

Nutrition Affects Pre- and Posttransplant Growth of Impatiens and Petunia Plugs

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Abstract. Pre- and posttransplant growth of plug seedlings is affected by the nutrition of the plants. The effects of weekly applications of nutrient solution with different N (8–32 mM) or P and K (0.25–1.0 mM) levels on the growth and nutrient composition of impatiens (*Impatiens wallerana* Hook. f.) and petunia (*Petunia ×hybrida* hort. Vilm.-Andr.) plug seedlings were quantified. Impatiens and petunia pretransplant seedling growth was most rapid with a NO₃⁻ concentration of 24 or 32 mM (N at 336 and 448 mg·L⁻¹), while P and K had little effect. Increasing the N concentration in the fertilizer also increased shoot tissue N levels of both impatiens and petunia and decreased shoot P level of impatiens and K level of petunia. Posttransplant growth was most rapid in plants that received N at 16 to 32 mM. Decreasing P and K from 1 to 0.25 mM in the pretransplant fertilizer reduced posttransplant growth. Shoot P level of impatiens 15 d after transplanting decreased from 6.9 to 4.8 mg·g⁻¹ as the pretransplant fertilizer N concentration increased from 8 to 32 mM, while N level increased from 18 to 28 mg·g⁻¹ as P and K fertilizer concentrations increased from 0.25 to 1 mM. Using posttransplant growth as a quantitative norm for plug quality, the sufficiency ranges for tissue N level are 28 to 40 mg·g⁻¹ for impatiens and 30 to 43 mg·g⁻¹ for petunia plugs. These results indicate that fertilization programs for high-quality plug production should focus on N nutrition, and that plugs can be grown with greatly reduced levels of P and K.

Proper fertilization is crucial in the production of high-quality bedding plant plugs. We have previously reported the effects of pretransplant N, P, and K fertilization (van Iersel et al., 1998) on the growth of impatiens, petunia, salvia (*Salvia splendens* Sell. ex Roem. & Schult.), and vinca (*Catharanthus roseus* L.) plugs. The results showed that plug seedling growth increased linearly with increasing N concentration in both the shoot tissue and the fertilizer (1–16 mM applied weekly). This is well beyond the range of the standard N application in plug production [3.5–11 mM once or twice weekly (Styer and Koranski, 1997)]. Higher N concentrations may result in more rapid growth, since seedling dry mass still increased linearly as fertilizer N concentration increased to 16 mM. There was little effect of P and K on seedling growth over concentration ranges of 0.125 to 2 mM and 0.5 to 8 mM, respectively (van Iersel et al., 1998).

Little published information is available

on plug fertilization effects on posttransplant growth of ornamental bedding plant seedlings. Most plug fertilization studies have focused on vegetable transplants (summarized by Dufault, 1997). Results indicate that pretransplant fertilization can affect posttransplant growth and yield of tomato (*Lycopersicon esculentum* Mill.) (Garton and Widders, 1990; Melton and Dufault, 1991; Widders and Garton, 1992), muskmelon (*Cucumis melo* L.) (Dufault, 1986) and many other vegetables (Dufault, 1997; Masson et al., 1991).

One of the main advantages of plugs over bare-root seedlings is the faster posttransplant growth of the plug seedlings (Styer and Koranski, 1997). Since posttransplant growth may be dependent on pretransplant nutrition and/or tissue nutrient concentrations of the plugs, an understanding of the relationships between plug fertilization, tissue nutrient concentration, and posttransplant growth can help determine plug quality.

The overall goal of this study was to determine optimal fertilization practices to produce impatiens and petunia plugs with a high potential for posttransplant growth. The specific objectives of this study were to: 1) confirm that high-quality plugs can be produced with low amounts of P and K; 2) quantify the amount of N fertilization needed for maximum plug growth; and 3) determine how pretransplant fertilization and tissue nutrient level affect the potential for posttransplant growth.

Plant material. Six flats of 'Impulse Rose' impatiens and 'Carpet Lilac' petunia were seeded in plug trays (388 cells/tray, 6 mL/cell) filled with a peat-based growing medium (a mixture of 75% sphagnum peat, 25% vermiculite, lime, and a nutrient charge; LG-3 growing medium, Sun Gro Horticulture, Bellevue, Wash.) at a commercial greenhouse on 2 Oct. 1995. This growing medium is recommended for seedling production and has a starter fertilizer incorporated. They were shipped overnight after germination [10 Oct., stage 2 as defined by Styer and Koranski (1997)] and immediately placed in a double-layered polyethylene greenhouse on arrival. Trays were cut into three pieces, containing either 104 or 117 seedlings. The plants received no fertilization before they were shipped.

