SECTION 12
WATER MANAGEMENT

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Recycled Irrigation Solutions and Method of Fertilization Influence Geranium Growth in a Subirrigation System

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Nature of the Work: Subirrigation is gaining popularity among growers who are concerned with producing quality plant material while reducing water use and fertilizer losses to the environment. Subirrigation has been shown to reduce water loss to the environment (3,4,8) and produce plants of similar quality to plants grown using overhead irrigation (1,2,5).

Recycling of both water and nutrients is a major advantage of subirrigation systems, yet literature is limited concerning the influence subirrigation with recycled irrigation solutions has on plant growth. Skimina (7) reported the effects of recycled overhead irrigation solutions on plant growth was crop specific for woody and herbaceous perennial nursery crops. Koch and Holcomb (6) reported that growth of marigolds grown on capillary mats and fertilized with controlled release fertilizers was greatest when solutions were recycled. Additionally, it is important for growers to understand the influence that different fertilizer sources have on various greenhouse crops when using recycled subirrigation solutions. The objective of this work was to evaluate the influence of recycled subirrigation solutions on the growth and development of *Pelargonium x hortorum* 'Scarlet Elite' when fertilized using continuous liquid fertilization (CLF) or controlled release fertilizer (CRF).

Uniform plugs of *Pelargonium x hortorum* 'Scarlet Elite' were grown in 4 in plastic pots from June 25 to August 3, 1993 in a polyethylene greenhouse under 40% shade. Greenhouse temperatures were maintained at 90/77° F max/min. The growing medium was a 1 pine bark : 3 peat moss : 1 perlite (v:v:v) mixture amended with 7 lb dolomitic limestone and 1 lb Micromax (Grace-Sierra, Milpitas, Calif.) per cubic yard. Plants were grown in subirrigation troughs consisting of 2 ft sections of plastic rain gutters filled with irrigation solutions to a depth of about 1 in.

Plants were fertilized with 250 ppm N as Peter's Geranium Special 15-15-15 (Grace-Sierra, Milpitas, Calif.) at each watering or 3.34 g Osmocote 14-14-14 (Grace-Sierra, Milpitas, Calif.) preplant incorporated. Plants were irrigated with 1000 ml of tapwater (CRF), a newly-mixed CLF solution, recycled solutions consisting of tapwater + leachate from previous recycled CRF irrigations, or newly-mixed CLF + leachate from previous recycled CLF irrigations. Recycled solutions consisted of the excess leachate from the previous irrigation brought to a volume of 1000 ml with either tapwater (CRF) or 250 ppm N CLF solution. Solution samples were taken before and after each irrigation and analyzed for nutrient composition (data not shown). Growth indices, shoot and root dry weights, and foliar color ratings were determined at experiment termination. Days to anthesis was also recorded for each plant.

Results and Discussion: *Irrigation solution type.* Irrigation method had no influence on plant growth indices (data not shown) or shoot dry weight, but root dry weights did increase when grown using recycled compared to nonrecycled irrigation solutions (Table 1). Recycled irrigation solutions resulted in decreased foliar color ratings and increased days to anthesis compared to plants receiving nonrecycled irrigation solutions (Table 1).

Fertilization method. Fertilization method had no influence on plant growth indices (data not shown) or root dry weight, but the use of CRF did increase shoot dry weights compared to plants receiving CLF (Table 1). The use of CRF also resulted in increased foliar color ratings compared to plants receiving CLF. Method of fertilization had no influence on days to anthesis (Table 1).

Significance to Industry: This experiment indicates that recycling has no influence on vegetative growth of 'Scarlet Elite' hybrid geranium but does increase production time and decrease foliar color ratings. The use of controlled release fertilizers resulted in plants similar in size to plants grown using continuous liquid fertilization while increasing foliar color ratings. These findings suggest that recycling subirrigation solutions using controlled release fertilizer could become a feasible method for production of 'Scarlet Elite' hybrid geranium.

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Table 1. Effect of recycled or nonrecycled irrigation solutions and fertilization method on 'Scarlet Elite' hybrid geranium.

