that a constant and favorable xylem pressure potential is maintained under a wide range of conditions. Further studies are warranted in order to evaluate this possibility. Nevertheless, insight into plant response to different environmental factors (as atmospheric humidity and temperature) would be helpful for using climate computers for environmental glasshouse control.

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Fertilizer and Irrigation Effects on Medium Leachate and African Violet Growth

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Abstract. **Of various controlled-release fertilizer materials, tested on African violet (*Saintpaulia ionantha* H. Wendl) at 300, 600, and 900 kg/ha for leachate soluble salts, Ca, P, K, and Mg and plant injury, Scott 25.0–4.4–8.3 gave the best result and Scott 15.0–8.7–4.2 gave the poorest result. Precise 8.0–4.8–4.2 leachate generally contained more Ca and Mg and lower leachate soluble salts, but was lower in P and K than the other fertilizers. With the exception of Precise, the leachate soluble salts of most of the fertilizers was initially (10th irrigation) too high. The 900 kg/ha rates for some fertilizers caused high leachate soluble salts and plant injury.**

The African violet is a popular flowering houseplant grown for its flowering and foliage characteristics. Kimmins (5) has described cultural methods for commercial production; however, information on fertilization practices is variable and limited. Many growers use high phosphorous water-soluble fertilizer, such as 15.0N–13.1P–12.5K (5). Several other water soluble fertilizer formulations have been recommended: 20.0N–2.2P–24.9K containing more nitrate than ammonical nitrogen (3), 20.0N–8.7P–16.6K (1), and 15.0N–6.5P–12.5K (6). Shanks (10) noted that African violets are very sensitive to high levels of soluble salts and suggested a solution containing only 75 ppm N and K. These low nutrient and soluble salts requirements suggest that controlled-release fertilizers would be ideal fertilizer materials for African violets. Organics, such as dried blood, fish meal, and bone meal have been used to provide controlled-release fertilization on African violets in the past (1). Recently, controlled-release fertilizers, such as Osmocote (resin coated inorganic fertilizer, Sierra Chemical Co., Newark, Calif.) and Mag-Amp (inorganic compound of limited water solubility, Jiffy Products of American, West Chicago, Ill.) have been reported to produce acceptable plants in peatlite media (2). In reporting successful growth of violets fertilized with Osmocote 14.0N–6.1P–11.6K, Payne and Adam (7) concluded that other controlled-release fertilizer types and analyses should be investigated. Sharma (9) has noted that very little information is available on liquid encapsulated urea (LEU) fertilizer on ornamental plants. Outstanding results have been obtained with a LEU fertilizer on foliage plants (8).

Controlled-release fertilizers can be incorporated into the medium or surface applied to African violets. Holcomb (4) has noted an accelerated release rate of Osmocote is from incorporated material; however, if the medium surface is moist, the release rate from surface material is quite comparable. African violets are overhead irrigated and subirrigated (using sand or a mat as capillary materials); therefore, a study of the new controlled-release fertilizers under both irrigation systems would be of interest.

The objectives of the current study were: 1) to compare Ca, P, K, and Mg availability and soluble salt level of several incorporated controlled-release fertilizers, including liquid encapsulated urea (LEU), ureaformaldehyde (UF), and ureaformaldehyde impregnated vermiculite (UIV); and 2) to observe the effects of surface and incorporated applications of these fertilizers on the growth of African violets irrigated overhead or subirrigated.

