Research Updates

Efficiency of Fertigation Programs for Baltic Ivy and Asiatic Lily

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Summary. Ebb-and-flow irrigation reduced water and fertilizer use by ≈ 40% when compared to overhead hand-watering by hose in the production of *Hedera helix*. In contrast, water and fertilizer use were not significantly different between ebb-and-flow and drip irrigation systems in the production of Asiatic hybrid lilies. Adequate growth of Hedera helix 'Baltica' was obtained with 50 mg N/liter of 20-10-20 (20N–4.4–16.6K) or 20-19-18 (20N-8.4P-14.9K). Also, good market-quality hybrid lilies were produced with 75 mg N/liter of 20-19-18 (20N-8.4P-14.9K), 16–4–12 (16N-1.8P-10K), 20-0-20 (20N-0P-16.6K), and 20-10-20 (20N-4.4P–16.6K).

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The efficient use of water and nutrients in greenhouse and nursery production is an important issue among growers in the United States. One reason is the increasing cost and decreasing availability of high-quality irrigation water. An additional consideration is the unfavorable environmental impact of nutrient runoff from commercial operations due to the inefficient use of fertilizers (Burger et al., 1987; Hasek et al., 1986; Skimina, 1986). In practice, growers have been challenged to grow the finest-quality plants in the shortest period of time with a minimal use of raw materials (Burger et al., 1987; Furuta, 1976).

Compared to overhead irrigation, drip systems are capable of reducing water use and nutrient runoff by confining water to the cropped area (Harbaugh and Wilfret, 1980). When comparing drip irrigation systems (capillary system, twin-wall, and combination emitter) with hand-watering by hose, Kaniszewski and Dysko (1988) found that water use in all drip systems was ≈ 35% less than that with hand-watering.

Fertigation systems in which irrigation water or fertilizer solutions are recycled offer another way to reduce water and fertilizer use and to minimize water contamination. In a study with marigolds, Koch and Holcomb (1983) demonstrated that recycled constant liquid fertilization (CLF) used 39% less water than nonrecycled CLF.

The ebb-and-flow system uses recirculated fertilizer solution to periodically subirrigate potted plants grown in specially designed bench trays. This system reduces fertilizer and water use compared to overhead watering and, in addition, offers a high degree of flexibility with respect to use with different crops and pot sizes (Elliott, 1990).

In a trial with azaleas, the growth of 'Helmut Vogel' was compared in ebb-and-flow, capillary matting base plus perforated tubing, or overhead sprinkler tubing systems. The latter two systems applied 32% and 35% more nutrient solution, respectively, than did the ebb-and-flow system (Beel and Piens, 1987).

The first objective was to compare drip irrigation and irrigation by hand, and ebb-and-flow and drip fertigation systems in relation to water use. A second objective was to evaluate the effects of different fertilizer treatments and irrigation systems on the growth of Baltic ivy and Asiatic lilies.

Baltic ivy *(Hedera helix* 'Baltica') does not have a high nutrient requirement (Grower Books, 1983). Fertilizer recommendations for ivy vary greatly, e.g., 750 mg N/liter of foliar-applied nutrients (Paparozzi and Tukey, 1979), 1200 lbs N/acre per year (McConnell et al., 1981), and 1500 lbs N/acre per year (Conover and Poole, 1984). In a commercial situation, *Hedera helix* is commonly fertilized at the grower's convenience with any fertilizer solution available.

Asiatic lilies are a highly marketable and profitable crop (Bakos, 1983; Beck, 1984; Klassen, 1987). However, fertilizer recommendations are limited and contradictory. McKenzie (1989) considers fertilization of Asiatic lilies as optional, while Aimone (1986) believes that the bulb should be able to support the plant until the shoot emerges and recommends fertilizing only after the shoot is 10 to 15 cm tall. Beck (1984) considers the bulb to be an excellent food reserve up to flowering and suggests "a well-balanced liquid fertilizer applied at half the recommended strength when plants are showing buds."

The constant liquid fertilizer rates used to grow hybrid lilies range from 200 to 500 mg N/liter, with 200 mg N/liter being the most commonly recommended (Aimone, 1986; McKenzie, 1989). No particular fertilizer type has been recommended.

Baltic ivy

Terminal stem cuttings of *Hedera helix* 'Baltica' with four to five nodes were dipped in 2500 mg indolebutyric acid/liter for 3 sec and rooted in a 1 peat : 1 perlite medium (v/v) under intermittent mist. Flats ofcuttings were placed on heating mats set at 70F (21C). After 4 weeks under the mist, 96 uniformly rooted cuttings were transplanted into 11-cm (600-cm^3) pots filled with Metro-Mix 250 (Grace-Sierra, Fogelsville, Pa.), one plant per pot. Plants then were grown in a greenhouse with the heating setpoint at 60F (16C) and the ventilation setpoint at 75F (24C).

