting the Optimum Slow-release Fertilizer Rate for Five Cultivars of Tissue-cultured *Hosta*

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Additional index words. Osmocote 14-6-11.5, Sierrablen 17-2.6-10 Plus Minors

Summary. Four rates of two slow-release fertilizers were tested for optimum growth of five hosta cultivars: *Hosta sieboldiana* 'Elegans', *Hosta plantaginea* 'Aphrodite', *Hosta* 'Jade Scepter', *Hosta* 'Hadspen Blue', and *Hosta* 'Francee'. Tissue-cultured hostas from 2.5-cm plugs were planted in 6-inch (15-cm) pots filled with a commercial soilless medium, and the slow-release fertilizer was dibbled into the medium at 0, 3, 6, or 12 g/pot. The plants were maintained for 4 months. Root and shoot fresh and dry weights were recorded at the end of the experiment. In addition, foliar nutrient analysis was conducted on 'Aphrodite', 'Francee', and 'Jade Sceptor'. Overall, hostas grew best when the medium was amended with 3 g of either Osmocote 14N–6P–11.5K or Sierrablen 17N–6P–12K slow-release fertilizer.

Hosta is the most popular shade-tolerant herbaceous perennial in the U.S. market. Because they naturally reproduce slowly by division, they are often propagated by tissue culture. Growing some tissue-cultured hosta to a saleable size in the nursery can be expensive, diffi-

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