Treatments. The seedlings were watered weekly (four times) with nutrient solutions containing varying levels of N, or P and K. The N treatments contained N at 8, 16, 24, and 32 mM (112, 224, 336, and 448 mg·L⁻¹), which was supplied from Ca(NO₃)₂. Ca(NO₃)₂ was chosen as the nitrogen source, because it allowed easy manipulation of N levels in the nutrient solution without affecting the other nutrients of interest (P and K). The solutions also contained P and K at 1 mM (from KH₂PO₄, 31 and 39 mg·L⁻¹ P and K, respectively), 2 mM Mg and S (from MgSO₄, 48 and 64 mg·L⁻¹ Mg and S, respectively), and micronutrients (13% S, 1.35% B, 2.3% Cu, 7.5% Fe, 8% Mn, 0.04% Mb, and 4.5% Zn; STEM, The Scotts Co., Inc., Marysville, Ohio, 1 g·L⁻¹). The P, K series contained P and K at 0.25, 0.5, or 1.0 mM (from KH₂PO₄), N at 16 mM, and Ca at 8 mM. The rest of the nutrient solution was the same as in the N series. Nutrient solution was applied at a rate of 2.2 mL per plant per application. In addition to the fertilizer applications, seedlings were hand-watered daily, until water leached from the bottoms. Leachate volume was not quantified, but was probably close to 25% of the total amount of water applied.

At 35 d after seeding, seedlings were transplanted into larger cells (36 cells/flat, 166 mL/cell) filled with a peat-lite growing medium (a mixture of composted pine bark, vermiculite, sphagnum peat, perlite, processed bark ash, washed sand, lime, and a nutrient charge; Metro-Mix 300, Grace Horticultural Products, Cambridge, Mass.). Plants grown with higher N levels reached a suitable size for transplanting earlier, but for experimental reasons the plants were transplanted when all plug seedlings had reached growth stage 4. They were grown for an additional 15 d to determine effects of pretransplant nutrient conditioning on early posttransplant growth. After transplanting, plants were fertilized twice weekly with 20N–4.4P–16.6K water-soluble fertilizer (20–10–20 Peat-Lite Special, The Scotts Co.) containing N at 200 mg·L⁻¹. Plants were watered overhead as needed between fertilizer applications. Temperature set points for the greenhouse were 23 °C day/18 °C night.

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Measurements. Shoot dry mass, leaf area, and stem length of the plants were determined at transplanting and at 15 d after transplanting (30 plants per experimental unit). Only early posttransplant growth was studied, because long-term posttransplant growth, development, and flowering are likely to be influenced more by posttransplant cultural practices than by pretransplant fertilizer applications. Leaf area and stem length were measured with a video image analysis system (Beverly and van Iersel, 1998). Root dry mass was measured at transplanting (30 plants per experimental unit) and at 12 d after transplanting (four plants). Shoot dry mass was also measured at 3, 6, 9, and 12 d after transplanting (four plants per experimental unit). Average shoot dry mass was calculated per experimental unit and these averages were used for regression analysis. Shoot growth rate was calculated as the derivative of a third-order polynomial fitted to the shoot dry-mass data (Hunt, 1982). The cubic term was dropped from the regression if it was nonsignificant ($P > 0.05$). After taking the derivative of the resulting function, this resulted in linear or quadratic functions describing shoot growth rate. Seedling shoots were collected for nutrient analysis at transplanting and at 15 d after transplanting. 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 was a randomized complete block with three replications and groups of 104 or 117 seedlings as the experimental unit. Nutrient analysis and plant size data were analyzed by linear regression.