Round plastic pots, 12 × 9 cm, containing a 1 sphagnum peat moss : 1 pine bark : 1 perlite medium (by volume) amended with 4.1 kg dolomitic limestone, 1.8 kg superphosphate, 0.9 kg Perk (a minor element additive), and 120 ml Aqua-Gro wetting agent per m^3, were irrigated with tap water to settle the medium prior to fertilizer treatment. Fertilizer treatments broadcast on the medium surface included the UIV ratios, 18.0N–3.9P–7.5K, 20.0N–2.2P–8.3K, and 15.0N–8.7P–4.2K manufactured by O.M. Scott and Sons Co., Maryville, Ohio, by adding a hot slurry of ureaformaldehyde, mondiammonium phosphate, and potassium sulfate to expanded vermiculite to produce 1–3 mm particles; UF (Scott's Pro-Grow), 25.0N–8.7P–

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Table 1. Leachate soluble salts, Ca, Mg, P, and K after 10 and 20 irrigations from a 1 sphagnum peat moss : 1 pinebark : 1 perlite medium (by volume) broadcast with controlled-release fertilizers.

Fertilizer N-P-K	Rate (kg N/ha)	Soluble salts[z] (millimhos/cm)		Leachate Ca (ppm)		Leachate P (ppm)		Leachate K (ppm)		Leachate Mg (ppm)	
		10[y]	20	10	20	10	20	10	20	10	20
Scott 18.0–3.9–7.5	300	2.0	0.5	32.2	16.6	64.8	11.4	109.3	35.0	68.6	11.8
	600	2.3	0.7	20.5	15.0	68.1	16.3	153.3	51.1	48.9	9.1
	900	2.5	0.8	18.6	13.7	93.0	24.8	246.0	58.6	55.8	6.7
Scott 20.0–2.2–8.3	300	1.7	0.4	25.0	15.5	52.0	7.7	76.0	26.2	56.9	10.1
	600	2.4	0.6	17.2	14.6	42.5	12.5	144.0	41.4	54.9	7.4
	900	3.1	0.7	20.9	13.3	30.6	19.5	205.3	59.9	55.2	7.3
Scott 25.0–4.7–8.3	300	2.1	0.6	32.3	23.0	79.9	15.3	68.0	24.6	70.7	14.8
	600	2.4	0.6	27.7	12.7	83.6	16.1	103.0	33.5	52.0	8.0
	900	2.6	0.7	21.5	10.6	107.9	22.0	131.0	40.0	49.9	5.8
Scott 15.0–8.7–7.42	300	1.9	0.5	24.4	15.0	116.7	18.6	74.0	24.0	62.1	10.4
	600	2.5	0.7	25.6	14.5	207.6	32.1	120.7	33.3	62.7	9.6
	900	3.5	0.8	30.2	14.5	27.2	43.5	200.0	44.6	77.9	8.8
Precise 8.0–4.8–4.2	300	1.4	0.7	101.8	31.3	44.9	24.4	34.4	26.2	77.9	28.2
	600	1.4	0.8	84.8	30.9	50.7	32.4	43.0	36.8	68.6	25.2
	900	1.9	0.9	127.5	36.1	74.4	20.6	52.3	43.7	105.8	26.2
Check (no treatment)	---	1.4	0.4	31.7	30.6	49.1	7.8	26.3	5.8	76.6	31.2
		Selected mean comparisons[x]									
Fertilizers		**	**	**	**	**	**	**	**	**	**
Nitrogen rate											
Linear		**	**	NS	**	**	**	**	**	*	**
Quadratic		**	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen rate × fertilizer											
Linear		**	NS	NS	NS	**	NS	**	NS	NS	NS
Quadratic		**	NS	NS	NS	NS	NS	*	NS	NS	NS
Check vs. others		**	NS	NS	**	*	**	**	**	NS	**
Precise vs. others		NS	NS	**	**	**	**	**	**	**	**

[z]Leachate collected after 80 ml of tap water was applied to a 15-cm pot containing media only.
[y]No. of irrigations.
[x]Contrasts by ANOVA.
NS,*,**Nonsignificant (NS) or significant at 5% (*) or 1% (**) level.

4.2K, manufactured by O.M. Scott and Sons Co. from urea, methylene ureas, monoammonium phosphate, and potassium sulfate to produce 3–5 mm granules; and LEU (Precise African violet fertilizer), 8.0N–4.8P–4.2K manufactured by 3M Co., Minneapolis, Minn. by encapsulating liquid urea, ammonium superphosphate, and muriate of potash. Each of the fertilizers was applied at 300, 600, and 900 kg N/ha. Fertilizer treatments were replicated 3 times (1 pot per replicate) in a randomized block design.