	Solution type		Fertilization method	
	Recycled	Nonrecycled	CRF[z]	CLF
Dry weight (g)				
Shoot	1.9a[y]	2.1a	2.1a	1.8b
Root	3.0a	2.3b	2.5a	2.8a
Foliar color rating	3.3b	3.6a	3.9a	3.1b
Days to anthesis	39.8a	36.0b	37.6a	38.2a

[z] CRF and CLF represent controlled release and constant liquid fertilization, respectively.

[y] Means for main effects within rows having the same letter are not different by T-test (= 0.05).

Water Use and Energy Efficiency of Four Greenhouse Irrigation Systems

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Nature of Work: Although commercial production of greenhouse-grown, potted plants for interior use is an economically important agricultural industry in the sunbelt states, very little is reported on the efficiency of irrigation systems used to grow these plants. Types of container irrigation systems and associated management criteria have been described by others (Clark et al., 1990), (Evans et al., 1992), and (Henley and Poole, 1981). Producers are concerned with water and energy conservation; however, production technologies must be economically feasible to justify their use. To provide more information on irrigation systems used by growers, a project was designed to demonstrate savings in water and direct energy through use of efficient irrigation systems and proper irrigation management. Four irrigation systems (overhead, drip tube, capillary mat, and ebb and flow), representative of types employed by industry, were selected for comparison.

Two crops of dieffenbachia *(Dieffenbachia maculata)* were produced at a spacing of one 6-inch pot per square foot. The demonstration was conducted in Tavares, FL, in a quonset-style greenhouse covered with a double-layer of polyethylene film which was shaded to approximately 70-75 percent and maintained between 66-92° F during the experiment. The fall crop was grown from 25 July 1991 through 7 Nov 1991 and the spring crop was planted 3 Mar 1992 and was terminated 9 July 1992.

The volume of water applied was measured with flow meters on each system and runoff water was captured underneath the benches and measured. The application efficiency of each system was calculated from these data. More detailed materials and methods and descriptions of each system are presented elsewhere (Neal and Henley, 1992).

Electrical energy requirements were calculated for each system based on the volume of irrigation water applied. A typical nursery water supply system consists of a pressure tank, pump, controllers and a deep well. It was assumed that the system would pump 40 gpm of water from a 4-inch well to a pressure tank and deliver water from the pressure tank to the benches with no further energy inputs for the overhead, drip tube, or capillary mat system. A commercial ebb and flow system would use the water supply system as described above to charge and replenish the water in the recirculating/supply tank which is typically located under the greenhouse floor. Calculation of the power required to deliver water from the supply tank to the ebb and flow benches was based on a 2-inch diameter by 8-foot suction pipe equipped with a 15.9 gpm pump. The total energy use of the ebb and flow system was the sum of the energy used in both processes: filling the supply tank from the well and pumping the water from the tank to the benches.

The direct energy and pumping costs for the four irrigation systems were computed from the water use data for the four irrigation systems, using Water Management Utilities software (Zazueta and Smajstrla, 1992). For calculation purposes, we assumed a 4-inch suction pipe diameter, a 60 psi outlet pressure, and dynamic pumping depths of 100, 150, 200, 250, and 300 feet. Pumping costs for each system were calculated by multiplying the HP Hrs by the hourly pumping costs. Electricity cost was estimated to be $0.08/kwh.

Results and Discussion: Although saleable, high quality dieffenbachia were produced under all of the irrigation systems (Neal and Henley, 1992), plants grown under overhead irrigation were slightly larger and received higher quality ratings (based on color and fullness) than plants grown under the more efficient systems (data not shown). These differences were greatest for drip-grown plants in comparison to overhead, and least obvious for the ebb and flow plants. Crop performance could undoubtedly be improved over time by fine tuning the nutrition and irrigation management of crops produced under these alternative systems. The drip, capillary mat, and ebb and flow systems used only 13%, 25%, and 12%, respectively, as much water as the overhead system (Table 1). Actual water use per crop (gal / 1,000 ft^2) ranged from 2,979 gal for ebb and flow to 24,799 gal for overhead (Table 1).

