Differences in Bedding Plant Growth and Nitrate Loss with a Controlled-release Fertilizer and Two Irrigation Systems

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SUMMARY. Growth of hand-watered and subirrigated 'Ultra Red' petunia (*Petunia* × *hybrida* Hort.) and 'Super Elfin Violet' impatiens (*Impatiens wallerana* Hook.f.) plants were compared when grown using four controlled-release fertilizer rates and four fertilizer placements in the pot. Furthermore, the amount of $\text{NO}_3\text{-N}$ leached from hand-watered plants was compared to amount captured by subirrigation system. Before planting, Osmocote (14N-6.2P-11.6K) (4 month release) was either topdressed (TD), layered in the middle of the pot (M), layered at the bottom of the pot (B), or incorporated throughout (I) the substrate at 1.25, 2.5, 5.0, or 7.5 $\text{kg}\cdot\text{m}^{-3}$ (oz/ft^3). Shoot dry mass of petunia plants was similar between both irrigation systems and among

the four fertilizer placements. Subirrigated petunias fertilized with 2.5 $\text{kg}\cdot\text{m}^{-3}$ had similar shoot dry mass as hand-watered petunias fertilized with 7.5 $\text{kg}\cdot\text{m}^{-3}$. Hand-watered impatiens had greater shoot dry mass than subirrigated impatiens. Hand-watered impatiens also had greater shoot dry mass in pots with fertilizer at TD, M, or I than with fertilizer at B, but no difference in growth was observed in subirrigated impatiens among the different fertilizer placements. Finally, significantly more $\text{NO}_3\text{-N}$ was leached from hand-watered plants than was captured with the subirrigation systems.

A major concern with traditional greenhouse irrigation systems such as hand watering and overhead irrigation is runoff. Runoff from greenhouse benches can be the single greatest cause of surface and groundwater contamination from fertilizer applied to floriculture crops (Weiler, 1996). Subirrigation systems reduce or eliminate fertilizer runoff in the greenhouse because the irrigation solution can be recaptured and reused.

Another technique to potentially control fertilizer runoff in the greenhouse is the use of controlled-release fertilizers. However, making recommendations for controlled-release fertilizer rates and placement when using subirrigation has been challenging because of conflicting reports. Payne and Adam (1980), for example, reported that topdress applications of controlled-release materials were equally effective as incorporating the material in the substrate for capillary mat subirrigation, but Evans et al. (1992) reported that topdress applications of controlled-release materials do not work well when only subirrigation is used. The objective of this experiment was to compare growth of petunia 'Ultra Red' and impatiens 'Super Elfin Violet' in hand-watered and subirrigation systems with four controlled-release fertilizer application rates and four fertilizer placements within the pot. Additional objectives were to compare the amount of $\text{NO}_3\text{-N}$ leached from hand-watered plants with the amount of $\text{NO}_3\text{-N}$ captured in the subirrigation tanks for subirrigated plants as well as to compare the amount of $\text{NO}_3\text{-N}$ in the substrates of plants grown with each irrigation system.

Materials and methods

Petunia and impatiens plants from #392 square plug trays were transplanted into 400-mL (13.5-fl oz) (10.2 cm diameter × 9.5 cm tall; 4 × 3.7 inches) pots filled with premoistened 60% Sphagnum peat, 25% vermiculite, and 15% perlite (by volume) amended with dolomitic limestone to a pH of 5.5. Before planting, Osmocote (14N-6.2P-11.6K) (4-month release) (Scotts Co., Marysville, Ohio) was either topdressed (TD), layered in the middle of the pot (M), layered in the bottom 1 cm of growing substrate of the pot (B), or incorporated throughout the substrate (I) at 1.25, 2.5, 5.0, or 7.5 $\text{kg}\cdot\text{m}^{-3}$ (oz/ft^3).

Five pots of each species per fertilizer application rate and placement combination were placed on 6 Ebb-Flow Benches (Midwest GroMaster, Inc., St. Charles, Ill.) in a randomized block design to give a total of 30 replications per fertilizer rate and placement combination. Pots on three of the six benches (per species) were hand watered while pots on the remaining three benches were subirrigated. Each hand-watered plant received ≈100 to 120 mL (3.4 to 4.1 fl oz) of water a day to establish a 0.2 to 0.3 leaching fraction. The subirrigation benches were flooded to a depth of 2.5 to 3 cm (1.0 to 1.2 inches) and drained after 10 min. All plants were watered daily before 0900 HR. The irrigation water used throughout the experiment had 0.36 $\text{dS}\cdot\text{m}^{-1}$ electrical conductivity (EC), 94 $\text{mg}\cdot\text{L}^{-1}$ (ppm) CaCO_3 total alkalinity (1.88 $\text{meq}\cdot\text{L}^{-1}$), 0.6 $\text{mg}\cdot\text{L}^{-1}$ $\text{NO}_3\text{-N}$, 28 $\text{mg}\cdot\text{L}^{-1}$ Ca, 6 $\text{mg}\cdot\text{L}^{-1}$ Mg, and 22 $\text{mg}\cdot\text{L}^{-1}$ Na.