Following the initial irrigation, the medium was irrigated every other day with 80 ml of surface-applied tap water per pot. At the 10th and 20th irrigations, the leachate was collected for Ca, P, K, Mg, and soluble salt analyses. Collection of leachate approximated the pour-through method of nutrient extraction outlined by Yeager et al. (12), except that tap water was utilized instead of distilled water and container moisture levels were not determined. No plants were grown in the medium. The experiment was conducted in a fiberglass greenhouse with a 267 $\mu mol\ s^{-1}m^{-2}$ PAR and a 21°C minimum night temperature.

Commercially-grown transplants of African violets 'Lisa' and 'Marta' were planted into 12 × 9 cm round plastic pots containing the medium described in the leachate tests. The previously mentioned Scott fertilizers at 3 different rates (300, 600, 900 kg N/ha), Precise African violet at a rate of 600 kg N/ha (manufacturer's recommended rate) and a check treatment (no fertilizer) were applied to the medium surface 1 week after transplanting. Treatments were replicated 3 times (1 pot per replicate) in a randomized complete block design. Separate experiments were conducted for each cultivar-irrigation combination. Irrigation treatments consisted of overhead watering (as needed) and subirrigation by a capillary mat. Plants were grown under the same environmental conditions as the leachate tests.

Nine weeks after treatment, the plants were rated for plant quality and injury. Plant quality was scored: 0 = dead; 1 = poor, small plant, yellow foliage not salable; 2 = fair, small plant, light green foliage, not salable; 3 = good, medium sized plant, light green foliage, salable; 4 = very good medium plant, medium green, salable; and 5 = excellent, large plants dark green, salable. Plant injury was scored on basis of the number of leaves exhibiting injury: 0 = dead; 1 = most severe, 90% of leaves damaged; 2 = severe, 75% of leaves damaged; 3 = medium, 50% of leaves damaged; 4 = little, 25% leaves damaged; and 5 = no damage.

Leachate tests. At the 10th irrigation, the soluble salts levels of the leachates from all the fertilizers except Precise 8.0–4.8–4.2 at 300 and 600 kg/ha (Table 1) exceeded 1.5 to 2.0 millimhos per cm, levels considered poor for irrigation water by Boodley (2). Irrigation water soluble salts levels between 0.75 to 2.0 millimhos per centimeter are permissible for use on plants according to Walter et al. (11). For a peat-lite medium, soluble salt levels between 1.0–2.3 are consider satisfactory for plant growth (2). Yeager et al. (12) found leachate soluble salts values for 100% pine bark medium to be 27% to 45% higher than soluble salt values obtained by the saturated soil extract method. Highest soluble salt readings occurred in leachates collected from media receiving 900 kg/ha of Scott 18.0–3.9–7.5, Scott 20.0–3.3–8.3, and Scott 15.0–8.7–4.2. Leachates from Scott 20.0–2.2–8.3 and Precise 8.0–4.8–4.2 applied at 300 kg/ha and Precise 8.0–4.8–4.2 applied at 600 kg/ha were similar to check leachates. Soluble salts for fertilizers, nitrogen rate linear, and quadratic, nitrogen rate × fertilizers linear and quadratic and check vs. other fertilizer were significant at the 10th irrigation. Soluble salts of most of the leachates were probably in a satisfactory range for plant growth at the 20th irrigation (Table 1). Fertilizers differed in their soluble salts and there was a linear response for nitrogen rate. Precise averaged the highest soluble salts readings.

Precise 8.0N–4.8P–4.2K at all rates had

Table 2. Effect of several controlled-release fertilizers on African violet plant quality and injury.