The fertilizer plots were a factorial combination of two rates of N and two fertilizer formulations. The fertilizer rates were 50 and 100 mg N/liter, and the formulations were 20-10-20 (20N–4.4P-16.6K) and 20-19-18 (20N-8.4P-14.9K) (Grace-Sierra). Fertilizer was applied with each irrigation. There were two locations in the greenhouse that served as blocks.

Half of the cuttings were grown on each of the two irrigation systems: conventional overhead hand-watering by hose and ebb-and-flow subirrigation. The decision of when to irrigate was based on appearance and weight of the medium when lifted. All plants were irrigated an average of once a week.

Plants grown with overhead irrigation were watered thoroughly each time to obtain ≈ 20% (by volume) runoffwater. The volume of water applied at each irrigation was measured. The nutrient solution used for overhead irrigation was prepared fresh at each irrigation from a concentrated stock solution.

The ebb-and-flow irrigation system consisted of 38-liter (10-gal) plastic containers that served as reservoirs, plastic trays (53 × 38 × 10 cm) with an inlet and an outlet, a pump to recycle the nutrient solution, and a timer to control the duration the pump was on. The reservoirs were filled once at the beginning of the experiment with the appropriate fertilizer solution. At each irrigation, the trays were flooded to a depth of ≈ 2 to 3 cm. The water level was maintained until the top of the medium appeared moist, requiring ≈ 45 min.

Plants were harvested 12 weeks after planting. Final plant length, fresh weights, and dry weights were recorded. This experiment was conducted from 14 Dec. 1988 through 14 Apr. 1989.

A second experiment was conducted from 15 Jan. through 20 Apr. 1989, using 256 one-node stem cuttings of *Hedera helix* ‘Baltica’ to obtain several replications. The cuttings were rooted and transplanted into 5-cm (100-cm^3) pots filled with Metro-Mix 250, one plant per pot. Irrigation and fertilization treatments were as in Expt. 1. The plants were harvested 9 weeks after planting.

The experiments were set up as 2 × 2 × 2 × 2 factorials (location in the greenhouse, irrigation method, fertilizer rate, and formulation) in a randomized complete-block design with six and 16 replications for Expts. 1 and 2, respectively. Data were tested by analysis of variance (ANOVA) using SAS techniques (SAS, 1985).

Asiatic lilies

Bulbs of *Lilium* ‘Crimson Pixie’ and ‘Lemon Pixie’ were provided by the Oregon Bulb Farm, Aurora. Upon arrival, the bulbs were precooled for 6 to 8 weeks at 40F (4.4C) and stored frozen for ≈ 30 weeks at 27F (-3). Two hundred-sixteen bulbs of each of two cultivars were potted with Metro-Mix 350 on 24 July. Bulbs were planted in 12.7-cm (5-inch) standard pots (1200 cm^3) 2.5 cm (1 inch) from the bottom and one bulb per pot. Bulbs were grown in the greenhouse with night air temperature at 62F (17C) and a ventilation setpoint of 75F (24C). One-half of the bulbs were grown on one side of the greenhouse and the other half on the other side to provide two blocks.

The fertilizer plots were a factorial combination of three levels of N (75,150, and 300 mgžliter^{-1}) and four fertilizer formulations [20-19-18, 16-4-12, 20-0-20, and 20-10-20 (Grace-Sierra)]. The fertilizers differed in the percentage of N that was in the nitrate form. The 16-4-12 formulation has ≈ 62% of the N as nitrate and 20-10-20 has ≈ 60% as nitrate. The 20-0-20 fertilizer has 100% as nitrate and the 20-19-18 has 26% of the N as nitrate. Fertilizers were applied with each irrigation. Fertilizer treatments were initiated after shoot emergence. Before shoot emergence the bulbs were irrigated with tap water.

Half of the bulbs of each cultivar were grown with each of two irrigation systems, ebb and flow and conventional trickle tube emitter. The drip system consisted of a peristaltic pump controlled by a timer and connected to a 0.64 cm (i.d.) plastic tube that served as the main line, laterals made of 0.11-cm (i.d.) tubing, and orifice emitters. The decision of when to irrigate was based on media appearance and by lifting the pot to estimate its weight. All plants were irrigated once a week on average. For the drip system, the volume of nutrient solution applied at each irrigation was measured. The runoff was collected in saucers, measured, and discarded at each irrigation.

