SECTION 12

Water Management

Ron Walden
Section Editor and Moderator

Section 1 and Section 13 may contain related titles.

Effect of Salinity and Alkalinity on Growth of Bedding Plants Grown in Three Media

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Nature of Work: The alkalinity level of water, not the pH, is what determines the effect water has on growing medium pH. When alkalinity levels are high in irrigation water (approximately 400 ppm) the medium pH is likely to rise very quickly. High levels of sodium bicarbonate ($NaHCO_3$) have been shown to cause general chlorosis, tip burn and defoliation (Bush et. al., 1989). Salinity also is a major concern when determining water quality, and sodium (Na^+) and chloride (Cl^-) are the two major elements involved in salinity. Sodium in irrigation water has important osmotic effects on water uptake, can decrease the structure of mineral soils leading to poor drainage and aeration, and can antagonize uptake by roots of other essential cations, such as calcium (Ca^{++}) and magnesium (Mg^{++}) (Biernbaum, 1994). The chemical and physical properties of peat and pine bark are very different (i.e. chemical composition, cation exchange capacity, and water holding capacity) and may react very differently to saline and alkaline water (Bunt, 1988). Two studies were conducted to investigate the effects of salinity and alkalinity on growth and nutrient content of pansies and impatiens grown in peat, pine bark, and peat:pine bark media.

Pansy and impatiens plugs were transplanted into 4" containers filled with peat, pine bark, and peat:pine bark media (1:1) and grown in a greenhouse maintained at day/night temperatures of 75/65°F. Plants were fertigated by drip irrigation on an as needed basis using a 20-10-20 fertilizer at 200 ppm N. The salinity and alkalinity treatments were mixed with the fertilizer 1 week after transplanting. The salinity treatments were 0 ppm (control), 100 ppm and 400 ppm NaCl:$CaC1_2$ (2:1 meq each) and the alkalinity treatments were 0 ppm (control), 100 ppm, 200 ppm, 300 ppm, and 400 ppm $NaHCO_3$. Plants were arranged in a complete randomized block design with 6 replications for each treatment. Plants were harvested 8 weeks after transplanting and dry weights were recorded. Saturated paste extracts were obtained and analyzed for Ca^{++}, Mg^{++}, Na^+, and Cl^-. The pH and EC of these extracts were also measured.

Results and Discussion: NaHCO3 Experiment: There were few significant differences of pH and electrical conductivity among the three media for both pansy and impatiens (Tables 1 and 2). As the $NaHCO_3$ concentration increased, the pH and EC of the three media also increased for both pansies and impatiens. The EC of the media never exceeded 2.5 dS/m, however, pH increased to a maximum level of 7 in the peat media at 400 ppm $NaHCO_3$.

Media type had little effect on the concentration of Ca^{++} and Mg^{++} across all $NaHCO_3$ treatments. As NaHCO3 concentrations increased, Ca^{++} and Mg^{++} concentrations decreased below acceptable levels in all media for pansy and impatiens. Media Na^+ concentration did not vary among the three media, however, as $NaHCO_3$ treatment concentrations increased, Na+ levels also increased above toxic concentrations (100 ppm Na^+) in each media. The increasing amount of Na^+ and/or HCO_3- seem to be responsible for a decrease in available Ca^{++} and Mg^{++} concentrations in all three media for both pansy and impatiens.

For both pansy and impatiens there were significant differences in dry weight among all media as well as among all treatments. As treatment concentrations increased from 0 to 400 ppm NaHCO3, dry weight decreased. Plants grown in peat media had the greatest dry weight, while plants grown in pine bark had the lowest.

$NaCl:CaCl_2$ Experiment: Calcium and magnesium concentrations were highest in the pine bark media, with lower concentrations in the peat:pine bark and peat media for both the pansy and impatiens (Table 3 and 4). There was a significant increase in Ca^{++} concentrations as the $NaCl:CaCl_2$ treatment concentrations increased. Results from the saturated paste extracts indicate that sodium and chloride were significantly higher in the pine bark media of pansy and that there was a significant increase of Na^+ and Cl^- concentrations above acceptable levels (>250 ppm) between treatments and among all three media for impatiens.

The dry weights of pansy and impatiens were significantly different among all media as well as among all treatments. Salinity levels above 100 ppm $NaCl:CaCl_2$ caused reduced growth in all media especially if grown in pine bark. The reduced growth was attributed to high EC, Na^+, and Cl^- levels.

