Influence of Substrate and Fertilizer Analysis and Rate on Growth and Quality of Five Species of Bedding Plants

Timothy K. Broschat and Kimberly A. Moore

ADDITIONAL INDEX WORDS. *Salvia splendens*, *Tagetes patula*, *Capsicum annuum*, *Impatiens wallerana*, *Begonia ×semperflorens-cultorum*, nitrogen, phosphorus, potassium

SUMMARY. Salvia (*Salvia splendens*) 'Red Vista' or 'Purple Vista,' french marigold (*Tagetes patula*) 'Little Hero Orange,' bell pepper (*Capsicum annuum*) 'Better Bell,' impatiens (*Impatiens wallerana*) 'Accent White,' and wax begonia (*Begonia ×semperflorens-cultorum*) 'Cocktail Vodka' were grown in 0.95-L (1-qt) containers using a 5 pine bark : 4 sedge peat : 1 sand substrate (Expts. 1 and 2) or Pro Mix BX (Expt. 2 only). They were fertilized weekly with 50 mL (1.7 fl oz) of a solution containing 100, 200, or 300 mg·L^{-1} (ppm) of nitrogen derived from 15N–6.5P–12.5K (1N–1P$_2$O$_5$–1K$_2$O ratio) or 21N–3P–11.7K (3N–1P$_2$O$_5$–2K$_2$O ratio) uncoated prills used in the manufacture of controlled-release fertilizers. Plants grown with Pro Mix BX were generally larger and produced more flowers or fruit than those grown with the pine bark mix. With few exceptions, plant color, root and shoot dry weights, and number of flowers or fruit were highly correlated with fertilization rate, but not with prill type. There appears to be little reason for using the more expensive 1–1–1 ratio prills, since they generally did not improve plant quality and may increase phosphorous runoff from bedding plant nurseries.

University of Florida, Ft. Lauderdale Research and Education Center, 3205 College Avenue, Ft. Lauderdale, FL 33314.

Florida Agricultural Experiment Station journal series R-07758. The authors wish to thank Susan Thor and Theodora Frohne for their assistance in this study. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Producers of container-grown ornamental plants in the United States often use controlled-release fertilizers (CRF) that are based on two commercially-available prill types: 15N–6.5P–12.5K [1N–1P$_2$O$_5$–1K$_2$O ratio (FERT A)] and 21N–3P–11.7K [3N–1P$_2$O$_5$–2K$_2$O ratio (FERT B)]. Container-grown foliage and woody ornamental plants are known to respond primarily to N and are typically fertilized with FERT B-based products (Conover and Poole, 1981; Wright and Niemiera, 1987). Flowering and fruiting plants grown in containers are believed to have higher P requirements than foliage or woody ornamental plants and thus are typically fertilized with FERT A-based products (Nelson, 1998). However, experimental evidence for P promotion of flowering and/or fruiting in horticultural crops has generally been limited to deficiency levels of P and not to higher P fertilization levels (Mengel and Kirkby, 1989). Others have shown that root and shoot quality and flowering in some bedding plant seedlings respond strongly to increasing substrate N levels, but not P and K (van Iersel et al., 1998; 1999).

Nitrate and phosphate-phosphorus (PO$_4$-P) runoff from nurseries and their impact on ground and surface water quality is a major concern in many production areas. Nitrate and PO$_4$-P leaching from containers can be considerable (Broschat, 1995; Cole and Dole, 1997), and it is important that no more nitrate-nitrogen (NO$_3$-N) or PO$_4$-P be applied than necessary to economically produce high quality crops. Since most studies have shown that N is the primary limiting factor in container production (Ogden et al., 1987; Wright and Niemiera, 1987), significant reductions in N applied may not be feasible. However, if P fertilizers are being applied to those crops at levels exceeding their requirements, reduction in P fertilization rates may decrease nursery PO$_4$-P runoff without reducing plant quality. The purpose of this study was to compare the root and shoot growth and flowering and/or fruiting in five species of bedding plants grown in two different potting substrates and fertilized with the two basic fertilizer sources, FERT A and FERT B, used in the manufacture of commonly used controlled-release fertilizers.

