Fertilizer Concentration Affects Growth and Nutrient Composition of Subirrigated Pansies

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Abstract. Ebb-and-flow irrigation is an economically attractive subirrigation method that reduces labor costs and eliminates runoff from greenhouses. The effects of fertilizer concentration on growth of subirrigated pansy (Viola × wittrockiana Gam.) and the leachate electrical conductivity (EC) and pH were quantified, using two growing media. Leachate EC increased as the EC of the fertilizer solution increased from 0.6 to 3.6 dS·m⁻¹ (70 to 530 mg·L⁻¹ N). The leachate EC was fairly constant over time when the EC of the fertilizer solution was 0.6 dS·m⁻¹, while it increased throughout the experiment at higher fertilizer concentrations. MetroMix 300 leachate consistently had a higher EC than did MetroMix 500. Leachate pH of both growing media was similar throughout the growing season. The pH decreased over time and was lower with higher fertilizer concentrations. Optimal plant growth occurred with a fertilizer EC of 1.2 or 1.8 dS·m⁻¹, and a leachate EC between 1.5 and 4 dS·m⁻¹. Increasing the concentration of the fertilizer solution resulted in increased shoot tissue levels of P and Mn and decreased tissue levels of K, Mg, and Na. The results of this study indicate that pansy is not very sensitive to the EC of the growing medium and can be grown successfully in a closed subirrigation system.

The greenhouse industry applies more fertilizer per unit area than any other agricultural system (Molitor, 1990), which can result in unacceptably high nitrogen levels (> 230 g·m⁻²) in the soil under commercial greenhouses (McAvoy, 1994). This is a potential threat to the surface and ground water supply and growsers are under increasing pressure to reduce the amount of runoff from greenhouses. This has resulted in an increasing interest in the use of closed watering systems.

Fertilizer management is more difficult in closed subirrigation systems than in overhead watering systems. With overhead watering, excess fertilizer in the growing medium can be removed by watering as water leaches from the bottom of the pots (Biernbaum, 1992). In contrast, with subirrigation salts are not leached out of the containers and often accumulate near the top of the growing medium, where evaporation occurs (Argo and Biernbaum, 1996). Because most of the root growth in subirrigated plants occurs in the bottom of the pot (Kent and Reed, 1996), the salt accumulation near the top of the growing medium is normally not detrimental to the plants. However, salts can also accumulate in the middle and bottom layers of the growing medium if the fertilizer concentration is high (Kent and Reed, 1996). Ideally, the nutrient concentration of the middle and bottom layers of the growing medium should be high enough to provide the plant with the needed nutrients, but not so high that it causes salt damage in the plants. An increase of the electrical conductivity (EC) of the bulk solution in the growing medium indicates that fertilizer is applied faster than the plants can take it up, while a low or decreasing EC suggests that there are not enough nutrients available for optimal plant growth.

The optimal fertilizer concentration in closed fertigation systems depends on the water use efficiency and nutrient requirements of the plants (Bugbee, 1995). Since water use efficiency greatly depends on environmental conditions, plant response to a range of fertilizer concentrations can be affected by greenhouse design and climatic conditions. For example, Vavrina (1996) has shown that the optimal fertilizer concentration for the production of vegetable transplants with ebb-and-flow irrigation differs in spring and fall; thus developing general recommendations for fertilizer concentrations in ebb-and-flow systems is almost impossible. Managing fertility programs using growing medium EC is more feasible, because this is a better indication of the amount of nutrients that is available to the plants than fertilizer concentration of the nutrient solution. The pH of the growing medium is also important because it can affect the availability of micronutrients to the plant (Bailey and Bilderback, 1997).

In subirrigation systems, most of the root growth normally occurs in the lower half of the growing medium (Kent and Reed, 1996), so EC and pH in that part of the container are most important for plant growth. The pour-through method (Wright, 1986; Yeager et al., 1983) is a simple and easy method to collect leachate from the bottom part of the growing medium and can be used to quantify changes in the EC and pH of the bulk solution in the growing medium. It is a good technique for monitoring EC and pH of subirrigated growing media, because the results are based on that part of the medium where most of the root growth occurs.

The objectives of this study were to: 1) quantify the effect of the concentration of the fertilizer solution on pH and EC of the leachate of two different growing media, 2) quantify the effect of fertilizer concentration on the growth and tissue nutrient levels of pansies, and 3) determine the optimal range of leachate EC for pansies.

Materials and Methods

Plant material. Pansy ‘Majestic Giant’ was seeded in plug flats (288 cells/flat) filled with soilless growing medium (Redi-Earth; The Scotts Co., Marysville, Ohio) on 30 Sept. 1997. The seeds were germinated in a laboratory and subsequently transferred to a polyethylene-covered greenhouse, where the seedlings were thinned to one seedling/cell. The temperature set points for the greenhouse were 25 °C during the day and 20 °C at night.

