Fertilizer Effects on the Growth of Impatiens, Petunia, Salvia, and Vinca Plug Seedlings

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Abstract. Good fertilizer management is important in plug seedling production of bedding plants to prevent nutrient deficiencies and toxicities. We determined the effect of N, P, and K nutrition on the growth of plugs of impatiens (*Impatiens wallerana* Hook. f.), petunia (*Petunia* × *hybrida* Hort. Vilm.-Andr.), salvia (*Salvia splendens* F. Sellow ex Roem. & Schult.), and vinca (*Catharanthus roseus* L.). For all four species, shoot N concentration was correlated linearly with shoot dry mass of the seedlings at transplant. Phosphorus or K concentration in the nutrient solution or shoot tissue had little or no effect on the shoot growth of seedlings, but shoot P levels increased with P concentrations in the fertilizer solution (luxury consumption). Salvia was the only species that also exhibited luxury consumption of K. Results of this study indicate that seedling growth of these species is mainly determined by N and this should probably be the main focus of fertility programs in the plug industry, while P and K applications can be reduced.

Nutrient management is important for growing bedding plant plugs. Plant nutrients must be supplied to the developing plant in the form, amount, time, and place necessary to support uptake and prevent nutrient deficiencies from limiting growth and quality. However, horticultural, economic, and environmental considerations limit the amount of nutrients that can be applied. Surplus fertilizer can result in excessive seedling size, nutrient toxicities, excess salinity, wasted fertilizer, and ground or surface water contamination.

Both qualitative and quantitative approaches can be used for fertilizer management. A qualitative approach consists of monitoring plants for visual symptoms of nutrient deficiency or toxicity. Lee et al. (1992), for example, described the symptoms of a range of micronutrient toxicities in petunia. Although monitoring plants for visual symptoms can be helpful, they do not give growers quantitative guidelines for fertilizer management.

Two different quantitative approaches, substrate testing and tissue analysis, are commonly used to determine appropriate fertility levels. Both methods have some advantages and disadvantages. Substrate testing may not give an adequate indication of the history of the plants, since substrate fertility can change rapidly because of fertilizer applications. Therefore, substrate testing is better suited to predicting future fertility problems than to detecting past problems. Unlike tissue analysis,

substrate testing can predict the possibility of future nutrient deficiencies before they occur (Compton and Nelson, 1997), and corrective action can be taken to prevent problems. However, timing is crucial in substrate testing, since results can be highly variable if samples are not taken at a set time after fertilization (Compton and Nelson, 1997). This variability has limited its use in the production of plug seedlings, but substrate testing can be a valuable tool if sampling procedures are consistent.

Tissue nutrient analysis gives an indication of nutrient deficiencies or toxicities permitting adjustments in fertilizer practices. Unlike substrate testing, tissue analysis is not well suited to predicting future problems, because it does not indicate current nutrient levels in the growing medium. A combination of both methods gives a good indication of whether fertility programs are adequate. Tentative levels for interpretation of substrate analysis have been proposed by Warncke and Krauskopf (1983), but there is little information on the relation between tissue nutrient levels and growth of bedding plant plugs.

Nutritional diagnosis, based on interpretation and application of plant tissue analysis, can provide information to optimize fertilizer management, assure product quality, and re-

duce the risk of environmental pollution. Its purpose is 3-fold: 1) to identify the cause of growth or quality problems associated with fertilizer applications; 2) to identify potential nutritional problems prior to growth or quality limitation, and to guide fertilization to prevent possible problems; 3) to verify that fertilizer management is adequate and appropriate, thereby preventing unnecessary fertilizer application. An understanding of the relation between tissue nutrient levels and plant growth is important in the interpretation of tissue analysis.

Despite the importance of nutritional diagnosis for bedding plant plug production, few nutritional data exist for ornamental plants, and especially for seedlings (Mills and Jones, 1996). Most plug nutrition research appears to have focused on concentration and frequency of fertilizer applications, with little attention to tissue nutrient levels (Styer and Koranski, 1997). The objective of this study was to quantify fertilizer (N, P, and K) concentration effects on tissue nutrient levels and growth of plugs of the popular bedding plants impatiens, petunia, salvia, and vinca.

Materials and Methods

Plant material. Seeds of 'Impulse White' impatiens, 'Ultra Salmon' petunia, 'Top Red' salvia, and 'Tropicana Blush' vinca were planted by a commercial grower in plug flats (338 cells/tray) filled with soilless growing medium (LG-3; Sun Gro Horticulture, Bellevue, Wash.) on 15 Mar., 12 Apr., and 10 May 1995, for N, P, and K experiments, respectively. After germination, flats were shipped overnight to the Georgia Station and immediately placed in a polyethylene-covered greenhouse. Seedlings received no fertilizer before they were shipped. All flats were cut into three pieces with 104 or 117 plants each.