Hand-watered pots were placed in a flat supported 2 cm (0.8 inches) above the bottom of another flat without holes to collect the leachate. Daily leachate samples were collected from the hand-watered benches and poured into a covered 38-L (10-gal) container. Once a week total leachate volume was measured and solution samples were taken. The water in the subirrigation tanks was not changed throughout the experiment. Weekly, the volume of water used to bring the subirrigation tanks back to initial volume was measured and solution samples were collected. Solution EC and nitrate ($\text{NO}_3\text{-N}$) concentrations were determined on all samples. Solution EC was determined using a platinum electrode at a

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standard 25 °C (77 °F) (Accumet model 20 pH/conductivity meter, Fisher Scientific, Pittsburgh) and NO₃-N concentrations were determined using an NO₃-N specific ion electrode (Accumet model 1003 meter; Fisher Scientific, Pittsburgh).

Shoots were cut at the substrate surface, 35 d after transplanting, dried at 93 °C (199 °F) for 48 h, and weighed. Substrate samples also were collected at this time. The surface 1 to 2 cm (0.4 to 0.8 inches) of the 9-cm (3.7-inch) substrate column from each pot was removed to ensure that substrate samples were taken from the active root zone. Nutrients in the substrate were extracted with distilled water using the saturated media extraction (SME) method (Warncke, 1986). Substrate EC and NO₃-N concentrations were determined from the extracted solution as indicated above.

The experiment was conducted in March 1997 in an open-sided greenhouse exposed to ambient air temperatures averaging 30/21 °C (86/70 °F) day/night at the University of Florida Fort Lauderdale Research and Education Center. All data were analyzed as a split plot with irrigation as the main plot and fertilizer placement as the subplot and fertilizer rate as the sub-subplot (SAS Systems, SAS Institute, Cary, N.C.).

Results and discussion

SOLUTION ANALYSIS. Solution EC from hand-watered benches was consistently twice that of subirrigated benches (Fig. 1). Furthermore, the total NO₃-N leached from hand-watered plants after 4 weeks was significantly greater than the total NO₃-N captured in the subirrigation tanks from subirrigated plants (Fig. 1). The EC and NO₃-N concentrations of recirculated solutions used for subirrigation changed little over time because water does not flow out of the substrate (Biernbaum, 1993; Weiler, 1996). However, water leached from hand watered pots probably contained fertilizer salts (Biernbaum, 1993; Weiler, 1996).

The volume of water used to water hand-watered plants also was significantly greater than the water used to irrigate subirrigated plants (Fig. 1). This supports previous reports that subirrigation reduces total water use compared with overhead irrigation with a 0.2 to 0.3 leaching fraction (Dole et

al., 1994; Holcomb et al., 1992).

PLANT GROWTH. Petunia shoot dry mass was not significantly different between hand-watered and subirrigated systems, but hand-watered impatiens had greater shoot dry mass than subirrigated impatiens (Fig. 2). Because impatiens are known to have a high moisture requirement (Armitage, 1993), water may have been a limiting factor for impatiens growth with subirrigation. Water, however, did not appear to be a limiting factor for petunia growth.

Petunia shoot dry mass was similar among the four fertilizer placements. However, hand-watered impatiens in pots with fertilizer at I, TD, or M had greater shoot dry mass than those with fertilizer at B (Fig. 2). No difference in growth existed among the various fertilizer placements for subirrigated impatiens (Fig. 2). Evans

Fig. 1. Weekly solution electrical conductivity (EC), total solution nitrate nitrogen (NO₃-N), and volume of water used for hand-watered (■) and subirrigated (●) benches over a 4-week growing period. Values are means of six replications (100 mg = 0.0035 oz; 1 L = 33.8 fl oz).

et al. (1992) reported that topdress applications of controlled release fertilizer products should not be used with subirrigation because the fertilizer will be in dry soil for part of the time. However, our results are similar to those of Payne and Adam (1980) and Kovacic and Holcomb (1981) who reported that plant response was similar in subirrigated pots that had Osmocote incorporated as in pots that had Osmocote topdressed.