Results and Discussion

N series. Increasing the N concentration in the nutrient solution resulted in larger shoots of impatiens and petunia at transplanting (stem length, leaf area, and shoot dry mass), but did not affect root dry mass (Fig. 1). There was a quadratic relationship between N concentration of the fertilizer and impatiens shoot dry mass, and stem length and leaf area of both impatiens and petunia. Stem length and shoot dry mass of impatiens were highest at a N concentration of 24 mM, while leaf area of impatiens and leaf area, stem length, and shoot dry mass of petunia were highest at 32 mM N. The quadratic relationship suggests that leaf area of impatiens and leaf area and stem length of petunia would have increased little had higher N concentrations been used. Since the relationship between shoot dry mass of petunia and N concentration of the fertilizer was linear (Fig. 1), shoot dry mass at transplanting might have been higher with higher N concentrations. Melton and Dufault (1991) found a similar increase in the growth of tomato transplants when the N concentration of the fertilizer was increased from 1.8 to 16 mM, while Weston and Zandstra (1989) reported that growth of tomato plugs increased with N concentration up to 28.5 mM. Growth of cauliflower [*Brassica oleraceae* L. Botrytis Group] seedlings also increased when the N concen-

tration was increased from 11 to 32 mM (McGrady, 1996). This implies that the commonly recommended range for plug N fertilization of 3.5 to 11 mM once or twice weekly (Styer and Koranski, 1997) is insufficient for maximum seedling growth. Since seedling growth is dependent on cell size (van Iersel, 1997), seedlings in larger cells probably would require more fertilizer. However, plants in larger cells would normally receive more fertilizer solution and the effect of cell size on optimal fertilizer concentration is probably small.

Nitrogen concentration of the fertilizer also affected the N, P, and K contents of both impatiens and petunia seedlings (Fig. 2). Tissue N level of impatiens and petunia increased linearly with increasing N concentration in the fertilizer, and their responses were very similar. Increasing the N concentration of the fertilizer decreased shoot P level of impatiens, but had little effect on that of petunia. The opposite was true for K, since increasing N in the fertilizer decreased K levels in petunia, but had little effect in impatiens. Although P level of impatiens and K level of petunia decreased with increasing N concentration, this does not imply that N decreased the total uptake of these elements. The increase in plant size more than compensated for the decrease in P or K,

and the total amount of N, P, and K in the shoots of the plant (shoot nutrient concentration \times shoot dry mass) increased with increasing N in the fertilizer (results not shown).

Pretransplant N fertilization also affected posttransplant growth of both impatiens and petunia, even though all plants were fertilized identically after transplanting. At 15 d after transplanting, plants that received N at 16, 24, or 32 mM before transplanting had larger shoots than those receiving 8 mM (Fig. 3). Root dry mass of petunia, but not that of impatiens, also increased. A stimulation of posttransplant growth by high pretransplant N applications also has been reported in several vegetable seedlings (Aloni et al., 1991; McGrady, 1996; Weston and Zandstra, 1989).

The differences in shoot dry mass at 15 d after transplanting were caused by differences in dry mass at transplanting and shoot growth rates after transplanting (Fig. 4). Plants that received N at 8 mM before transplanting had the lowest posttransplant growth rate, possibly as a result of their smaller size at transplanting. Small plants will intercept less light and thus grow more slowly than larger plants. At the end of the experiment, the highest growth rate was observed in impatiens that had been fertilized with 16 or 24 mM N, and in petunia, fertilized pretransplant with 16 mM.