Materials and methods

EXPERIMENT 1. Plugs [2 × 2 × 4 cm deep (0.75 × 0.75 × 1.5 inches)] of 'Red Vista' salvia, 'Better Bell' bell pepper, and 'Little Hero Orange' french marigold were transplanted on 2 Dec. 1999 into 0.95-L plastic containers filled with a 5 pine bark : 4 Florida sedge peat : 1 sand (by volume) substrate (pine bark mix). This substrate was amended with dolomitic limestone at 7.1 kg·m^{-3} (12 lb/yard^3) and Micromax (Scotts Co., Marysville, Ohio) at 0.89 kg·m^{-3} (1.5 lb/yard^3). Each pot received 50 mL of a fertilizer solution weekly that contained 100, 200, or 300 mg·L^{-1} [30, 60, or 90 mg/pot (28,350 mg = 1.0 oz)] of N from either FERT A or FERT B uncoated prills (Scotts Co., Marysville, Ohio) dissolved in deionized water. FERT A also provided (per pot) 13, 26, or 39 mg of P and 25, 50, or 75 mg of K, while FERT B provided (per pot) 4, 8, or 12 mg of P and 6.5, 13, or 19.5 mg of K. Ten replicate pots of each species, substrate, and fertilizer treatment were arranged in a completely randomized design.

All plants received about 2 cm (0.75 inch) of water daily from overhead irrigation and were grown in an open-sided greenhouse (maximum photosynthetic photon flux = 1350 μmol·m^{-2}·s^{-1}) in Ft. Lauderdale, Fla. The number of inflorescences or fruit ≥ 1 cm (0.5 inch) in diameter (bell peppers only) per plant were counted and removed weekly. On 3 Feb. 2000 all plants were rated for leaf color on a scale of 1 to 5 (1 = light yellow, 3 = light green, 5 = dark green) by both authors and the mean rating of the authors was recorded. Plants were also cut off at the soil line and the potting substrate was washed from the roots. Roots and shoots were oven-dried at 62 °C (144 °F) until constant weight was achieved.

Data were analyzed using analysis of covariance (SAS Proc GLM, SAS Inst., Cary, N.C.) with substrate and fertilizer prill type as class variables and fertilizer rate as the quantitative covariate.

EXPERIMENT 2. Plugs of 'Purple Vista' salvia, 'Better Bell' bell pepper, 'Little Hero Orange' french marigold, 'Cocktail Vodka' wax begonia, and 'Accent White' impatiens were transplanted into 0.95-L pots as in Expt. 1 using two potting substrates, the pine bark based

Table 1. Effects of substrate and fertilizer source and rate on color, number of flowers, and root and shoot dry weight of ‘Purple Vista’ salvia, ‘Orange Little Hero’ french marigold, ‘Better Bell’ bell pepper, ‘Accent White’ impatiens, and ‘Cocktail Vodka’ wax begonia.