Treatments. Six weeks after seeding, the seedlings were transplanted into 10-cm square pots (510 mL) filled with one of two soilless growing mixes (MetroMix 300 and MetroMix 500, The Scotts Co.). Media compositions and chemical properties are given in Table 1. The pots were placed in trays on 1.2 × 2.4-m² ebb-and-flow benches (MidWest GroMaster, St. Charles, Ill.). Plants were subirrigated daily with a fertilizer solution with an EC (EC_ebb) of 0.6, 1.2, 1.8, 2.4, 3.0, or 3.6 dS·m⁻¹. Fertilizer solutions were made using a water-soluble 20N–4.4P–16.6K fertilizer (20–10–20 Peat-Lite Special, The Scotts Co.) and the range of EC levels corresponded to N concentrations of 70 to 530 mg·L⁻¹. The fertilizer was selected because it is a popular water-soluble fertilizer in the bedding plant industry in the southeastern United States. It is a mixture of NH₄NO₃, KH₂PO₄, KNO₃, MgSO₄, H₃BO₃, Cu-EDTA, Fe-EDTA, Mn-EDTA, Zn-EDTA, and Na₂MoO₄. It contains 7.77% (w/w) ammoniacal N and 12.23% NO₃⁻-N. It is an acid-forming fertilizer, and the pH of the fertilizer solu-

Table 1. Composition and chemical characteristics of MetroMix 300 and MetroMix 500 soilless growing media. Both media also contain lime and a starter nutrient charge.

| Medium      | Spatium peat | Vermiculite | Perlite | Bark ash | Pine bark | pH | EC (dS·m⁻¹) |
|-------------|--------------|-------------|---------|----------|-----------|----|-------------|
| MetroMix 300| 10–25        | 25–40       | 5–15    | 0–10     | 25–45     | 5.7| 2.10        |
| MetroMix 500| 12–22        | 20–35       | 0       | 0–10     | 40–50     | 5.6| 1.40        |
Data collection. Three plant shoots were harvested from every experimental unit at 1 to 2 h after the last irrigation event. Data were collected until 42 DAT, when the plants started to flower and reached the stage that they would normally be sold. Entire shoot samples from the last destructive harvest were analyzed for nutrient content. Tissue N was determined with a CNS 2000 analyzer (LECO Corp., St. Joseph, Mich.) (Mills and Jones, 1996), while P, K, Ca, Mg, S, Al, B, Cu, Fe, Mn, Na, and Zn were determined by dry ashing and inductively coupled plasma spectrometry (Jones and Case, 1990).

Experimental design. The experiment was conducted on 12 ebb-and-flow benches (two replications × six fertilizer rates) with 60 plants (30 in each growing medium) on each bench at the start of the experiment. Thus, the experimental design was a randomized complete block with fertilizer EC as the main blocking factor and a split for the growing media. Initially, a group of 30 plants (on one bench, planted in the same growing medium) was the experimental unit, but this number decreased as plants samples were collected during the experiment. Data were analyzed by linear regression and analysis of variance (ANOVA). Shoot dry weight and leaf area were log-transformed before the analyses to stabilize the variances. Polynomial regression models were developed to describe the effects of ECfert and DAT on the pH and EC of the growing media, and on leaf area and shoot dry weight of the plants. The initial models included linear, quadratic, and cubic effects of both ECfert and DAT, and interaction terms between them (ECfert·DAT, ECfert·DAT 2, ECfert·DAT 3, ECfert·DAT 2, ECfert·DAT 3, and ECfert·DAT 2). Nonsignificant (P > 0.05) terms were dropped from the models, until all remaining terms were significant.

Results and Discussion

Growth was similar in the two soilless media (data not shown). As expected, ECfert did affect growth. Throughout the experiment, regression analysis indicated a decline in leaf area and shoot dry weight with increasing ECfert (Fig. 1), suggesting that the lowest fertilizer level resulted in maximum growth. However, ANOVA indicated that at the end of the experiment, maximum leaf area occurred with an ECfert of 0.6 to 1.8 dS·m−1 and maximum shoot dry weight with an ECfert of 1.2 to 2.4 dS·m−1. At the end of the experiment, a group of 30 plants (on one bench, planted in the same growing medium) was the experimental unit, but this number decreased as plants samples were collected during the experiment. Thus, the experimental design was a randomized complete block with fertilizer EC as the main blocking factor and a split for the growing media. Initially, a group of 30 plants (on one bench, planted in the same growing medium) was the experimental unit, but this number decreased as plants samples were collected during the experiment. Data were analyzed by linear regression and analysis of variance (ANOVA). Shoot dry weight and leaf area were log-transformed before the analyses to stabilize the variances. Polynomial regression models were developed to describe the effects of ECfert and DAT on the pH and EC of the growing media, and on leaf area and shoot dry weight of the plants. The initial models included linear, quadratic, and cubic effects of both ECfert and DAT, and interaction terms between them (ECfert·DAT, ECfert·DAT 2, ECfert·DAT 3, ECfert·DAT 2, ECfert·DAT 3, and ECfert·DAT 2). Nonsignificant (P > 0.05) terms were dropped from the models, until all remaining terms were significant.