Retained water, which was the amount applied minus the amount recovered in the drainage tanks, was primarily water remaining in the pots and plants after irrigation and drainage. A portion of retained water in the capillary mat system was held in the mat and was not necessarily available to the plants.

The efficiency of each system was calculated as the ratio of the volume of water retained to the volume of water applied, expressed as a percentage. A high ratio indicates that little water was wasted, whereas a low ratio indicates that much of the water was lost from the root zone and could serve as a carrier for nutrients to enter ground or surface waters. The efficiency of overhead sprinklers was less than ten percent due to pot spacing, overspray, deflection by the crop canopy, and percolation through the pots. Closer spacing early in production would improve efficiency because a higher percentage of the bench surface would be occupied with containers. Improvement of overhead irrigation efficiency could also be achieved through use of shallow moisture recovery trays underneath the pots to capture some of the water which would otherwise fall between pots.

The drip tube and capillary mat systems were only about 50% efficient, meaning that half of the water applied was not available for plant growth. The container medium did not absorb as much water during irrigation by drip tubes or capillary mats as it did under overhead irrigation. It was therefore necessary to irrigate more frequently with drip tube and capillary mat systems than with ebb and flow and overhead systems. The efficiency of drip tube systems could be improved by using: 1) saucers underneath the pots, 2) a less porous potting media, and/or 3) a pulse schedule of irrigation. The inefficiency of the capillary mat system is largely due to evaporation of water from the mat.

Since the ebb and flow system reused the water recovered from previous irrigations, very high efficiency (78%) was achieved. Calculation of the ebb and flow efficiency in this experiment included the volume of water used initially to fill the recirculating tank. After the final irrigation of the experimental crop, a portion of the irrigation water was returned to the supply tank and was counted as part of the total water used. In commercial applications of ebb and flow irrigation, the efficiency would be greater than indicated if the carryover water Tom one crop were used for irrigation of the next one.

The total pumping power requirement was highest for the overhead system - 45.86 Water HP Hr/1000 sq. ft. at 300 feet (Table 2). Pumping energy savings for capillary mat, ebb and flow and drip tube systems was 75% or more when compared to the overhead system under the same conditions (Figure 1). The pumping costs for overhead irrigation were four to five times higher than for the next most expensive system, capillary mats. The drip tube and ebb and flow systems were least expensive to operate, followed by capillary mat and overhead (Table 2).

Significance to Industry: Adoption of more efficient greenhouse irrigation systems will occur on a large scale when systems become cost effective in terms of initial cost and long term management considerations. The potential imposition of new regulations and the potential rising cost of energy may also influence the rate of adoption. Even without rising costs or regulation, the efficient use of energy allows for the avoidance of environmental costs associated with generating electricity to power the pumps. Progressive producers are already phasing in alternatives to overhead systems and learning the management requirements of these systems to produce top-quality plants.

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Table 1. Irrigation frequencies, volumes (gallons/1000 square feet) and efficiencies for production of *Dieffenbachia maculata* (spring crop) in 6- inch pots under four irrigation systems.

Irrigation system	Average no. days between irrigation	Water applied	Runoff water	Water retained	Efficiency (%)
Overhead	3.5	24,799	22,852	1,947	8
Drip	2.8	3,252	1,605	1,647	51
Capillary mat	1.8	6,198	3,082	3,115	50
Ebb and flow	3.3	2,979[y]	NA[z]	2,324	78

[y]Volume of well water used to charge and replenish recirculating tank
[z]NA = not applicable

Table 2. Water horsepower-hours (per 1000 square feet of irrigated bench surface) for four greenhouse irrigation systems and five dynamic pumping depths.