		Quality rating[z] Irrigation and cultivar				Injury rating[y] Irrigation and cultivar			
		Capillary		Overhead		Capillary		Overhead	
Fertilizer N-P-K	Rate kg N/ha	Lisa	Marta	Lisa	Marta	Lisa	Marta	Lisa	Marta
Scott 18.0–3.9–7.5	300	2.7	3.7	2.7	2.0	4.7	4.7	4.7	5.0
18.0–3.9–7.5	600	2.7	2.0	2.7	3.3	4.7	4.0	5.0	5.0
18.0–3.9–7.5	900	3.0	2.3	2.0	3.0	4.0	3.7	4.0	4.7
Scott 20.0–2.2–8.3	300	3.3	3.0	2.7	3.3	5.0	4.7	5.0	4.7
20.0–2.2–8.3	600	3.3	2.3	3.3	3.3	5.0	4.3	5.0	4.7
20.0–2.2–8.3	900	3.3	2.3	2.0	3.0	4.7	4.0	4.7	4.7
Scott 25.0–4.4–8.3	300	3.7	3.0	2.3	2.3	5.0	4.7	5.0	4.7
25.0–4.4–8.3	600	2.3	3.0	2.7	2.7	4.6	4.3	4.7	4.7
25.0–4.4–8.3	900	3.3	2.7	2.7	3.3	4.0	4.3	4.7	5.0
Scott 15.0–8.7–4.2	300	2.3	2.3	2.7	2.0	4.0	4.3	4.3	4.3
15.0–8.7–4.2	600	3.7	1.3	1.3	3.0	5.0	3.7	3.7	5.0
15.0–8.7–4.2	900	1.7	1.3	3.0	2.7	3.6	3.3	4.7	4.3
Precise 8.0–4.8–4.2	600	2.7	3.3	2.7	3.7	4.3	4.0	5.0	5.0
Check		2.0	2.0	1.6	2.3	5.0	5.0	5.0	5.0
				Selected mean comparisons[x]					
Fertilizers		NS	*	NS	NS	NS	*	**	NS
Nitrogen rate									
Linear		*	**	NS	NS	*	**	*	NS
Quadratic		NS	NS	NS	NS	*	NS	NS	NS
Nitrogen rate × fertilizer									
Linear		NS	NS	NS	NS	NS	NS	NS	NS
Quadratic		NS	NS	*	NS	NS	NS	**	NS

[z]Plant quality scored: 0 = dead; 1 = poor, small plant, yellow foliage, no salable; 2 = fair, small plant, light green; 3 = good, medium plant, light green foliage, salable; 4 = very good, medium plant, medium green, salable; and 5 = excellent, large plant, dark green, salable.

[y]Plant injury was scored: 0 = dead; 1 = most severe, 90% of leaves damaged; 2 = severe, 75% of leaves damaged; 3 = medium, 50% of leaves damaged; 4 = little, 25% of leaves damaged; and 5 = no damage.

[x]Contrasts by ANOVA.

NS,*,**Nonsignificant (NS), or significant at 5% (*) or 1% (**) level.

higher leachate Ca at the 10th irrigation than did the check and other fertilizer treatments (Table 1). Leachate Ca from control and Scott-fertilized media were similar. At the 20th irrigation, Precise 8.0N–4.8P–4.2K at all rates had higher leachate Ca than the Scott fertilizer leachates and the check leachates. Nitrogen rate gave a linear response for leachate Ca.

Leachates from media receiving Scott 15.0–8.7P–4.8K at 600 kg/ha contained the most P at the 10th irrigation. Nitrogen rate gave a linear response for P leachate. Leachates from all Precise 8.0N–4.8P–4.2K treatments differed in P from other treatment leachates. At the 20th watering, the trends were very similar to the 10th irrigation; however, leachate P readings were much lower than at the 10th irrigation (Table 1).