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Fig. 1. The effect of fertilizer EC (ECfert) on the leaf area (A) and shoot dry weight (B) of subirrigated pansy. Pansies were grown in 10-cm square pots and subirrigated daily with fertilizer solution. Bars are means for both growing media (12 plants per mean). Lines represent regression models [ln(leaf area) = 1.623 + 0.0769·DAT + 2.45·10⁻³·DAT² – 4.38·10⁻⁵·DAT³ – 2.05·10⁻³·ECfert·DAT; r² = 0.98, P = 0.0001; ln(shoot dry weight) = 2.898 – 0.03007·ECfert + 0.1067·DAT + 7.78·10⁻⁴·DAT² – 2.05·10⁻⁵·DAT³, r² = 0.99, P = 0.0001].
dS·m–1 is optimal for most greenhouse crops. This is because the pour-through method (Yeager et al., 1983) generally gives lower readings than EC with the saturated media extract method, which Warncke and Krauskopf (1983) determined to be 0.75 to 2 dS·m–1 is acceptable, while 2 to 3.5 dS·m–1 led to a decrease in shoot dry weight and leaf area were reduced. Warncke and Krauskopf (1983) reported that a growing medium EC of 5 dS·m–1 resulted in reduced growth between the two growing media, MetroMix 300 leachate consistently had a higher EC than did MetroMix 500 (Fig. 2), possibly because of its higher initial EC (Table 1). In both media, leachate EC was relatively constant when the plants were fertilized with a 0.6 dS·m–1 solution. Leachate EC increased throughout the experiment at the higher ECfert values and the rate rose with fertilizer concentration (Fig. 2). At the higher fertilizer concentrations, nutrients apparently were supplied faster than the plants could absorb them, resulting in an accumulation of fertilizer salts in the pots.

Table 2. The effect of fertilizer EC on the nutrient composition of pansy grown with daily subirrigation for 42 d.

| Fertilizer EC (dS·m–1) | N (mg·g–1) | P (mg·g–1) | K (mg·g–1) | Ca (mg·g–1) | Mg (mg·g–1) | S (mg·g–1) | Al (mg·g–1) | B (mg·g–1) | Cu (mg·g–1) | Fe (mg·g–1) | Mn (mg·g–1) | Na (mg·g–1) | Zn (µg·g–1) |
|------------------------|-----------|------------|------------|-------------|-------------|-----------|-------------|------------|-------------|-------------|-------------|-------------|-------------|
| 0.6                    | 53.8      | 10.9       | 63.1       | 11.6        | 7.66        | 2.06      | 98          | 54         | 23          | 152         | 215         | 1468        | 170         |
| 1.2                    | 54.6      | 14.2       | 60.9       | 12.8        | 7.74        | 2.04      | 83          | 46         | 22          | 154         | 247         | 1059        | 177         |
| 1.8                    | 54.2      | 15.8       | 58.6       | 12.1        | 6.86        | 2.01      | 87          | 56         | 21          | 148         | 274         | 758         | 161         |
| 2.4                    | 53.2      | 18.7       | 62.0       | 13.3        | 7.20        | 2.12      | 87          | 55         | 21          | 149         | 295         | 765         | 220         |
| 3.0                    | 55.6      | 18.4       | 56.7       | 10.8        | 6.32        | 2.05      | 71          | 58         | 19          | 135         | 294         | 770         | 202         |
| 3.6                    | 55.3      | 19.0       | 56.3       | 10.2        | 6.32        | 2.01      | 69          | 57         | 20          | 140         | 303         | 700         | 192         |

Significance: N.S = non-significant, * = significant at P ≤ 0.05 or 0.01 by regression analysis. L = linear, Q = quadratic.

