

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·L⁻¹ is preferable for commercial application, as this correlates to the general commercial recommendations that suggest adding S at 20 to 30 mg·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·L⁻¹ (Ecke and Matkin, 1976) to 125 mg·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 Scepter'. 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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Table 1. P and F values for shoot and root dry weights (data combined for the five hosta cultivars).

Source	Shoot F	Shoot P	Root F	Root P
Fertilizer	0.28	0.6003	2.52	0.0061
Rate	4.39	0.0153	10.52	0.0001
Fertilizer × rate	1.33	0.2699	1.25	0.2929
Cultivar	5.33	0.0007	25.37	0.0001
Cultivar × control	1.77	0.1428	1.59	0.1829
Cultivar × fertilizer	1.27	0.2866	1.37	0.2497
Cultivar × rate	0.89	0.5273	5.12	0.0001

cult, and time-consuming. To produce a salable hosta in a 1.0-gal (3.8-L) nursery pot from a tissue culture tube could be as short as 6 months for very vigorously growing cultivars to as long as 2 years for slow-growing cultivars.

However, there is little information available on the fertilization of this popular perennial. We are aware of no specific nutritional recommendations for hosta, although it would appear that nutrition would depend on the stage of plant development. For instance, Adam (1988) reported that fertilization of the tuberous roots of newly transplanted field-grown *Hemerocallis* had no immediate effect on flowering or growth. Rather, the effect was noted during the next growing season. Similarly, fertilizing field-grown, spring-transplanted hosta would probably have less effect on growth during the current season than it would the next. However, many hosta are tissue cultured and sold as plugs (Nau, 1996) for which a storage root system has not had time to develop. Under these conditions, these plants would probably respond much more quickly to fertilizer application.

Research has been done to assess the optimum rate of slow-release fertilizers for a number of other plants. *Blandfordia grandiflora* (Christmas Bells) yielded larger plants using 4.0 g/7.5-cm pot of Osmocote 18N-2.6P-10K compared with rates of 0, 0.5, 1.0, 2.0, and 8.0 g/pot (Lamont et al., 1992). Conover and Poole (1985) reported that *Viburnum odoratissimum* grew better with Osmocote 13N-5.7P-10.5K and Customblen 17N-3P-10K than other formulations of either Osmocote or Customblen. *Brassaia actinophylla* grew best with treatments of Osmocote 13N-5.7P-10.5K and 18N-2.6P-10K and Customblen 17N-

2.6P-10K at N rates of 1.2, 1.8, and 2.4 kg·m⁻³ respectively. From the preceding it is clear that the optimum slow-release fertilizer and rate must be determined for each plant species.

Placement of the slow-release fertilizer may be important. The fertilizer can be topdressed or dibbled. Kovacic and Holcomb (1981) determined that topdressing a slow-release fertilizer was as effective as incorporating it. Coleman et al. (1978) determined that dibbling was as effective as incorporation.

Materials and methods

Tissue cultured plants from 2.5-cm plugs that were ≈4 months out of tissue culture of *Hosta sieboldiana* 'Elegans', *Hosta plantaginea* 'Aphrodite', *Hosta* 'Jade Scepter', *Hosta* 'Hadspen Blue', and *Hosta* 'Francee' were used for this experiment because this is the starting material most frequently used by industry. The cultivars were planted

Table 2. Average shoot and root dry weights for each hosta cultivar and fertilizer treatment.

Cultivar	Fertilizer	Rate (g/pot)	Shoot wt (g)	Root wt (g)	
Aphrodite	Control	0	1.71 c ^z	7.20 b	
		3	6.03 a	12.17 a	
		6	4.92 b	10.55 a	
		12	4.23 b	6.07 b	
	Sierra	3	7.63 a	14.78 a	
		6	2.93 bc	4.13 c	
		12	3.66 bc	4.85 bc	
	Elegans	Control	0	1.70 b	5.40 a
			3	2.18 b	5.37 a
			6	1.12 b	3.16 a
			12	2.61 b	4.14 a
Sierra		3	6.94 a	5.79 a	
		6	2.87 b	5.40 a	
		12	2.24 b	3.37 a	
Hadspen Blue		Control	0	0.60 a	1.83 a
			3	0.38 a	0.81 a
			6	1.07 a	1.68 a
			12	1.27 a	1.55 a
	Sierra	3	1.21 a	1.51 a	
		6	0.97 a	1.22 a	
		12	0.69 a	1.06 a	
	Francee	Control	0	4.11 a	8.86 a
			3	4.35 a	8.05 a
			6	3.58 a	8.72 a
			12	2.97 a	6.28 a
Sierra		3	4.26 a	6.23 a	
		6	3.99 a	8.13 a	
		12	2.14 a	2.20 b	
Jade Scepter		Control	0	1.22 a	3.23 a
			3	3.72 a	5.38 a
			6	3.36 a	4.35 a
			12	1.87 a	2.94 a
	Sierra	3	3.08 a	4.70 a	
		6	2.67 a	3.35 a	
		12	2.24 a	1.81 a	