The same physical setup used for the ebb-and-flow experiments with ivy was used in this experiment; however, each tank was filled with the specific nutrient solution and refilled when the solution was depleted. No water was added to the nutrient solution in the tanks, and the pH and electrical conductivity were not adjusted throughout the duration of the experiment. The trays were flooded to a depth of ≈ 2 to 3 cm. The water level was maintained until the top of the medium appeared moist. This process took ≈ 1 h at each irrigation. The total volume of nutrient solution used was determined at the end of the experiment by subtracting the amount of nutrient solution left over in the tanks from the initial volume.

Each plant was harvested as soon as the first flower bud opened, 37 to 50 days after planting for ‘Crimson Pixie’ and 47 to 57 days for ‘Lemon Pixie’. The following plant characteristics were measured at harvest: total plant height; stem, leaf, root, and flower dry weights; total number of flower buds per plant; and number of blasted flower buds per plant. Height was measured from the rim of the pot to the highest flower.

This experiment was conducted from 24 July to 19 Sept. 1989. The experiment was set up as a 2 × 2 × 3 × 4 factorial (location in the greenhouse, irrigation method, fertilizer rate, and fertilizer formulation) in a randomized complete-block design with three replications. Data for each cultivarwere tested by ANOVA using SAS techniques (SAS, 1985).

Baltic ivy

There was no significant difference in vine growth whether the plants were fertilized with 20-10-20 or 20-19-18 (data not presented). In addition, plants fertilized at 50 mg N/liter were not significantly different from those fertilized at 100 mg N/liter.

In Expt. 1, the rates of 50 and 100 mg N/liter provided the plants ≈ 183 and 366 mg of fertilizer, respectively, per month per 11 -cm pot. Satisfactory growth of *Hedera helix* was observed at both rates, and the amounts of fertilizer used were less than that recommended by Conover and Poole (1984), 500 mg / 10-cm pot per month.

The nitrate : total N ratio in the fertilizer and the amount of P, which were the principal differences between these two fertilizers, did not affect plant growth. These results agree with those reported by Conover and Poole (1984), in which no difference in growth or quality was observed when foliage plants were grown at a 50:50 ratio of nitrate to ammonia or urea nitrogen.

The two irrigation systems, overhead hand-watering and ebb and flow, had no significant effect on plant growth (data not presented). No significant interaction(s) of irrigation method and fertilizer rate and / or fertilizer formulation was observed.

For Expt. 1, a total of 106 liters of water was applied to plants grown with overhead irrigation, which equals 2.2 liters / l l-cm pot in a 90-day growing period. Twenty-one liters, or 20% of the total water applied, was lost as runoff. A total of 64 liters of water was applied to the plants under the ebb-and-flow system, 1.33 liters / pot. This represents a 40% savings in water as well as fertilizer usage in the ebb-and-flow system as compared to conventional overhead irrigation.

For Expt. 2, a total of 72 liters of water was applied to plants grown with overhead irrigation, which equals 0.56 liters / 5-cm liner in a 64-day growing period. A total of 30 liters of water was applied to the plants grown with the ebb-and-flowsystem, 0.23 liters / liner. This represents a 42% savings in water as well as fertilizer usage in the ebb-and-flow system as compared to conventional overhead irrigation.

The results of this experiment agree with other research (Bee1 and Piens, 1987; Elliott, 1990; Koch and Holcomb, 1983), which demonstrated that water and fertilizer are saved through recirculation. Plant growth, quality, and uniformity were similar with both irrigation systems.

Asiatic lilies

A significant difference in total height of 'Crimson Pixie' plants was observed due to the fertilizer formulation (Table 1). 'Crimson Pixie' plants grown with 20-0-20 were taller than those grown with 164-12. 'Crimson Pixie' plants grown with 20-19-18 and 20-10-20 were intermediate between 20-0-20 and 164-12. The height of plants grown with ebb and flow varied considerably, depending on the fertilizer formulation. The tallest 'Crimson Pixie' plants, 24.1 cm, were produced with 20-o-20 and the smallest, 14.6 cm, with 164-12. In contrast, 'Crimson Pixie' plants irrigated with a conventional drip system showed no significant differences in height due to fertilizer formulation.

Total height of 'Crimson Pixie' plants was not significantly affected by fertilizer concentration or the method of irrigation (Table 1).

In contrast to 'Crimson Pixie,' the total height of 'Lemon Pixie' plants was not affected by the fertilizer formulation (Table 1). However, a significant interaction of fertilizer concentration and irrigation method was observed when analyzing total plant height of 'Lemon Pixie'. The fertilizer concentration applied with drip irrigation as compared to ebb and flow had an opposite effect on plant height.