Significance to Industry: Alkaline irrigation water containing $NaHCO_3$ above 200 ppm caused an increase in pH above acceptable levels (>6), especially in peat based media. As sodium concentrations increased above acceptable levels (100 ppm Na+) in the media of pansy and impatiens, Ca^{++} and Mg^{++} concentrations decreased below optimum levels. This resulted in reduced growth, decreased flower number, downward cupping of leaves and necrosis of leaf edges of pansy and decreased growth, general chlorosis, water soaked appearance of leaves, and leaf abscission of impatiens.

Salinity levels at 100 ppm NaCl and higher caused an increase of EC, Na^+, and Cl^- above acceptable levels (2.0 dS/m, >50ppm, and >140 ppm respectively) in all three media, with the highest levels in pine bark media. Treatment symptoms for pansy were decreased growth, necrosis of leaf edges and downward cupping of leaves and increased symptom severity of plants grown in pine bark media. Treatment symptoms for impatiens were reduced growth and general chlorosis.

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Table 1. $NaHCO_3$ treatment means of dry weight pH EC and ppm of calcium magnesium and sodium for pansy.

			PANSY				
ppm $NaHCO_3$	Media	Drv Wt (grams)	pH	EC (dS/m)	Ca^{++} (ppm)	Mg^{++} (ppm)	Na^+ (ppm)
0	Peat	3.09a[1]	5 79b[1]	1.29ab[1]	82.60a[1]	13.38a[1]	44.00a[1]
	Peat :Pine Bark	3.29a	5.97a	1.01b	55.40a	9.20b	51.25a
	Pine Bark	2.06b	5.75b	1.42a	55.40b	12.95ab	46.21a
100	Peat	3.43a	6.18a	1.50b	35.03a	6.44a	188.83b
	Peat :Pine Bark	2.80a	6.04a	1.98a	51.68a	9.60a	232.00a
	Pine Bark	2.00b	5.99a	1.49b	47.92a	6.32a	176.80b
200	Peat	3.45a	6.45a	2.04a	35.97a	6.82a	339.33a
	Peat :Pine Bark	2.5.0b	6.31b	1.84a	35.71a	6.72a	297.67ab
	Pine Bark	2.02b	6.33ab	1.61a	28.98a	3.94a	266.33b
300	Peat	2.83a	6.84a	2.20a	27.03a	4.68a	439.50a
	Peat :Pine Bark	3.37a	6.43b	1.85b	16.03b	2.48b	363.33b
	Pine Bark	1.74b	6.13c	1.98ab	20.46b	2.76b	331.67b
400	Peat	2.48a	6.75a	2.28a	25.68a	4.39a	429.17a
	Peat :Pine Bark	2.81a	6.51a	2.25a	16.43a	2.49a	451.00a
	Pine Bark	2.15a	6.67a	2.29a	19.00a	2.81a	466.83a

[1] Separate ANOVA for media within each treatment level. Means with the same letter are not significantly different (P >0.05)

Table 2. $NaHCO_3$ treatment means of dry weight, pH, EC and ppm of calcium, magnesium, and sodium for impatiens.

		IMPATIENS					
ppm $NaHCO_3$ Media		**Dry Wt (grams)**	**pH**	**EC (dS/m)**	**Ca^{++} (ppm)**	**Mg^{++} (ppm)**	**Na^{+} (ppm)**
0	Peat	4.60a[1]	5.60b[1]	1.36a[1]	74.57a[1]	25.93a[1]	45.00a[1]
	Peat ;Pine Bark	5.08a	5.77a	1.35a	40.22b	6.62a	42.03a
	Pine Bark	2.95b	5.81a	0.92b	92.17a	12.31a	44.33a
100	Peat	3.85a	5.90a	2.19a	59.10ab	11.97a	215.83a
	Peat :Pine Bark	3.68a	6.03a	1.75b	39.00b	6.91b	175.57a
	Pine Bark	2.38b	6.00a	1.84ab	64.02a	9.01ab	177.00a
200	Peat	3.23a	6.28a	2.47a	33.51a	6.63a	361.50a
	Peat :Pine Bark	3.15a	6.24a	2.54a	35.08a	6.46a	377.40a
	Pine Bark	2.03b	6.28a	1.81b	39.80a	5.49a	265.83b
300	Peat	3.08a	6.65a	2.04a	16.00b	2.83a	353.67a
	Peat :Pine Bark	2.63a	6.41b	2.31a	18.35ab	3.39a	398.17a
	Pine Bark	1.85b	6.25c	l.99a	23.15a	3.15a	359.67a
400	Peat	2.30b	7.06a	2.01b	15.68a	2.50ab	398.50a
	Peat :Pine Bark	3.13a	6.73a	2.09ab	14.61a	2.21b	420.33a
	Pine Bark	1.50c	6.10b	2.35a	21.83a	2.95a	432.00a