Irrigation system	Water HP-Hr/1000 sq ft				
	Dynamic pumping depth				
	100 ft	150 ft	200 ft	250 ft	300 ft
Overhead	24.89	30.16	35.33	40.60	45.86
Drip	3.25	3.94	4.62	5.30	5.99
Capillary mat	6.22	7.53	8.82	10.14	11.45
Ebb and flow					
Well	2.99	3.62	4.24	4.87	5.51
Recirculating	1.85	1.85	1.85	1.85	1.85
Total	4.84	5.47	6.09	6.72	7.36

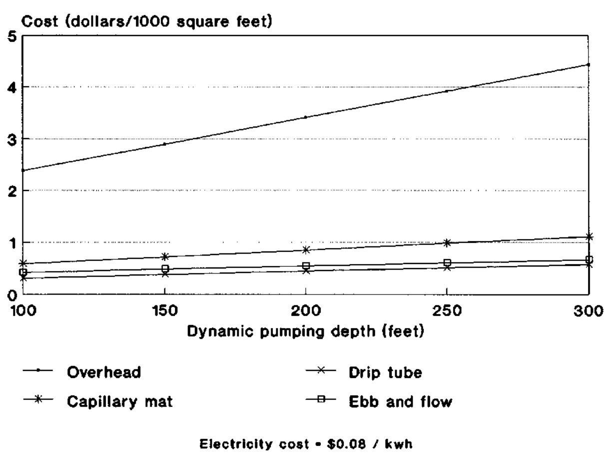

Figure 1. Pumping cost for production of a 6-inch dieffenbachia crop, comparing four irrigation systems and five dynamic pumping depths.

Evaluation of a Unique Greenhouse Subirrigation System with Two Container Systems

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Nature of Work: A demonstration was designed to evaluate a new greenhouse subirrigation system for container-grown plants. The system utilizes the relative buoyancy of each container within an irrigation zone to control the nutrient solution or water applied to each plant. Components of the prototype system included: 1) a nutrient solution supply; 2) a manifold for maintaining a constant solution level; 3) a solution distribution system consisting of a main line and pot tubes; and 4) a series of specially designed, pairs of nesting containers which independently control water emission for each potted plant in an irrigation zone (Figure 1). Conventionally potted plants and plants potted in polyethylene enclosed packs of medium were inserted inside the upper pot of each nested container pair.

Nutrient solution was stored in a 5-gallon carboy inverted and positioned over the manifold which supplied solution to a main distribution line and pot tubes under constant pressure, which was adjustable by changing of the vertical level of the carboy. The carboy was shrouded with aluminum foil to exclude light and prevent algae growth inside the container. Solution was supplied to each pot plant position through a pot tube attached to the base of the lower (outer) container of the container pair. The basal container was water tight except for the water inlet, and it had a raised diaphragm bonded to the inside-center of the container base. The diaphragm consisted of a latex-silicon film membrane stretched tightly over a 1/4inch-long section of 1/2-inch PVC pipe. The upper (inside) container of the nested pair was also water tight except for a small hole centered in the base which held an 1/8-inch ID brass ferrule that extended approximately 1/4-inch through the base. Pots containing potting mix and liner were then nested inside the upper unit of the paired containers.

The nutrient solution level of the system was adjusted by changing the vertical level of the 5-gallon carboy. As a potted plant lost water through transpiration and evaporation, it and the upper container became more buoyant and rose due to solution pressure in the system. As the paired containers separated, the seal between the diaphragm in the bottom container and the ferrule in the upper container was broken. Breaking of the seal permitted water to flow into the upper unit of the container pair and subsequently to the potted plant. As solution contacted the potting medium it moved upward and laterally by capillary action. The potted plant eventually gained enough weight to force the upper unit of the paired containers downward and sealed the opening until the next cycle. Each assembly holding a potted plant in this system of 24 pot positions operated independently. The irrigation system used in this demonstration was adapted from a concept developed and patented by U. Bednarzik.