		Pine bark mix				Pro mix BX			
Fertilizer	**Rate (mg/pot)[z]**	**Color[y]**	**No. of flowers or fruit**	**Shoot dry wt (g)[z]**	**Root dry wt (g)**	**Color**	**No. of flowers or fruit**	**Shoot dry wt (g)**	**Root dry wt (g)**
				‘Purple Vista’ salvia					
FERT A[x]	200	3.5	4.5	2.44	0.83	3.6	6.3	4.55	1.96
FERT A	400	3.9	6.0	4.56	1.20	4.1	10.4	6.67	2.08
FERT A	600	4.7	6.9	5.48	1.22	4.7	12.1	8.70	2.05
Mean		4.0	5.8	4.16	1.08	4.1	9.6	6.64	2.03
FERT B	142	3.5	4.8	2.57	0.89	3.4	6.1	4.34	1.47
FERT B	284	3.9	5.5	4.18	1.24	4.1	7.3	5.91	2.08
FERT B	426	4.6	6.3	5.27	1.29	4.6	8.0	7.34	2.16
Mean		4.0	5.5	4.01	1.31	4.0	7.1	5.86	2.39
Significant effects									
Substrate (S)		NS	***	***	***				
Fertilizer (F)		NS	NS	NS	NS	NS	*	*	NS
Rate (R)		***	**	***	***	***	**	***	*
S × F		NS	NS	NS	NS				
S × R		NS	NS	NS	NS				
F × R		NS	NS	NS	*	NS	NS	NS	NS
				‘Orange Little Hero’ french marigold					
FERT A	200	4.5	5.9	4.26	0.43	3.9	9.8	6.89	2.13
FERT A	400	4.6	7.7	6.07	0.86	4.1	10.2	8.79	3.06
FERT A	600	4.9	8.9	6.75	1.06	4.6	11.8	8.61	2.30
Mean		4.7	7.5	5.69	0.78	4.2	10.6	8.09	2.50
FERT B	142	4.3	5.7	3.79	0.44	3.3	8.7	6.02	2.50
FERT B	284	4.7	7.8	5.93	1.06	4.0	11.1	7.41	2.12
FERT B	426	4.7	9.0	6.72	1.49	4.2	11.6	9.10	2.88
Mean		4.6	7.5	5.48	1.00	3.8	10.5	7.51	2.50
Significant effects									
Substrate (S)		***	***	***	****				
Fertilizer (F)		NS	NS	NS	NS	**	NS	NS	NS
Rate (R)		***	***	***	***	***	***	***	***
S × F		NS	NS	NS	NS				
S × R		NS	NS	NS	NS				
F × R		NS	NS	NS	NS	NS	NS	NS	NS
				‘Better Bell’ bell pepper					
FERT A	200	3.9	1.4	2.54	1.34	3.7	1.6	6.48	2.62
FERT A	400	4.5	2.7	4.99	1.61	4.3	3.3	11.06	3.71
FERT A	600	4.9	4.0	5.91	1.69	4.8	3.7	13.93	4.21
Mean		4.4	2.7	4.48	1.55	4.3	2.9	10.49	3.51
FERT B	142	3.9	2.3	2.93	1.04	3.6	2.8	7.10	2.47
FERT B	284	4.3	3.7	4.63	1.57	4.2	2.6	9.98	3.08
FERT B	426	5.0	3.6	5.91	1.69	4.9	4.0	12.72	3.66
Mean		4.4	3.2	4.49	1.43	4.2	3.1	9.9	3.07
Significant effects									
Substrate (S)		NS	NS	***	***				
Fertilizer (F)		NS	NS	NS	NS	NS	NS	NS	*
Rate (R)		***	**	***	***	***	*	***	***
S × F		NS	NS	NS	NS				
S × R		NS	NS	***	**				
F × R		NS	NS	NS	NS	*	NS	NS	NS

[z]28,350 mg = 28.35 g = 1.0 oz.
[y]1 = light yellow, 3 = light green, 5 = darkest green.
[x]FERT A = 15N–6.5P–12.5K (1N–1P_2O_5–1K_2O ratio), FERT B = 21N–3P–11.7K (3N–1P_2O_5–2K_2O ratio).
NS,*,**,***Nonsignificant or significant at P = 0.05, 0.01, and 0.001, respectively.

Table 1. Effects of substrate and fertilizer source and rate on color, number of flowers, and root and shoot dry weight of 'Purple Vista' salvia, 'Orange Little Hero' french marigold, 'Better Bell' bell pepper, 'Accent White' impatiens, and 'Cocktail Vodka' wax begonia (continued).

		Pine bark mix				Pro mix BX			
Fertilizer	Rate (mg/pot)^z	Color^y	No. of flowers or fruit	Shoot dry wt (g)^z	Root dry wt (g)	Color	No. of flowers or fruit	Shoot dry wt (g)	Root dry wt (g)
				'Accent White' impatiens					
FERT A	200	3.1	12.0	2.75	0.37	3.3	21.4	4.59	0.51
FERT A	400	3.8	15.2	4.37	0.70	4.2	20.2	6.05	1.75
FERT A	600	4.5	13.1	4.91	0.68	4.4	18.2	7.97	1.80
Mean		3.8	13.4	4.01	0.58	4.0	19.9	6.20	1.35
FERT B	142	3.1	13.0	2.40	0.43	3.6	16.3	4.68	1.17
FERT B	284	3.5	15.1	3.84	0.43	3.8	19.9	5.84	1.67
FERT B	426	4.6	12.5	4.85	0.69	4.7	15.7	7.79	1.74
Mean		3.7	13.5	3.70	0.52	4.0	17.3	6.10	1.53
Significant effects									
Substrate (S)		**	**	***	***				
Fertilizer (F)		NS	NS	NS	NS	NS	NS	NS	NS
Rate (R)		***	NS	***	***	***	NS	***	***
S × F		NS	NS	NS	NS				
S × R		NS	NS	NS	***				
F × R		NS	NS	NS	NS	NS	NS	NS	NS
				'Cocktail Vodka' wax begonia					
FERT A	200	5.0	11.6	3.63	0.35	5.0	28.9	6.79	0.51
FERT A	400	5.0	18.4	4.97	0.35	5.0	25.1	7.22	1.43
FERT A	600	5.0	17.5	5.85	0.43	5.0	23.5	6.94	0.56
Mean		5.0	15.8	4.82	0.38	5.0	25.9	6.98	0.83
FERT B	142	5.0	10.1	2.98	0.23	5.0	25.0	6.06	0.96
FERT B	284	5.0	18.3	4.30	0.46	5.0	34.0	6.88	0.61
FERT B	426	5.0	16.4	5.70	0.50	5.0	23.4	6.61	1.31
Mean		5.0	14.9	4.33	0.40	5.0	27.5	6.52	0.96
Significant effects									
Substrate (S)		NS	***	***	***				
Fertilizer (F)		NS	NS	NS	NS	NS	NS	NS	NS
Rate (R)		NS	***	***	**	NS	NS	NS	NS
S × F		NS	NS	NS	NS				
S × R		NS	NS	**	NS				
F × R		NS	NS	NS	NS	NS	NS	NS	NS