[1] Separate ANOVA for media within each treatment level. Means with the same letter are not significantly different (P>0.05).

Table 3. NaCl:$CaCl_2$ treatment means of dry weight, pH, EC and ppm of calcium, magnesium, sodium, and chloride for pansy.

		PANSY						
ppm NaCl:CaCl,	Media	Dry Wt (grams)	pH	EC (dS/m)	Ca^{++} (ppm)	Mg^{++} (ppm)	Na^{+} (ppm)	Cl (ppm)
0	Peat	4.0a[1]	5.64a[1]	1.55a[1]	97.13a[1]	14.36a[1]	39.70a[1]	218.30a[1]
	Peat :Pine Bark	2.96b	5.49a	1.84a	94.57a	14.91a	53.88a	116.70a
	Pine Bark	2.43b	5.48a	2.23a	103.50	a14.86a	56.63a	255.00a
100	Peat	2.69a	5.86a	2.27b	130.48b	13.40b	181.33b	388.33b
	Peat :Pine Bark	2.78a	5.84a	1.76b	102.84	b8.67b	152.50b	354.00b
	Pine Bark	2.18a	5.45b	3.70a	245.40a	20.66a	244.20a	636.00a
400	Peat	0.83b	6.21a	2.33b	133.55	b6.098b	229.50b	385.00a
	Peat :Pine Bark	1.03a	b5.97b	1.78b	152.25b	7.10b	239.50b	576.70a
	Pine Bark	1.22a	5.47b	5.44a	392.29a	19.04a	427.43a	1320.00a

[1] Separate ANOVA for media within each treatment level. Means with the same letter are not sign)ficantly diffierent (P>0.05).

Table 4. NaCl:$CaCl_2$ treatment means of dry weight, pH, EC and ppm of calcium magnesium, sodium, and chloride for impatiens.

		IMPATIENS						
ppm NaCl:$CaCl_2$	Media	Drv Wt (grams)	pH	EC (dS/m)	Ca^{++} (ppm)	Mg^{++} (ppm)	Na^{+} (ppm)	Cl (ppm)
0	Peat	3 73a[1]	5.12b[1]	1.53a[1]	103.92a[1]	1l.98a[1]	38.15a[1]	150.00a[1]
	Peat :Pine Bark	3.49a	5.23ab	1.41a	75.72a	11.33a	36.22a	125.00a
	Pine Bark	2.65b	5.32a	1.63a	98.80a	12.53a	57.30a	111.00a
100	Peat	3.04a	5.16a	2.78a	190.17a	17.61b	191.83a	463.33a
	Peat :Pine Bark	3.28a	5.08a	3.24a	212.33a	20.40ab	233.17a	60500a
	Pine Bark	2.04b	5.14a	3.40a	261.67a	23.93a	215.67a	573.33a
400	Peat	0.98a	5.40a	4.95a	381.50a	13.43b	479.00a	1183.30b
	Peat:Pine Bark	1.00a	5.27a	5.43a	424.17a	14.49b	527.17a	1393.30ab
	Pine Bark	1.14a	5.09b	5.08a	496.00a	27.30a	475.17a	1525.00a

[1] Separate ANOVA for media within each treatment level. Means with the same letter are not significantly different (P>0.05).

Using Canopy Dimensions and Potential Evapotranspiration to Schedule Irrigation of *Ligustrum japonicum*

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Nature of Work. In many container nurseries, irrigation is scheduled by time clocks or inspection of plants. Often time clocks are not adjusted to account for cloudy days and infrequently adjusted to match changes in plant growth or climate. Waiting until plants exhibit physical signs of irrigation need induces water stress that restricts growth (Beeson, 1991). Conversely, irrigating when unnecessary wastes both water and money associated with pumping costs. Scheduling irrigations based on meteorological factors that drive plant water use would optimize irrigation and growth and could be incorporated into computer control systems. This project modeled water use of *Ligustrum japonicum* (waxleaf ligustrum) as a function of potential evapotranspiration (ET_P) at different moisture allowable deficits (MAD) during growth from a #1 to marketable #3 container plant. Different ways of normalizing actual evapotranspiration (ET_A) were evaluated.