^zMeans within a cultivar followed by the same letter are not significantly different as determined by least squares means at P = 0.05.

between 3 and 4 Dec. 1994 into 2000-mL (6-inch) pots filled with a commercial soilless medium (Fison's #4, Fison Horticulture, Inc., Warwick, N.Y.). The slow-release fertilizer (either Osmocote 14-6-11.5 (Grace Sierra, Milpitas, CA) or Sierrablen 17-2.6-10 plus minors (Grace Sierra, Milpitas, Calif.) was dibbled into the medium of each pot at a rate of 0, 3, 6, or 12 g/pot. To dibble the fertilizer, a hole was made in the center of the pot, the slow-release fertilizer was added, and then the hosta plug was placed in the hole so that the plant was at the same depth that it had been growing. For the control treatment there was no hole dibbled and no fertilizer was added to the pots. The plants were arranged in four randomized complete blocks with three replications per treatment. The experiment was located in the horticulture greenhouses at Pennsylvania State Univ., University Park, Pa. Greenhouse temperature set points were 68 °F (20 °C) during the day and 60 °F (15.5 °C) at night. The plants were treated once with a micronutrient fertilizer (STEM; Peters Fertilizer Products, Fogelsville, Pa.) by overhead watering at a rate of 2.26 g/gal.

The plants were watered overhead by hand as needed. Supplementary HID lighting at 58 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PAR was provided starting 20 Jan. 1995, and the lights were on from 6 AM to 12 AM daily for the duration of the experiment. The plants were harvested 18 Apr. 1995, and fresh and dry weights were determined on the aerial portion. The medium was washed from the roots and the root and crown fresh and dry weights were also recorded. Ma-

ture leaves of 'Aphrodite', 'Francee', and 'Jade Scepter' were randomly selected from plants within the treatment, combined into a single sample for each treatment, and analyzed for nutrient content by inductively coupled plasma atomic emission spectrometer (Dahlquist and Knoll, 1978) and Kjeldahl (Isaac and Johnson, 1976) by the Agricultural Analytical Services Laboratory at Pennsylvania State Univ. Analysis of variance using the general linear models procedure was used to statistically analyze the data obtained from harvested roots and shoots (SAS, 1989).

Results and discussion

There were no significant differences in shoot dry weight due to the type of slow-release fertilizer used, but there was a significant difference in root dry weight. There was no significant interaction between the cultivar and slow-release fertilizers used (Table 1). There was a significant difference in the shoot and root dry weights due to fertilizer rate and cultivar (Table 1).

The fertilizer rate of 3 g of either fertilizer produced significantly larger shoots than using rates of 6 and 12 g of fertilizer for 'Aphrodite' (Table 2). For 'Elegans' only, Sierra at 3 g produced significantly larger shoots than 6 or 12 g of Sierra. For the other cultivars the plants fertilized with 3 g were generally larger than those fertilized with 6 or 12 g, but the differences were not significant. 'Hadspen Blue' had consistently poor growth throughout the entire experiment. The only significant difference in root dry weight was for 'Aphrodite', where 3 and 6 g of Osmocote and 3 g of Sierra produced

significantly larger root dry weights than the other treatments. The root dry weight of the other four cultivars was not affected by fertilizer (Table 2)

For each of the three cultivars analyzed for foliar nutrient content, the 3-g/pot treatment consistently contained the smallest percentage of N, P, and K of all the fertilizer treatments except the control (Table 3). All of the control plants (0 g/pot) contained similar percentages of N, P, K, Ca, and Mg. 'Aphrodite' average shoot weight was the largest of all five cultivars and had the smallest percentage of N for all rates of slow-release fertilizer compared to 'Francee' and 'Jade Scepter' (Tables 2 and 3).