^{z}28,350 mg = 28.35 g = 1.0 oz.
^{y}1 = light yellow, 3 = light green, 5 = darkest green.
^{x}FERT A = 15N–6.5P–12.5K (1N–1P_2O_5–1K_2O ratio), FERT B = 21N–3P–11.7K (3N–1P_2O_5–2K_2O ratio).
^{NS,*,**,***}Nonsignificant or significant at P = 0.05, 0.01, and 0.001, respectively.

substrate used in Expt. 1 and Pro Mix BX (Premier Horticulture, Red Hill, Pa.). Before transplanting, initial air-filled porosity, water-holding capacity, and total pore space were determined using volume displacement methods with 0.95-L pots. Experiment 2 was set up on 29 Feb. 2000 with plants being harvested when they reached a marketable size (impatiens harvested on 6 Apr., marigolds on 10 Apr., salvias on 13 Apr., bell peppers on 19 Apr., and wax begonias on 27 Apr.). In all other aspects, Expt. 2 was identical to Expt. 1.

Results and discussion

The overall effects of fertilizer source and rate on root and shoot dry weights, plant color ratings, and number of flowers or fruit for salvias, marigolds, and bell peppers grown in pine bark mix in Expt. 1 were similar to those obtained for these same species in Expt. 2. For that reason, only the results of Expt. 2 are presented.

In Expt. 2 all plants grown in Pro Mix BX had consistently greater root and shoot dry weights than those grown in pine bark mix (Table 1). Similarly, with the exception of number of fruit in bell peppers, number of flowers or fruit was also greater for plants grown in Pro Mix BX. Significant plant color differences between substrates occurred for marigolds and impatiens, with marigolds producing more flowers in the pine bark mix, but impatiens producing more in Pro Mix BX. The overall superiority of Pro Mix BX in promoting bedding plant growth and flowering could be due to its greater water-holding capacity (Table 2) or differing N levels. Pine bark-based substrates are known to cause N depletion (Ogden et al., 1987), while Pro Mix BX contains a nutrient precharge (in mg·L^{-1}) of 110 NO_3-N, 45 PO_4-P, and 120 K. However, these five species' responses to fertilizer source or rate generally did not differ between the two substrates as indicated by their nonsignificant substrate × fertilizer and substrate × rate interactions (Table 1).

Table 2. Initial substrate pH, electrical conductivity (EC) determined by saturated media extract (Warncke, 1986) and air-filled porosity (AFP), water-holding capacity (WHC), and total pore space determined on three samples of each substrate in 0.95-L (1-qt) pots by volume displacement methods (Niedziela and Nelson, 1992).

Substrate	pH	EC ($dS \cdot m^{-1}$)	AFP (%)	WHC (%)	Total pore space (%)
Pine bark mix	5.8 a[z]	0.79 a	22 a	30 b	52 b
Pro Mix BX	5.6 a	0.71 a	23 a	45 a	67 a

[z]Mean separation within columns by the Waller-Duncan k ratio method (k = 100).

The only exceptions were significant substrate × rate interactions for impatiens root dry weight, begonia shoot dry weight, and bell pepper root and shoot dry weights.

Fertilizer A slightly increased shoot dry weight and number of flowers produced in salvia, color ratings in marigold, and root dry weight in bell peppers growing in Pro Mix BX over than of Fertilizer B (Table 1). All other plant quality variables in Pro Mix Bx plants and all plant quality variables for pine bark mix were unaffected by fertilizer source. Fertilizer rate effects were highly significant for all variables in all species except for number of flowers in impatiens for both substrates, begonia color in both substrates, and all other variables for begonias in Pro Mix BX (Table 1). Fertilizer source × rate interaction effects were significant only for salvia root dry weight in pine bark mix and bell pepper color in Pro Mix BX. Thus, fertilizer source does not appear to be particularly important in determining bedding plant quality.