Treatments. Responses of the seedlings to N, P, and K nutrition were quantified in three separate experiments. Plants were fertilized weekly with nutrient solution containing 1, 2, 4, 8, or 16 mm of N (with 1 mm P and 6 mm K); 0.125, 0.25, 0.5, 1, or 2 mm of P (with 16 mm N and 6.1 to 8 mm K); or 0.5, 1, 2, 4, or 8 mm of K (with 16 mm N and 1 mm P). Micronutrients were added as a soluble trace element mix (STEM; The Scotts Co., Marysville, Ohio) at 1.0 g·L⁻¹. These fertility levels were chosen because they encompass the N, P, and K levels that are normally used in plug production (Styer and Koranski, 1997). A more detailed

Table 1. Nutrient composition (mm), pH, and electrical conductivity (EC) (dS·m⁻¹) of the fertilizer solutions used to determine the response of bedding plant plugs to N, P, and K fertilization.

	N series					P series					K series				
KH ₂ PO ₄	1	1	1	1	1	0.125	0.25	0.5	1	2	---	---	---	---	---
K ₂ SO ₄	2.5	2.5	2.5	2.5	2.5	---	---	---	---	---	0.25	0.5	1	2	4
CaCl ₂	4.5	4	3	1	0	---	---	---	---	---	---	---	---	---	---
MgSO ₄	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ca(NO ₃) ₂	0.5	1	2	4	8	5	5	5	5	5	8	8	8	8	8
KNO ₃	---	---	---	---	---	6	6	6	6	6	---	---	---	---	---
Ca(H ₂ PO ₄) ₂	---	---	---	---	---	---	---	---	---	---	0.5	0.5	0.5	0.5	0.5
pH	6.3	6.2	6.2	6.2	6.2	6.7	6.7	6.4	5.9	5.9	5.1	5.1	5.2	5.3	5.3
EC	2.6	2.6	2.6	2.6	3.0	2.2	2.3	2.2	2.3	2.4	2.0	2.1	2.2	2.4	2.7

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composition of the nutrient solutions is shown in Table 1. Plants were watered overhead as required between weekly fertilizations.

Data collection and analysis. Because of the small size of the plugs, entire shoots were collected for nutrient analysis. Samples were taken on 18 Apr. (N series), 3 May (P series), and 30 May (K series), dried, weighed, ground, and analyzed for nutrient levels. Every sample consisted of a minimum of 30 plants. Tissue N was determined with a CNS 2000 analyzer (LECO Corp., St. Joseph, Mich.) (Mills and Jones, 1996). Tissue P and K were determined by dry ashing and ICP spectroscopy (Jones and Case, 1990).

The experimental design for all three experiments was a randomized complete block

with three replications and a group of 104 or 117 plants as the experimental unit. Data for the different species were analyzed separately. Treatment effects were tested by fitting a second order polynomial using linear regression analysis. Effects were considered to be significant if the regression parameter for the quadratic term of the polynomial was significantly different from zero ($P \leq 0.05$). If the quadratic term was not significant, it was dropped from the analysis and treatment effects were tested for a linear correlation.

Results and Discussion

Tissue nutrient levels and growth. Plug size of all four species increased with increas-

ing tissue N concentration (Figs. 1–4). For all species, there was a highly significant positive linear relation between shoot N concentration and shoot dry mass ($P < 0.01$). Slopes of the regression lines of shoot dry mass (mg) vs. tissue N concentration ($\text{mg} \cdot \text{g}^{-1}$) were 30, 34, 31, and 20 g for impatiens, petunia, salvia, and vinca, respectively, indicating that petunia was most responsive and vinca least responsive to increased tissue N level over the N range tested. The N concentrations of the fertilizer solutions in this experiment (14 to $224 \text{ mg} \cdot \text{L}^{-1}$) cover the range of N fertilization commonly recommended for plugs (50 to $150 \text{ mg} \cdot \text{L}^{-1}$) (Styer and Koranski, 1997). The linear correlation between tissue N concentration and shoot dry mass suggests that higher fertilizer N lev-

Fig. 1. The effects of nutrient solution composition on tissue nutrient (N, P, and K) concentrations, and the relationship between tissue nutrient concentrations and shoot dry mass of impatiens plugs. Plants were fertilized weekly with water-soluble fertilizer containing different amounts of N, P, or K. The legends indicate the amounts of N, P, or K in the nutrient solution (mm). The line indicates a significant correlation between tissue N concentration (C) and dry mass (DM).

Fig. 2. The effects of nutrient solution composition on tissue nutrient (N, P, and K) concentrations, and the relationship between tissue nutrient concentrations and shoot dry mass of petunia plugs. Plants were fertilized weekly with water-soluble fertilizer containing different amounts of N, P, or K. The legends indicate the amounts of N, P, or K in the nutrient solution (mm). The line indicates a significant correlation between tissue N concentration (C) and dry mass (DM).

Fig. 3. The effects of nutrient solution composition on tissue nutrient (N, P, and K) concentrations, and the relationship between tissue nutrient concentrations and shoot dry mass of salvia plugs. Plants were fertilized weekly with water-soluble fertilizer containing different amounts of N, P, or K. The legends indicate the amounts of N, P, or K in the nutrient solution (mm). The line indicates a significant correlation between tissue N concentration (C) and dry mass (DM).