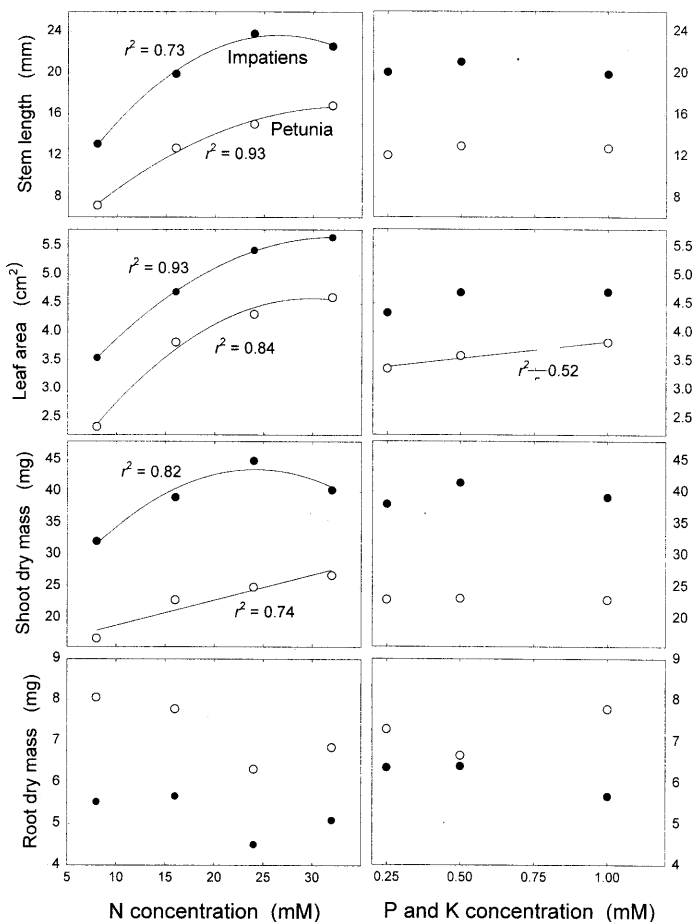


Fig. 1. The effect of N or P and K concentrations in the nutrient solution on the size of impatiens (●) and petunia (○) plug seedlings 35 d after seeding. Seedlings were watered weekly with 2.2 mL of nutrient solution per plant. The lines indicate significant linear or quadratic effects ($P < 0.05$) of the fertilizer concentration on the growth of the seedlings.

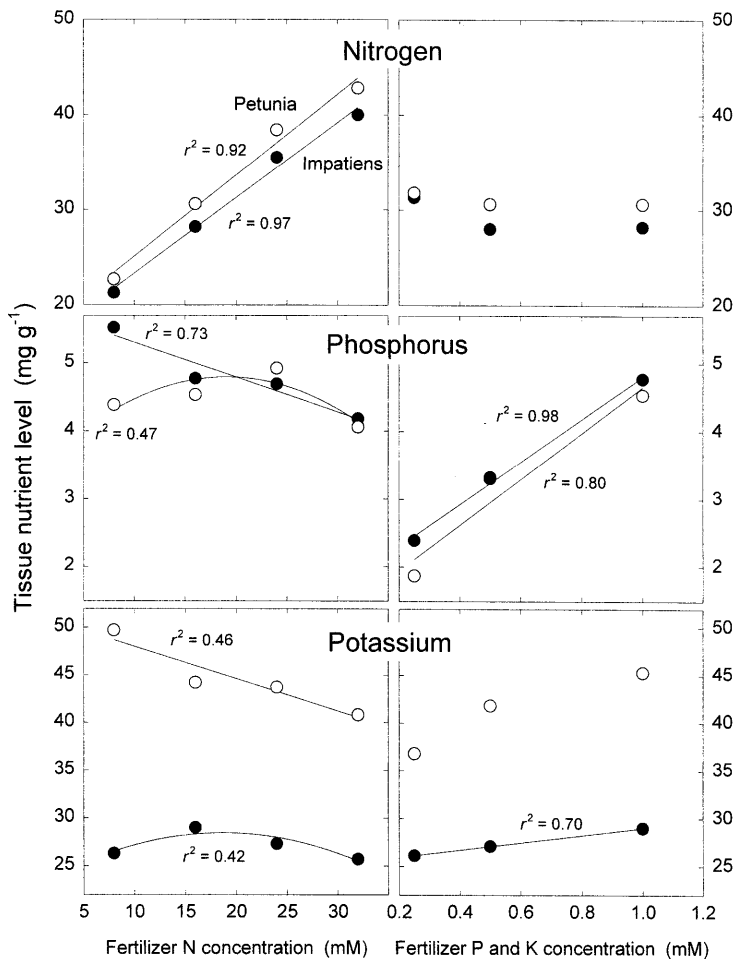


Fig. 2. The effect of N or P and K concentrations in the fertilizer solution on the shoot N, P, and K concentrations of impatiens (●) and petunia (○) plug seedlings at 35 d after seeding. The lines indicate significant linear or quadratic relationships ($P < 0.05$) between the tissue nutrient level and the nutrient concentration in the fertilizer.