Both petunia and impatiens shoot dry mass increased linearly as fertilizer

Fig. 2. Shoot dry mass of impatiens 'Super Elfin Violet' grown with hand watering or subirrigation. Substrates were amended with Osmocote (14N-6.2P-11.6K) that was either topdressed, layered in the middle of the pot, layered in the bottom 1 cm (0.4 inches) of growing substrate of the pot, or incorporated throughout the substrate. Values are means of 20 replications (1 g = 0.035 oz).

application rate increased (Fig. 3). The general recommendation with subirrigation is that fertilizer rates should be half the rate used with overhead irrigation (Beytes, 1996; Elliott, 1990). The average shoot dry mass of hand-watered petunias receiving Osmocote at $7.5 \text{ kg}\cdot\text{m}^{-3}$ [2.67 g (0.09 oz)] was similar to the average shoot dry mass of subirrigated petunias receiving Osmocote at $2.5 \text{ kg}\cdot\text{m}^{-3}$ [2.44 g (0.086 oz)]. Thus, using one-third the recommended rate of fertilizer with subirrigation produced a similar size petunia as using the recommended rate with hand watering.

FINAL SUBSTRATE ANALYSIS. Final substrate EC and $\text{NO}_3\text{-N}$ concentrations were similar between the irrigation systems and between species. Since the top 1 to 2 cm (0.4 to 0.8 inches) of the substrate was removed and substrate samples were taken from the active root zone, substrate NO_3 and EC concentrations should be similar. For example, data from Morvant et al.

(1997) show that the EC in the middle of the pot for hand-watered geraniums (*Pelargonium x hortorum* L.H. Bailey) were similar to the EC in the middle of the pot for subirrigated geraniums.

Overall, final substrate EC and $\text{NO}_3\text{-N}$ concentrations were significantly greater in pots with fertilizer at TD, I, or M than in pots with fertilizer at B (Fig. 4). Final EC and $\text{NO}_3\text{-N}$ concentrations also linearly increased as fertilizer rate increased for pots with fertilizer at TD, I, or M, but no significant differences in substrate EC and $\text{NO}_3\text{-N}$ concentrations for fertilizer rate were observed for pots with fertil-

izer at B (Fig. 4). At lower application rates (1.25 and $2.5 \text{ kg}\cdot\text{m}^{-3}$), no significant differences in EC or NO_3 were observed for fertilizer placement but as application rate increased differences due to fertilizer placement became evident.

Conclusions

Subirrigation has the potential to prevent environmental pollution due to fertilizer leached from overhead bedding plant irrigation. No fertilizer salts were leached from our subirrigation system because we recirculated and reused the water used to irrigate both the subirrigated petunia and impatiens plants. Even if we had not reused the solution in the subirrigation tanks, the total $\text{NO}_3\text{-N}$ escape from the subirrigation system was less than the hand-watered system. An additional benefit of the subirrigation system was that less water was used than the hand-watered system.

Furthermore, subirrigation produced similar size 'Ultra Red' petunia plants as hand watering but with lower fertilizer application rates and with no $\text{NO}_3\text{-N}$ leachate loss. However, 'Super Elfin Violet' impatiens plants were larger with the hand-watered system than with subirrigation. Therefore, the

Fig. 3. Shoot dry mass of petunia 'Ultra Red' and impatiens 'Super Elfin Violet' grown with Osmocote (14N-6.2P-11.6K) applied at 1.25, 2.5, 5.0, or $7.5 \text{ kg}\cdot\text{m}^{-3}$. Values are means of 40 replications. Equations of the line are $y = 0.24x + 1.36$, $r^2 = 0.99$ (petunia) and $y = 0.12x + 0.77$, $r^2 = 0.98$ (impatiens) (1 g = 0.035 oz).

Fig. 4. Final substrate electrical conductivity (EC) and nitrate ($\text{NO}_3\text{-N}$) concentrations averaged for both impatiens and petunia plants as well as for both irrigation systems (hand watered and subirrigation). Values are means of 20 replications. Substrates were amended with Osmocote (14N-6.2P-11.6K) that was either topdressed (■), layered in the middle of the pot (●), layered at the bottom of the pot (▲), or incorporated throughout the substrate (◆) at 1.25, 2.5, 5.0, or 7.5 $\text{kg}\cdot\text{m}^{-3}$. Equations of the line for final substrate EC are topdress, $y = 0.02x^2 + 0.02x + 0.95$, $r^2 = 0.99$; middle, $y = 0.10x + 0.72$, $r^2 = 0.94$; bottom, nonsignificant; incorporate, $y = 0.17x + 0.58$, $r^2 = 0.99$. Equations of the line for final substrate $\text{NO}_3\text{-N}$ are topdress, $y = 9.8x + 0.15$, $r^2 = 0.99$; middle, $y = -0.85x^2 + 12.5x - 6.04$, $r^2 = 0.94$; bottom, nonsignificant; incorporate, $y = 1.64x - 0.13$, $r^2 = 0.97$ (1 $\text{mg}\cdot\text{L}^{-1}$ = 1 ppm).

use of subirrigation may not be the best choice of irrigation systems for growing impatiens 'Super Elfin Violet' plants.

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