One crop of nephthytis *(Syngonoum podophyllym* 'White Butterfly) was grown at spacing of one 6-inch azalea pot per square foot. The project was conducted in Tavares, Fl, in a quonset-style, double-layer-inflated, polyethylene-covered greenhouse. The greenhouse cover was shaded to approximately 70-75 percent and maintained between 70-92°F during the experiment. Ventilation was accomplished with exhaust fans and evaporative pads were utilized for cooling. Tissue-cultured, 72-cell, nephthytis plugs were planted in a peatlite mix (Verlite Nursery Mix A) on 4 April 1992 and the crop was finished by 26 June 1992. Half the plants (12) were potted into 6-inch plastic azalea pots and the other half were potted into tailored plastic film packs which contained the same volume of Verlite mix as held by the azalea pots. The packs were perforated in the base for drainage and the top was slit for insertion of the plant. The planted packs were inserted into azalea pots which were in turn placed inside the upper paired container. The use of the pot pack in this experiment provided a second treatment that limited the evaporation of water from the potting medium surface. Results from previous research on related crops indicated that approximately 30% less water is needed for production of crops grown in pot packs than in conventional open top pots. Constant fertilization consisted of 200 ppm N from a soluble 24-8-16 fertilizer (Grace/ Sierra - Peters - Tropical Foliage). Measurements of plant height, plant width, and water use were made weekly.

Results and Discussion: Plants in both the open top pots and in the pot packs grew rapidly and finished as very high quality foliage plants. Although the subirrigation system did not malfunction, it was necessary to raise the solution level in the system approximately three weeks before the crop was finished. This adjustment compensated for the increased crop weight (roots and tops) and permitted the crop to finish on a schedule comparable to those grown commercially. At harvest, there was no statistical difference in height of plants grown in the two potting systems (Figure 2). There was a statistical difference at the P = 0.01% level in plant width between the two potting systems. The additional vine growth of the open-top-pot-grown plants may reflect an increase in potting medium fertility from the additional nutrient solution drawn into those pots as water was lost by evaporation from the exposed surface medium.

The mean volume of nutrient solution used by the 24 plants which shared a common subirrigation system is presented (Figure 3). Since half the plants on the system were grown in open top pots and the others were in pot packs, it was not possible to present actual data on nutrient solution used by each container system. Based on previous experience with Syngonium in pots and packs (data not presented) and research on a related plant (Henley, 1991), it was estimated that the cumulative solution requirement for plants in open top pots was approximately 15% more than for the mean of the two containers systems combined, and the amount used by packs was approximately 15% less than the mean (Figure 3).

Significance to Industry: The evaluation of this subirrigation system prototype indicated it was very reliable for production of a least one greenhouse crop. The authors feel that the commercially manufactured version of the tested system would be justified primarily in situations where crops of the same species, pot size, stage of growth, and spacing are grown on a continuing basis. Although the hardware cost required at each pot position exceeds that of other greenhouse irrigation systems, with the exception of some ebb and flow technologies, the simplicity of other parts of the system is unequalled. No controllers, pumps or valves are needed other than the initial pumping which may be needed to raise the water to a point above crop level. More research is needed which would consider additional factors needed to determine economic feasibility of this irrigation system for specific plant production situations.

With the evolution of regulations for water use and point source pollution from fertilizers, greenhouse operators will need systems which can irrigate potted plants with little or no water or fertilizer leaching from the pot and potentially contaminate water resources. The irrigation system evaluated in this study is a closed system which supplies water only to the pot and root system, thereby preventing water resource contamination.

Information on hardware for the commercially manufactured version of this subirrigation system is available from Precision Irrigation, Inc., 2807 Rock Springs Road, Apopka, FL 32712.

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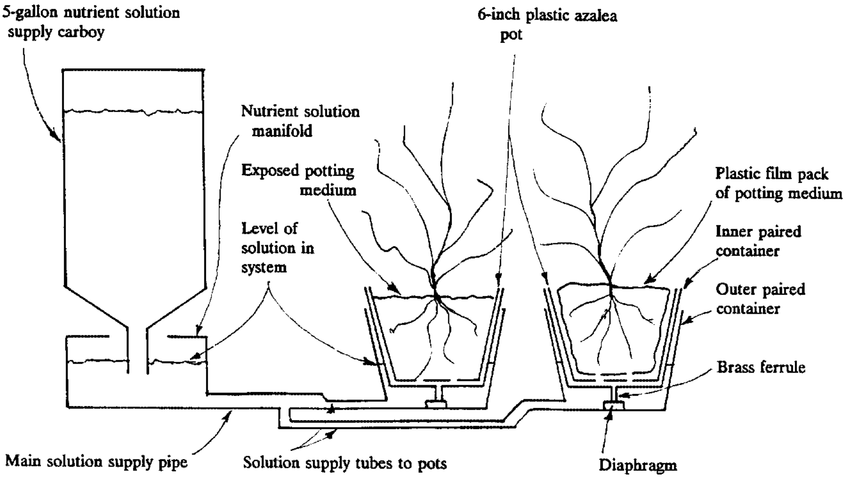