Generally, the 900 kg/ha rate of all fertilizers yielded leachates with the highest K at the 10th irrigation (Table 1). Precise 8.0N–4.8P–4.2K differed from the other fertilizer treatments. Nitrogen rate caused a linear response for leachate K. Most of the Scott fertilizers at 600 and 900 kg/ha were providing adequate K at the 10th irrigation. The K fertilization requirements (5) of African violets probably are not met by the Precise treatments and perhaps by some of the 300 kg/ha rates of Scott fertilizers. Trends for leachate K at the 20th irrigation were similar to those at the 10th irrigation; however, nitrogen × fertilizer linear and quadratic were not significant.

Precise 8.0N–4.8P–4.2K at 900 kg/ha had the highest leachate reading of Mg at the 10th irrigation and differed from other treatments (Table 1). The Mg leachate response was linear with nitrogen rate. At 20th irrigation, trends were similar to those at the 10th irrigation. Dolomitic limestone was probably the major source of Mg; however, Precise apparently contributed considerable Mg.

Growth tests. Nitrogen rate reduced visual quality linearly for both cultivars on capillary irrigation (Table 2). Visual quality ratings of most 'Lisa' plants grown on capillary irrigation was judged fair to very good (Table 2). Quality of 'Lisa' plants in the various fertilizers and capillary irrigation was similar except for the plants receiving 900 kg/ha Scott 15.0N–8.7P–4.2K, the poorest quality. As N rate increased, the plant quality ratings of both cultivars receiving this fertilizer and capillary irrigation usually was reduced. This response may be attributed to high soluble salts. Nell and Gurdaian (6) reported differences in the growth of 'Lisa' African violets to be associated clearly with increases in soluble salt levels. Capillary irrigated 'Marta' receiving all fertilizer treatments except 600 and 900 kg/ha Scott 15.0N–8.7P–4.2K, had similar quality ratings. Plants of both cultivars receiving overhead irrigation and various fertilizer treatments were of similar quality. A nitrogen rate × fertilizer reaction was significant for 'Lisa' plants.

Severe injury did not occur to either cultivar in any treatment. Increasing N rates caused a linear increase in injury for both cultivars irrigated capillary (Table 2). A quadratic response was also noted with 'Lisa' plants. Fertilizers produced differences in injury on capillary irrigated 'Marta' plants. Fertilizers, and nitrogen rate × quadratic, were significant in injury ratings of 'Lisa' plants irrigated overhead. Fertilizer treatments did not cause differences in plant injury on 'Marta' plants irrigated overhead.

Many of the controlled-release fertilizers tested were satisfactory for a the growth of African violets when irrigated overhead or by capillary mat, but high rates caused a reduction in quality and increased injury with capillary irrigation. Scott 25.0N–4.4P–8.3K gave the best overall performance on the basis of leachate soluble salts, Ca, P, K, and Mg, and plant quality and injury, indicating that UF fertilizers can be used on African violets. The poorest fertilizer was Scott 15.0M–8.7P–4.2K which had high leachate soluble salts, poor quality, and considerable plant injury. The release rate for this and other UIV fertilizers may be so rapid that African violets are injured. Precise 8.0N–4.8P–4.2K at 300 and 600 kg/ha provided more Ca, Mg, and lower initial soluble salts than the other fertilizers, but may have been low in P and K. With the exception of Precise, most fertilizers at 300 and 600 kg/ha had high leachate soluble salts initially (10th irrigation). This study indicates the need for additional information on the effects of soluble salts and relationships of various nutrient elements on the growth of African violets.