In Feb. 1994, ligustrum in #1 containers were upcanned into #3 containers using a 6 pine bark: 3 sledge peat: 1 sand substrate. Sixty-five plants were spaced about 5 inches apart in a square arrangement in 5 independently overhead-irrigated areas. Within each area, 2 plants were suspended in lysimeters with weights recorded hourly from early March until mid-Sept. (Beeson, 1995). Meteorological data of maximum and minimum temperatures, incoming solar radiation, rainfall, and wind run (miles per day) at the site were recorded manually for Monday through Thursday. From this data, ET_P was calculated by the Penman equation (Zazueta et al., 1989) and calibrated to estimate ET_P for well-watered short turf grass (Jones et al., 1984).

Moisture deficit treatments (MAD) of 20, 40, 60, and 80% of plant available water and a 0.72-inch daily control irrigation were imposed (Beeson, 1995). Containers in MAD treatments were irrigated to resaturation nightly as required. Plant available water was determined at potting and in mid-May (Beeson, 1995). Canopy growth, consisting of widest canopy width, the width perpendicular to it, and average height were recorded every 4 to 6 weeks. In Sept. each plant was graded (Div. of Plant Indust., 1993) and other quality evaluations recorded (Beeson, 1995).

Actual evapotranspiration (ET_A) was computed for each plant on container surface area (78 in^2; 510 cm^2), allocated bed area (1.7 ft^2, 1650

cm^2), and estimated daily canopy surface area (canopy area) for the same days which ET_P were calculated. Daily canopy area was calculated from regression equations developed from growth measurements. Correlations between ET_P and ET_A, and calendar day and ET_A, normalized for each surface area were calculated using SAS (SAS Institute, Cary, N.C.). Correlations were calculated for the entire production period and the period divided into two phases. Phase 1 ranged from March until mid-May. Phase 2 ranged from mid-May until terminated in mid-Sept. 1994.

Results and Discussion. Plant available water initially was the same as the maximum available in #1 containers (39 oz, 1.1 L). By mid-May, available water had increased to nearly a gallon (3.5 L) per container, indicating roots fully exploited all the available water in this container/ substrate system (Beeson, unpubl. data). In mid-May, canopies completely covered the container surface and generally 117% of the allocated bed area. Through May, canopy growth and ET_A among MAD treatments were similar. Thereafter, MAD treatments were based on available water within the #3 containers. By mid-Sept., significant differences in canopy growth (Table 1) and ETA occurred. While all but the 80% MAD treatment resulted in high percentages of marketable plants, only control, 20 and 40% MAD treatments were economically valid (Beeson, 1995).

Over the entire period of March to Sept., ET_A was poorly correlated ($r^2 < 0.3$) with ETP when based on a fixed area (pot or bed area), but well correlated ($r^2 > 0.56$) with the time after experiment initiation. Dependence on time and not ET_P reflects the increase in ET_A as plants grew, and ET_P values which were generally consistent over this period.

When ET_A was normalized by canopy areas over the entire period, correlations with ET_P were higher than with time only for control and 20% MAD treatments, although r^2 were still low ($r^2 < 0.35$). When analyzed by Phases, ET_A during Phase 1 was not or only weakly correlated with ET_P (Table 2). During Phase 1, canopies were small but spaced for marketable size. ET_A was dependent on the entire plant canopy rather than the upper canopy surface. By Phase 2, canopy growth was overlapping. In which case, the majority of transpiration could be accounted for by upper canopy surface area, evidenced by relatively high r^2 in the well-irrigated treatments down to 40% MAD. These same treatments were those considered economically viable. Correlations were weaker in 60 and 80% MAD treatments which induced higher water stress, slowing canopy growth (Table 1).

Ratios of ET_A to ET_P are termed crop coefficients (Kc). Multiplying local ET_P by this ratio and canopy surface area will estimate daily water loss.