Figure 1. Stylized diagram of potted plant subirrigation system.

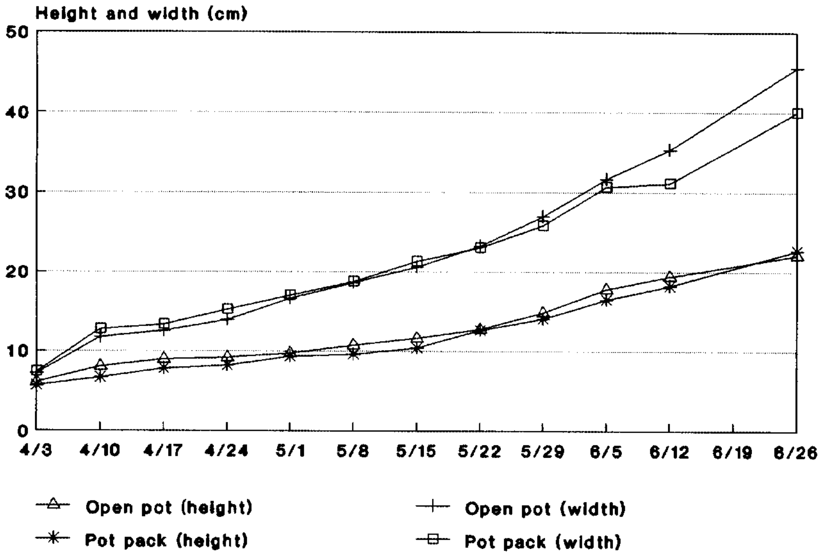

Figure 2. Height and width of *Syngonium* 'White Butterfly' grown in two container systems during a 12-week period.

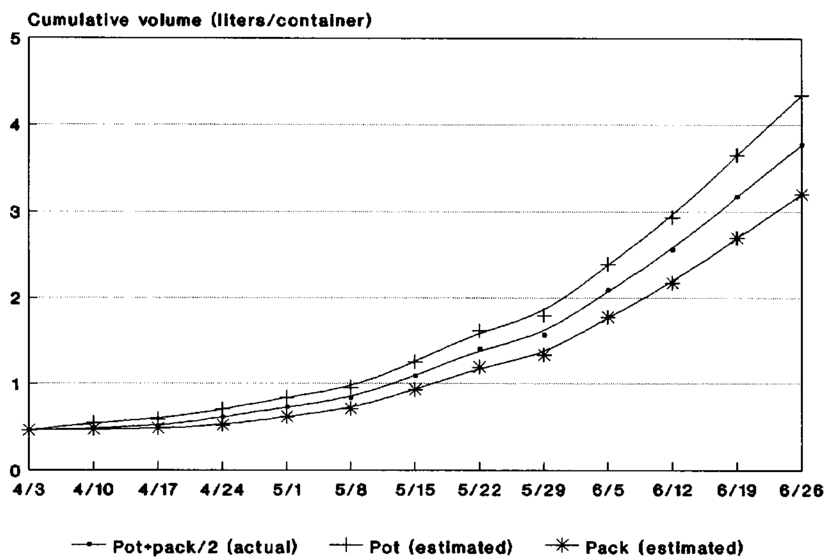

Figure 3. Cumulative volume of nutrient solution used by 6-inch *Syngonium* 'White Butterfly' plants during a 12-week period.