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Propagation of *Abies fraseri* by Semidormant Hardwood Stem Cuttings

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Additional index words. Fraser fir, Christmas trees, rooting

Abstract. **Dormant hardwood stem cuttings of Fraser fir [*Abies fraseri* (Pursh) Poir.] were severed from upper and lower tree crowns and artificially chilled at 4°C for 0, 4, or 8 weeks to achieve a partial break in rest. Following chilling, the resulting semidormant cuttings were treated with 0, 1500, 3000, or 4500 ppm IBA, and rooted for 135 days using a heated medium in a cool greenhouse. Rooted cuttings were evaluated, potted, and rechilled for 11, 7, or 3 weeks so that all cuttings were chilled a total of 11 weeks. Vegetative growth then was evaluated after a 12-week growing period. Cuttings initially chilled 4 weeks rooted in highest percentages, regardless of crown position, and exhibited little or no bud activity. Subsequent expansion of terminal and subterminal buds was greatest for cuttings initially chilled 0 or 4 weeks. Superior overall responses were achieved with upper-crown cuttings chilled 4 weeks and then treated with 4500 ppm IBA, or lower-crown cuttings dipped in 3000 ppm IBA after 4 weeks of chilling. The separation of rooting and budbreak apparently produced rooted cuttings comparable in size to 2-year-old plants grown from traditional hardwood cuttings. Chemical name used: 1*H*-indole-3-butanoic acid (IBA).**

Fraser fir is native to high elevations of the Southern Appalachians and is currently propagated by seed for the Christmas tree and landscape industries (11). Vegetative propagation would allow cloning of individuals with superior morphological or physiological characteristics. Many factors which influence the rooting of hardwood Fraser fir cuttings have been studied (2, 3, 4, 5, 7, 8), but concurrent vegetative growth of these cuttings has been consistently poor. Additional shoot growth after the rooting phase does not occur for at least 12 months, since the species exhibits only one cycle of preformed shoot extension per year (fixed growth). Rooting and budbreak processes recently have been separated by rooting softwood cuttings in the summer, then allowing buds to break the following season after winter chilling (12). Resulting cuttings were comparable to 2-year-old plants propagated by hardwood cuttings. A similar separation of rooting from budbreak was suggested in data from Miller (6) where dormant Fraser fir cuttings rooted well under short days after 4 to 6 weeks of artificial chilling, but exhibited little terminal bud activity at the end of the rooting period. Fall-collected Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco] cuttings also require less artificial chilling for rooting than for rapid budbreak (9). This study investigated the influences of artificial chilling, crown position, and auxin treatment on the rooting and subsequent vegetative growth of dormant hardwood cuttings of Fraser fir.

Stem cuttings were collected 8 Oct. 1982 from 14-year-old Fraser firs grown as sheared Christmas trees at the Mountain Research Station, Waynesville, N.C. (35° 30' N latitude, 82° 58' W longitude, elevation = 810 m). Stock plants were of unknown prove-

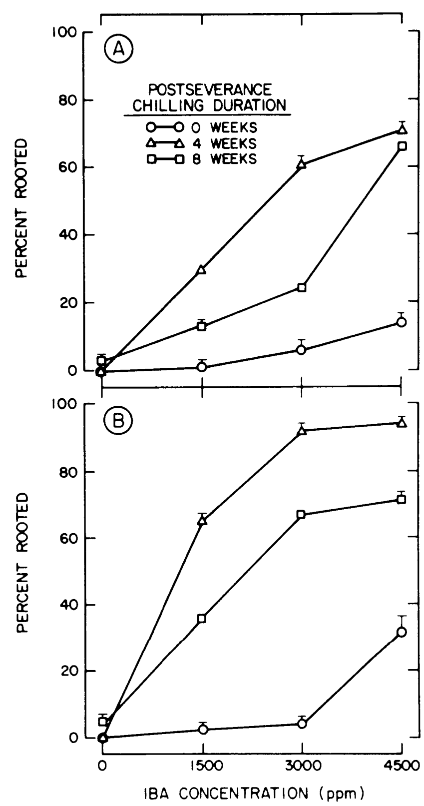

Fig. 1. Percentage of rooting for dormant Fraser fir cuttings collected 8 Oct. 1982, chilled at 4°C prior to rooting, and treated with IBA. (**A**) upper crown, (**B**) lower crown. Evaluations were made after 135 days. Vertical bars represent the SE of the means.

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