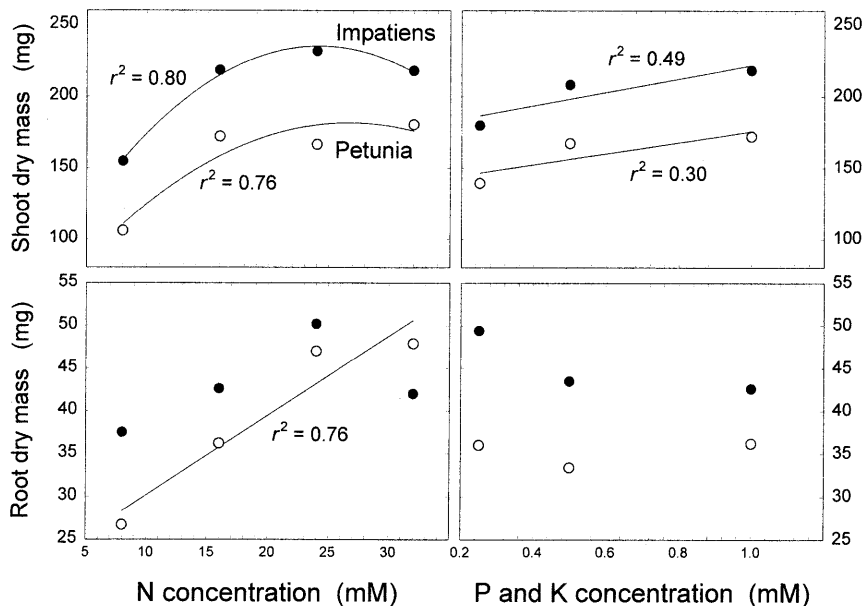


Fig. 3. Pretransplant fertilization effects on shoot (15 d after transplanting) and root dry mass (12 d after transplanting) of impatiens (●) and petunia (○). Before transplanting, seedlings were fertilized weekly with a nutrient solution containing 8, 16, 24, or 32 mM N or 0.25, 0.5, or 1 mM P and K.

Aloni et al. (1991) showed that posttransplant growth of bell peppers (*Capsicum annum* L.) increased when pretransplant N fertilizer was increased from 0 to 14.3 mM.

Most of the pretransplant fertilizer effects on tissue nutrient concentration disappeared after transplanting, when all plants received the same amount of fertilizer. At 15 d after transplanting, only the tissue P concentration of impatiens was still affected by the pretransplant N treatments (Fig. 5). The tissue level of P in impatiens decreased with increasing N concentration in the pretransplant fertilizer, but stayed between 4.5 and 7 mg·g⁻¹. This is well within the range of optimal tissue P levels for most ornamental crops (Mills and Jones, 1996; Reuter and Robinson, 1986) and the induction P or K deficiencies by the high N fertility treatments seems unlikely. The lack of long-term effects of pretransplant fertilization on posttransplant tissue nutrient levels suggests that differences in growth rates after transplanting (Fig. 4) were not a direct effect of the nutritional status of the plants. Although increased posttransplant N-fertilization might have increased the posttransplant growth of the plants, this probably would have affected all treatments similarly.

These results indicate that pretransplant N nutrition affects the posttransplant performance of plugs. This complicates the issue of determining nutritional diagnostic norms for plug seedlings. Diagnostic norms are needed to help growers determine whether their fertilizer program is adequate to produce high-quality plugs. Because of the lasting effects of plug nutrition on plant performance, post-transplant growth has to be considered when determining diagnostic norms.

Dufault (1997) stated that the simplest fertility program should be chosen unless another nutritional program results in improved long-term performance. The primary goal of plug production is to grow transplants for subsequent production, and one of the main advantages of using plugs over bare-rooted seedlings is their faster growth after transplanting (Styer and Koranski, 1997). Therefore, post-transplant growth (until 15 d after transplanting) was used as a quantitative measure to determine plug quality. Shoot dry mass of impatiens and petunia 15 d after transplanting was lowest for the plants that received 8 mM N before transplanting, but similar among the other three N treatments (Fig. 3). Since increasing pretransplant fertilizer N concentration from 16 to 32 mM provided little or no benefits for the subsequent production of the plants, we consider the tissue N levels in these three treatments to be sufficient for the production of quality plugs. Based on this standard, the sufficiency range for tissue N level is 28 to 40 mg·g⁻¹ for impatiens and 30 to 43 mg·g⁻¹ for petunia plugs. Higher tissue N levels may also be acceptable, since no negative effects of the highest pretransplant N fertility rates were observed in this experiment. Tissue N levels of <21 mg·g⁻¹ for impatiens and 23 mg·g⁻¹ for petunia are suboptimal, because they result in decreased pre- and posttransplant growth. Nutritional diagnostic norms for