FERT A-based products are often used in the production of bedding plants since their higher P content is believed to enhance flower and/or fruit production. In this study FERT A significantly improved flower production only for salvia grown in Pro Mix BX. In none of the other species did FERT A significantly improve flower or fruit production. Since root and shoot growth of most container-grown ornamental plants do not respond to increasing P beyond a minimal sufficiency level (Broschat and Klock-Moore, 2000; van Iersel et al., 1998, 1999) and PO_4-P runoff from nurseries is a potential environmental concern, there appears to be little need for the higher levels of P in the FERT A fertilizers. FERT A also costs more than FERT B, but yields little or no improvement in bedding plant growth or quality for the increased cost.

Literature cited

Broschat, T.K. 1995. Nitrate, phosphate, and potassium leaching from container-grown plants fertilized by several methods. HortScience 30:74–77.

Broschat, T.K. and K.A. Klock-Moore. 2000. Root and shoot growth responses to phosphate fertilization in container-grown plants. HortTechnology 10:765–767.

Cole, J.C. and J.M. Dole. 1997. Temperature and phosphorus source affect phosphorus retention by a pine bark-based container medium. HortScience 32:236–240.

Conover, C.A. and R.T. Poole. 1981. Guide for fertilizing tropical foliage plant crops. Univ. Fla. Apopka Agr. Res. Ctr. Res. Rpt. RH-81-1.

Mengel, K. and E.A. Kirkby. 1989. Principles of plant nutrition. Intern. Potash Inst., Berne, Switzerland.

Nelson, P.V. 1998. Greenhouse operation and management. Prentice-Hall, Upper Saddle River, N.J.

Niedziela, Jr., C.E. and P.V. Nelson. 1992. A rapid method for determining physical properties of undisturbed substrates. HortScience 27:1279–1280.

Ogden, R.J., F.A. Pokorny, H.A. Mills, and M.G. Dunavent. 1987. Elemental status of pine bark-based potting media. Hort. Rev. 9:103–131.

van Iersel, M.W., R.B. Beverly, P.A. Thomas, J.C. Latimer, and H.A. Mills. 1998. Fertilizer effects on the growth of impatiens, petunia, salvia, and vinca plug seedlings. HortScience 33:678–682.

van Iersel, M.W., R.B. Beverly, P.A. Thomas, and H.A. Mills. 1999. Nitrogen, phosphorus, and potassium effects on pre- and post-transplant growth of salvia and vinca seedlings. J. Plant Nutr. 22:1403–1313.

Warncke, D.D. 1986. Analyzing greenhouse growth media by saturation extraction method. HortScience 21:223–225.

Wright, R.D. and A.X. Niemiera. 1987. Nutrition of container-grown woody nursery crops. Hort. Rev. 9:75–101.

Effects of Flutolanil Fungicide and Primer Wetting Agent on Water-repellent Soil

Keith J. Karnok[1] and
Kevin A. Tucker[2]

Additional index words. hot spots, dry patch, isolated dry spots, hydrophobic soil

Summary. **Localized dry spot (LDS) caused by water repellent soil is a common problem on golf course putting greens having a predominately sand root zone. Fairy ring often causes LDS by developing hydrophobic soil. Although the fungicide flutolanil is labeled for the control of fairy ring, golf course superintendents often apply flutolanil to all LDS caused by hydrophobic soil and other conditions. The objective of this study was to determine the effect of flutolanil on an existing hydrophobic soil. The study was conducted on a creeping bentgrass [*Agrostis palustris* (synonym *A. stolonifera*)] experimental golf green in which the top 4 inches (10.2 cm) of the root zone was a moderately hydrophobic sand. Six treatments were used: uncored, cored, flutolanil (two applications.), flutolanil + Primer wetting agent (two applications.), Primer (two applications.) and Primer (three applications.). Plots receiving the fungicide and wetting agent treatments were cored before application. Each treatment containing the wetting agent significantly reduced soil water repellency. Flutolanil without wetting agent had no effect on soil hydrophobicity.**

Department of Crop and Soil Sciences, Plant Sciences Bldg., University of Georgia, Athens, GA 30602.

Use of trade names does not imply endorsement of the products named nor criticism of similar ones not named. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Professor.

[2]Research associate.