Fig. 4. The effects of nutrient solution composition on tissue nutrient (N, P, and K) concentrations, and the relationship between tissue nutrient concentrations and shoot dry mass of vinca plugs. Plants were fertilized weekly with water-soluble fertilizer containing different amounts of N, P, or K. The legends indicate the amounts of N, P, or K in the nutrient solution (mm). The lines indicate significant correlations between tissue N and P concentration (C) and dry mass (DM).

els would have resulted in even faster growth. However, maximum shoot dry mass is not necessarily the goal of commercial plug producers. Optimal growth rate or size of bedding plant plugs is hard to define, since quality of plugs is not only dependent on plant size but also on such factors as plant height and seedling uniformity.

There was no significant effect of P or K concentration on the growth of impatiens, petunia, and salvia (Figs. 1–3), indicating that even the lowest amounts of P and K applied did not limit growth. Although shoot P concentration was significantly correlated with shoot dry mass of vinca (Fig. 4), its effect on plug growth was very small. Good vinca seedling growth was observed in the N experiment,

where tissue P levels were lower. These data clearly show that low concentrations of P and K can be used in the fertilizer solution without limiting plug growth of any of these four species.

The results of this study suggest that the growth of bedding plant plugs is mainly determined by nitrogen within the fertility ranges tested. Plug growth was positively correlated with N tissue level and concentration in the nutrient solution, but not with P or K levels. This is of great practical significance, since it will allow growers to control plug growth by adjusting N applications.

Fertilizer concentration and shoot nutrient levels. Nitrogen concentration in the nutrient solution not only affected seedling growth,

but also tissue N level. Tissue N level of all four species increased with increasing concentrations of N in the nutrient solution (Fig. 5), although there were some differences between species. Of the four species, salvia had the highest tissue N level at low fertilizer N concentrations, but the level did not increase significantly as the N concentration increased from 1 to 8 mm. Only at 16 mm was there an increase in tissue N level of salvia. Tissue N levels of impatiens, petunia, and vinca increased linearly with increasing amounts of N in the nutrient solution, impatiens and vinca showing the greatest response. Shoot P concentrations in all four species also increased with increased P levels in the nutrient solution, but there were large differences between spe-

Fig. 5. Shoot nitrogen levels of bedding plant plugs as affected by the nitrogen concentration of the nutrient solution. Plants were watered with nutrient solution at weekly intervals. Plugs were harvested 34 d after seeding. The lines indicate significant correlations between fertilizer N concentration (C) and tissue N level (N).

Fig. 6. Shoot phosphorus levels of bedding plant plugs as affected by the phosphorus concentration of the nutrient solution. Plants were watered with nutrient solution at weekly intervals. Plugs were harvested 21 d after seeding. The lines indicate significant correlations between fertilizer P concentration (C) and tissue P level (P).

cies (Fig. 6). The relationship between fertilizer and tissue P level was linear for petunia, salvia, and vinca, and quadratic for impatiens. Although this correlation was significant for all species ($P < 0.0001$), the increase in P tissue level of vinca was only 12% (from 3.2 to 3.6 mg·g⁻¹). In impatiens and salvia tissue P level increased greatly (67% to 90%) in response to increased P in the fertilizer solution (from 3.5 to 6.7 mg·g⁻¹ and 4.5 to 7.5 mg·g⁻¹, respectively). Since P level in the shoot tissue did not affect growth of the seedlings, the accumulation of P in the shoots could be considered luxury consumption and appears to provide no immediate advantage to the plant. However, this P reserve can be used later if the supply of P becomes limiting to growth. Nutrition during the production of seedlings affects the subsequent field performance of several vegetables (Dufault, 1986; Knavel, 1977; Tremblay et al., 1987) and similar effects may occur in bedding plants.

Although luxury consumption of K is common (Marschner, 1995), only salvia accumulated significantly more K in its shoots in response to increased K concentrations in the nutrient solution (Fig. 7), and even this increase was small (from 54 to 58 mg·g⁻¹). Tissue K levels differed greatly in the four species, ranging from an average of 30 mg·g⁻¹ for vinca to 50 to 60 mg·g⁻¹ for petunia and salvia.

Conclusions

Phosphorus and K had no significant effect on seedling growth. Based on these results, decreasing P and K levels in fertilizers for plugs appears possible, and this may help to decrease the potential of nutrient runoff from greenhouses. Because growth of impatiens, petunia, salvia, and vinca seedlings is strongly dependent on the amount of N in the fertilizer and/or shoots of the plants, N fertilization can be used effectively to manage the growth of plugs. All four species accumulated increased N levels in their shoots in response to higher N concentrations in the nutrient solution. Luxury consumption of P occurred in all species, although the amount of luxury consumption was species-dependent. Only salvia exhibited luxury consumption of K.

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Fig. 7. Shoot potassium levels of bedding plant plugs as affected by the potassium concentration of the nutrient solution. Plants were watered with nutrient solution at weekly intervals. Plugs were harvested 20 d after seeding. The line indicates a significant correlation between fertilizer K concentration (C) and tissue K level of salvia (K).

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