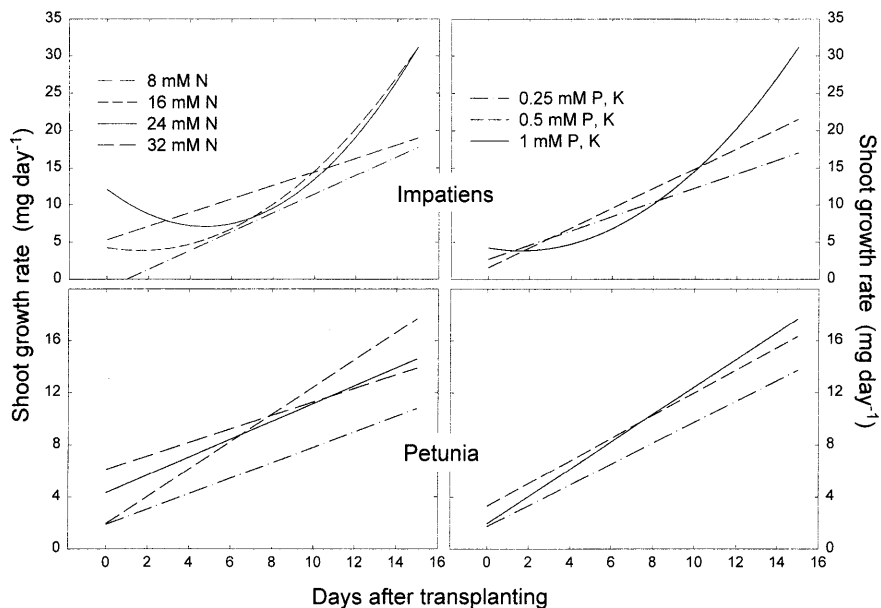


Fig. 4. Posttransplant shoot growth rate of impatiens and petunia seedlings as affected by (left) pretransplant N or (right) P and K fertilization. Transplants were fertilized weekly with a nutrient solution containing 8, 16, 24, or 32 mM N or 0.25, 0.5, or 1 mM P and K. Growth rates were calculated by regression analysis.

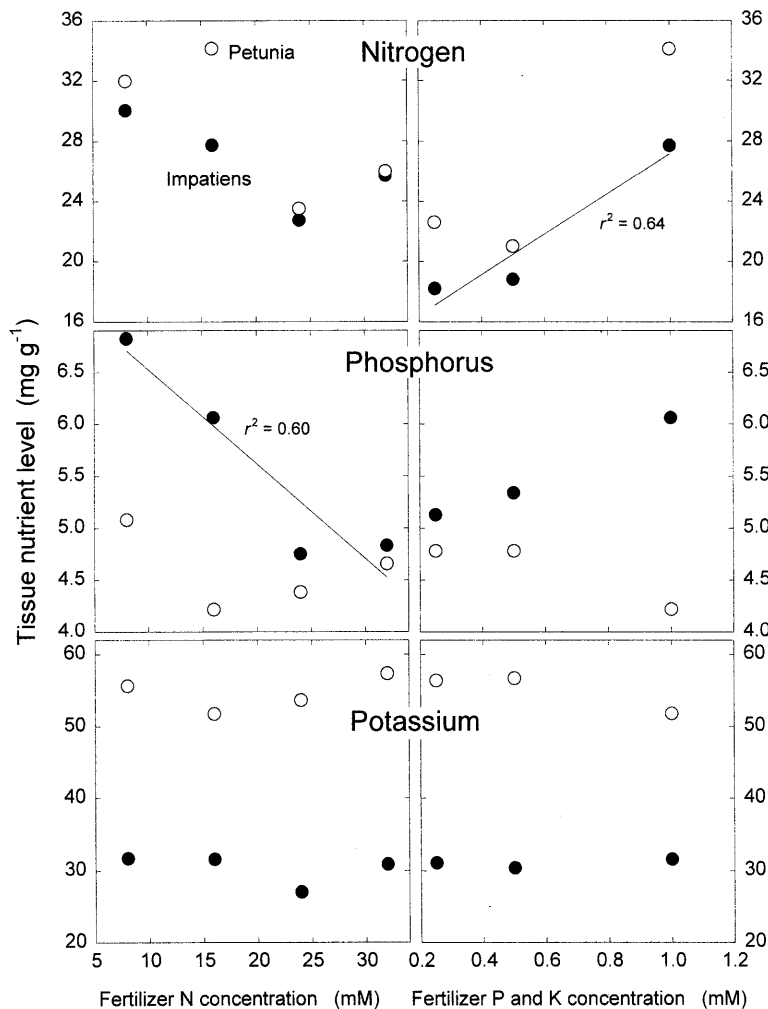


Fig. 5. The effect of the (left) N or (right) P and K concentrations of the pretransplant fertilizer on the shoot N, P, and K concentrations of impatiens (●) and petunia (○) shoots at 15 d after transplanting. The lines indicate a significant linear relationship ($P < 0.05$) between the tissue nutrient level and the nutrient concentration in the fertilizer.

many ornamental crops are in this same range (Mills and Jones, 1996).