The optimal ECfert of 1.2 to 1.8 dS·m–1 corresponds to a N concentration of 11.7 to 18.3 mM (164–256 mg·L–1 N). This is slightly higher than the optimal N concentrations for subirrigated New Guinea impatiens (Impatiens hawkeri Bull.) and peace lily (Spathiphyllum Schott), which are 8 and 10 mM, respectively (Kent and Reed, 1996). Since pansy does not appear to be very sensitive to different ECfert levels, it can be grown alongside many other crops. The optimal ECfert of 1.2 to 1.8 dS·m–1, the EC of the growing medium remained within 1.5 to 4 dS·m–1 and this appears to be the optimal range for pansies. In the treatments where the leachate EC exceeded 5 dS·m–1, shoot dry weight and leaf area were reduced. Warncke and Krauskopf (1983) reported that a growing medium EC of 0.75 to 2 dS·m–1 is acceptable, while 2 to 3.5 dS·m–1 is optimal for most greenhouse crops. Warncke and Krauskopf (1983) determined EC with the saturated media extract method, which generally gives lower readings than does the pour-through method (Yeager et al., 1983). Taking into account the difference between the two methods, the optimal range for leachate EC in this study is similar to that reported by Warncke and Krauskopf (1983).

Although there were no differences in plant growth between the two growing media, MetroMix 300 leachate consistently had a higher EC than did MetroMix 500 (Fig. 2), possibly because of its higher initial EC (Table 1). In both media, leachate EC was relatively constant when the plants were fertilized with a 0.6 dS·m–1 solution. Leachate EC increased throughout the experiment at the higher ECfert values and the rate rose with fertilizer concentration (Fig. 2). At the higher fertilizer concentrations, nutrients apparently were supplied faster than the plants could absorb them, resulting in an accumulation of fertilizer salts in the pots.

This inability to absorb excess nutrients is also supported by the analysis of the plants. Surprisingly, N content was high (>53 mg·g–1) in all treatments and not affected by the different fertilizer concentrations (Table 2). Only tissue P and Mn levels increased significantly with increasing ECfert while tissue K, Mg, and Na level decreased. Calcium and Mg were the only nutrients affected by the growing media. Calcium tissue concentrations generally were 2 mg·g–1 higher in plants grown in Metro-Mix 300 than in Metro-Mix 500, while manganese levels were 40 µg·g–1 lower in Metro-Mix 500 (results not shown). Tissue nutrient concentrations were high enough to support good growth, and the growth of the plants was probably not significantly affected by nutrient deficiencies or toxicities.

The different ECfert also resulted in differences in leachate pH among the fertilizer treatments, but the pH was not affected by growing medium (Fig. 3). The pH of the leachate decreased throughout the experiment and also decreased with increasing ECfert, which would be expected with an acid-forming fertilizer. The recommended range for the pH of growing media for floricultural crops is 5.4 to 6.3 (Bailey and Bilderback, 1997). The leachate pH was within this range throughout the first 3 weeks of the growing period, but dropped to 5.2 near the end of the experiment when ECfert was 1.2 dS·m–1 or higher. This had no obvious effect on the growth or nutrient uptake of the plants.

No visual symptoms of micronutrient toxicities or deficiencies were observed and
Fig. 3. The effect of fertilizer EC (EC_fert) and time on the pH of leachate from soilless media. Pansies were grown in 10-cm square pots and subirrigated daily with fertilizer solution. Bars are means for two growing media and two replications (eight total samples) and the lines represent a regression model (pH = 6.69 – 1.29·EC_fert + 0.059·DAT + 0.56·EC_fert^2 – 4.33·10^-3·DAT^2 – 0.081·EC_fert^3 + 6.46·10^-5·DAT^3, r^2 = 0.61, P = 0.0001). Note that increasing bar height indicates increasing acidity and decreasing pH.

tissue levels of all nutrients were adequate at the end of the experiment (Table 2).

Conclusions

Pansies can be successfully produced in ebb-and-flow systems if the leachate EC is maintained between 1.5 and 4 dS·m⁻¹. Maximum growth of the plants occurred with an EC_fert of 1.2 or 1.8 dS·m⁻¹ (164 to 256 mg·L⁻¹ N). Daily subirrigation with solutions with an EC_fert higher than 0.6 dS·m⁻¹ increased the EC of the growing medium throughout the growing period. MetroMix 300 leachate consistently had a higher EC than that of MetroMix 500. The difference in EC between the two growing media had no significant effect on the growth of the plants. The leachate pH of both growing media was similar and decreased throughout the experiment; the decrease was greater with more concentrated fertilizer solutions, but did not cause nutritional deficiencies or toxicities. Fertilizer EC had some effect on the nutrient composition of the plants. Only P and Mn content of the shoots increased, while K, Mg, and Na decreased with increasing EC_fert. These differences did not appear to affect growth.

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