It is of interest to note that nutrient analysis for the leaves of 'Jade Scepter' revealed higher levels of Na than the leaves of 'Francee' and 'Aphrodite.' High levels of Na usually inhibit the uptake of Mg and Ca (Mengel and Kirby, 1978). 'Jade Scepter' leaves, however, had higher percentages of Ca and Mg than the other cultivars. There was no major difference between the micronutrient levels of Sierrablen-treated leaves and Osmocote-treated leaves (data not presented).

Survival for each of the cultivars for this experiment was calculated. 'Aphrodite' had 100% survival rate except for treatments of 6 and 12 g using Sierrablen (Table 4). 'Hadspen Blue' had the smallest percent survival rate of all the cultivars in the experiment. 'Francee' had 100% survival rates using 6 g/pot Osmocote and 3 and 6 g/pot Sierrablen. 'Jade Scepter' had 100% survival in the control treatment.

The best overall treatment for

Table 3. Nutrient analysis for *Hosta plantaginea* 'Aphrodite', *Hosta* 'Francee', and *Hosta* 'Jade Scepter' leaf tissue fertilized with Osmocote at four rates: 0 (control), 3, 6, and 12 g/6-inch pot.

Cultivar	Treatment (g/6-inch pot)	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Al	Zn	Na
		N P K (%)			$(\mu\text{g}\cdot\text{g}^{-1})$								
Aphrodite	0	0.68	0.20	1.92	0.52	0.33	118	28	3	29	42	19	102
	3	1.76	0.25	2.36	0.63	0.36	168	44	3	27	25	18	80
	6	2.01	0.31	2.89	0.65	0.36	228	37	3	26	23	22	82
	12	1.88	0.33	2.81	0.62	0.34	304	39	2	29	31	19	124
Francee	0	0.68	0.18	1.49	0.49	0.23	68	22	3	15	21	23	133
	3	2.34	0.33	2.57	0.81	0.34	102	38	4	19	17	24	238
	6	2.50	0.34	2.77	0.79	0.31	147	46	4	20	19	26	273
	12	2.46	0.36	2.79	0.75	0.31	155	51	3	23	17	26	300
Jade Scepter	0	0.79	0.20	2.26	0.67	0.40	135	29	4	25	31	28	231
	3	2.36	0.32	2.70	1.14	0.56	100	43	4	27	37	22	623
	6	2.74	0.37	3.21	1.25	0.60	166	42	3	29	28	22	537
	12	2.78	0.40	3.79	1.02	0.56	198	50	2	33	28	24	769

Table 4. Percent survival for each of the five hosta cultivars grown at four rates of slow-release fertilizer: 0 (control), 3, 6, and 12 g/6-inch pot.

Cultivar	Fertilizer	Rate (g/ pot)	Survival (%)	
Aphrodite	Control	0	100	
		3	100	
		6	100	
	Osmocote	12	100	
		Sierra	3	100
			6	83
12	92			
Elegans	Control	0	92	
		3	92	
		6	50	
	Osmocote	12	67	
		Sierra	3	83
			6	50
12	58			
Hadspen Blue	Control	0	67	
		3	25	
		6	42	
	Osmocote	12	17	
		Sierra	3	42
			6	17
12	0			
Francee	Control	0	75	
		3	92	
		6	100	
	Osmocote	12	92	
		Sierra	3	100
			6	100
12	75			
Jade Scepter	Control	0	100	
		3	92	
		6	92	
	Osmocote	12	42	
		Sierra	3	92
			6	25
12	25			

hosta cultivar shoots is using Osmocote at a rate of 3 g/pot, or one-half the recommended rate for general nursery stock. These findings correspond Aden's recommendation for fertilization of hosta in the garden, which was one-half the recommended dos-

age of Osmocote (Aden, 1988). Because all of the average shoot yields were adequate for all cultivars at a rate of 3 g/pot, Osmocote 14-6-11.5 and Sierrablen 17-2.6-10 can be used as fertilizers for hosta in the nursery.

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