Since optimal nutrition of seedlings can be affected by environmental conditions (Vavrina, 1996), optimal fertilizer and tissue nitrogen levels may vary with factors that affect growth rate, e.g., light and temperature. The photosynthetic capacity of leaves depends on their N status (Thornley, 1998). Under conditions that favor rapid growth (high light and optimal temperature), leaves need more N to achieve maximum growth. The seedlings in this experiment were grown under relatively low light (double-layered polyethylene greenhouse in fall). Optimal shoot N levels for petunia and impatiens might be higher under more favorable growing conditions.

P, K series. The different P and K concentrations used in this study had very little effect on growth of the plug seedlings. Only the leaf area of petunia increased significantly with increasing P and K fertilizer concentrations (Fig. 1), but this effect was small. Melton and Dufault (1991) showed that increasing the P concentration from 0.17 or 0.5 to 1.5 mM results in faster growth of tomato seedlings, but these growth effects were much smaller than those of increasing N concentrations. Potassium concentration (0.64–5.8 mM) had no effect on the growth of the tomato transplants.

Although P and K fertilization had little effect on the growth and tissue N level of the plugs, it did affect tissue levels of P and K (Fig. 2). Impatiens P and K and petunia P levels increased linearly with increasing P and K concentrations in the fertilizer. This corroborates our previous findings that growth of bedding plant plugs is mainly determined by N fertilization, while plugs exhibit luxury consumption of P and sometimes K (van Iersel et al., 1998).

Surprisingly, pretransplant P and K fertilizer levels affected the posttransplant dry mass of the plants at 15 d after transplanting (Fig. 3), although they had no effect on shoot dry mass at transplanting. The posttransplant shoot growth rate of impatiens in the 0.25 mM P and K treatment was lower than those of the other two treatments from 9 to 15 d after transplanting, while the 0.25 mM P and K treatment resulted in the lowest posttransplant growth rate of petunia during the entire posttransplant period (Fig. 4). There was a linear correlation between the P and K concentration of the pretransplant fertilizer and shoot dry mass at 15 d after transplanting for both impatiens and petunia (Fig. 3), but no significant effect on root dry mass. Phosphorus and K fertilization of vegetable plugs also had little effect on posttransplant performance in two previous studies (McGrady, 1996; Weston and Zandstra, 1989).

Whether the P and K effects on posttransplant growth were a direct effect of P or K luxury consumption during the plug stage is not clear. Broschat (1979) showed that high soil or foliar levels of some nutrients (including K) can affect the uptake of other growth-limiting nutrients. Similar interactions may have occurred in this experiment, thus creating

an indirect effect of pretransplant P and K fertilization on posttransplant growth. For example, the tissue N level of impatiens at 15 d after transplanting increased linearly with increasing pretransplant P and K fertilization, while petunia N level showed a similar, yet nonsignificant, trend (Fig. 5).

Conclusions

The results of this experiment indicate that plug fertilization programs affect both pre- and posttransplant growth of seedlings. This makes plug fertilization even more challenging, since fertilizer management needs to be adjusted to ensure both good plug quality and rapid posttransplant growth. For example, very low concentrations of P and K have little effect on plug growth, but may reduce posttransplant growth. Using early posttransplant growth of plugs as a quality standard, tissue N levels of 28 to 40 mg·g⁻¹ for impatiens and 30 to 43 mg·g⁻¹ for petunia were sufficient to produce plugs with a good posttransplant growth potential. Weekly applications of fertilizers containing 16 mM N resulted in optimal pre- and posttransplant growth of impatiens and petunia plug seedlings. Under conditions that favor more rapid growth, higher fertilizer rates may be necessary, while less leaching would decrease the required amounts of fertilizer. A 20N-3P-3K fertilizer can supply adequate amounts of these three nutrients, when applied at the optimal rate. Additional research is needed to determine whether pretransplant fertilization affects the time to first bloom and

the number of flowers, which are important quality characteristics for bedding plants.

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