The fertilizer formulation had a significant effect on stem dry weight of 'Lemon Pixie', but it did not affect the stem dry weight of 'Crimson Pixie'. The stem dry weight of both cultivars was affected by irrigation method, although it had opposite effects on each cultivar. When compared to drip irrigation, ebb and flow yielded a greater stem dry weight for 'Lemon Pixie' but smaller stem dry weight for 'Crimson Pixie'. A significant interaction offer-. tilizer formulation and irrigation system-was observed when analyzing stem dry weight of 'Lemon Pixie'. This interaction suggests that fertilizer 164-12 interacted with the irrigation, creating the significant differences in stem dry weight, attributed previously to fertilizer formulation. Stem dry weights of both cultivars were not significantly affected by the different fertilizer concentrations (Table 1).

None of the fertilizer or irrigation treatments affected root dry weight of 'Lemon Pixie'. The root dry weights of 'Crimson Pixie' plants grown with 20-O-20 were significantly greater than those of plants grown with 164-12. The root dry weights of 'Crimson Pixie' plants grown with 150 mg N / liter were less than those of plants grown with 75 and 300 mg N / liter.

A significant interaction of concentration and irrigation method reveals that the differences in root dry

Table 1. ***The effect of fertilizer and irrigation treatments on growth of Asiatic hybrid lilies.***

Treatment		Total ht (cm)		Dry wt (g)					
				Stem		Leaves		Roots	
		CP[z]	LP[z]	CP	LP	CP	LP	CP	LP
Fertilizer formula[y]	20–0–20	22.5 a	30.5 a	0.58 a	0.82 a	1.11 a	0.74 a	1.76 a	1.23 a
	20–19–18	20.2 ab	30.1 a	0.51a	0.79 a	0.98 a	0.73 a	1.60 ab	4.59 a
	20–10–20	19.4 ab	29.4 a	0.54 a	0.76 ab	1.03 a	0.69 a	1.48 ab	1.04 a
	16–4–12	18.0 b	29.6 a	0.54 a	0.71 b	1.05 a	0.66 a	1.37 b	7.89 a
Fertilizer concn	75 mg N/liter	19.9	30.3	0.53	0.78	1.02	0.64	1.62	1.29
	150 mg N/liter	19.7	29.4	0.55	0.77	1.01	0.73	1.36	3.53
	300 mg N/liter	20.5	30.1	0.55	0.76	1.11	0.71	1.68	6.35
Significance		NS	NS	NS	NS	NS	NS	*	NS
Irrigation	Ebb and flow	19.0	30.4	0.53	0.80	1.0 a	0.73	1.52	4.46
	Drip	21.0	29.5	0.56	0.74	1.03	0.68	1.59	2.88
Significance		NS	NS	*	*	NS	NS	NS	NS

[z]*CP = 'Crimson Pixie'; LP = 'Lemon Pixie'.*
[y]*Mean separation by Student–Newman–Keuls test,* P *= 0.05.*
[NS], **Nonsignificant or significant at* P *= 0.05.*

weights of 'Crimson Pixie' associated with fertilizer concentration occurred frequently on plants grown with ebb and flow.

With ebb-and-flow irrigation, the lowest root dry weights were those of plants grown with 150 mg N/liter. In contrast, the increase in root dry weight of 'Crimson Pixie' plants grown with drip irrigation was proportional to the increase in concentration.

Growth, as defined by height and increase in dry matter, and quality of hybrid lilies appears to be controlled or affected by factors other than fertilizer formula or concentration. Plant quality was not affected by the fertilizer treatments. Good-quality, saleable plants were produced with 75 mg N/liter.

Flowering of 'Crimson Pixie' or 'Lemon Pixie' was not affected by any of the fertilizer or irrigation treatments. The results of this experiment show that the number of blasted flower buds of 'Crimson Pixie' and 'Lemon Pixie' were not significantly affected by the amount or concentration of fertilizer. Similarly, the total number of flower buds, flower dry weight, and days to flower were not significantly affected by the fertilizer and irrigation treatments.

Bulbs grown with drip and ebb-and-flow systems were irrigated about once a week. A total of 726 liters of fertilizer solution was applied to a crop of 324 hybrid lily bulbs grown with conventional drip irrigation; whereas, a total of 764 liters was applied to 324 bulbs grownwith ebb-and-flow irrigation. When compared to each other, 5% less water was used with drip irrigation in this experiment than with ebb and flow. Drip and ebb-and-flow irrigation appear to be similarly efficient in conserving water and liquid fertilizer.

In summary, ebb-and-flow irrigation reduced water and fertilizer used by ≈ 40% when compared to overhead hand-watering by hose in the production of *Hedera helix*. However, water and fertilizer use were not significantly different between ebb-and-flow and drip irrigation in the production of Asiatic hybrid lilies.

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