Comparing daily water loss to the amount of plant available water can estimate a crop's MAD level and be used to schedule irrigation. Kc based on canopy surface areas were 0.51, 0.63, and 0.50 for the control, 20 and 40% MAD treatments, respectively.

Significance to the Industry. Plant water use of spaced plants, is higher on a canopy surface area basis, than when canopies have merged. When adjacent canopies merge, water is lost principally through the upper canopy surface. Whereas when canopies are isolated, water loss occurs from the entire canopy. Water can be conserved and canopy growth increased if canopy isolation is minimized throughout production. With knowledge of local ET_p and canopy widths, the Kc from the 40% MAD treatment (Kc = 0.50) can be used for the most efficient irrigation scheduling where canopy isolation is minimized.

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Table 1. Comparison of growth indices (GI) and final canopy dry mass (Dwt) between treatments. Growth indices were calculated by multiplying the widest canopy width by the width perpendicular to it times the height.

Treatment	GI(m^3)	Dwt(g)
Control	0.248 b[z]	171.4 b
20% MAD	0.330 a	210.4 a
40% MAD	0.235 b	188.2 ab
60% MAD	0.179 c	164.2 bc
80% MAD	0.143 c	135.3 c

[z]Means with the same letter are not significantly different within columns at = 0.05 using Fishers Protected LSD. Means arerepresentative of 10-plant replicates.

Table 2. Regression equations and r^2 for ET_A with ET_P based on canopy surface areas. Phase 1 extended from mid-March until mid-May. Phase 2 consisted of the period from mid-May until termination in early September.

Treatment	Equation	r^2
Phase 1		
Control	$0.42\ ET_P + 0.05$[z]	0.367[y]
20% MAD	$0.13\ ET_P + 1.64$	NS
40% MAD	$0.45\ ET_P + 0.97$	0.269
60% MAD	$0.81\ ET_P + 0.33$	0.369
80% MAD	$0.16\ ET_P + 1.90$	NS
Phase 2		
Control	$0.46\ ET_P + 0.22$[w]	0.564
20% MAD	$0.71\ ET_P - 0.33$	0.533
40% MAD	$0.56\ ET_P - 0.22$	0.622
60% MAD	$0.49\ ET_P + 0.38$	0.385
80% MAD	$0.27\ ET_P + 0.87$	0.170

[z]Regression equations calculated from 24 pairs of ET_A and ET_P measurements.
[y]Numerical values were significant to $\alpha = 0.05$. NS - Regression equations were not significant to $\alpha = 0.05$.
[w]Regression equation calculated from 52 pairs of ET_A and ET_P

Developing a Nursery Crops Research/Education Facility For Evaluating Water Management

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Nature of Work: In Texas, and throughout the United States, greater emphasis is being placed on prevention of surface and ground water contamination by all areas of agriculture and industry. The cost of complying with new, more stringent regulations is having a significant economic impact as producers seek solutions to environmental challenges. One of the primary objectives of the Texas Agricultural Extension Serviceís Target 2000 project is to reduce water consumption to 1990 levels by the year 2000, while encouraging growth and expansion within the nursery industry (Wilkerson, 1995).

During a recent expansion of the nursery research facility at Texas A & M University in College Station, Texas, (Fig. 1) the irrigated section of the nursery was graded to an approximate 1% to 3% slope then lined with an 8 millimeter polyethylene liner and covered with 7.5 cm (3 in.) of 3 cm (1.25 in.) river rock. All runoff created within the nursery runs into a polyethylene lined modified French drain system consisting of a 60 cm (2 ft.) trench with a 10 cm (4 in.) diameter perforated drainage pipe placed into it and covered with river rock. This system runs the entire length of the nursery and collects all wastewater in a 3,800 L (1,000 gal.) submerged two-staged tank that allows solids to settle in the first stage before a submerged pump in the second stage pumps the nursery effluent into a raised 7,600 L (2,000 gal.) storage tank. Untreated wastewater from this tank can be 1) reapplied to nursery crops, 2) used for irrigation of the surrounding landscape, or 3) passed through a series of 10 constructed wetland cell [2.5 m (8 ft.) x 1 m (3 ft.) x 0.7 m (2 ft.) galvanized water troughs, 1,150 L (300 gal.)] (Fig. 2). Five of these cells are designed as free-surface-flow systems, which mimic a natural marsh. Each free-surface cell is covered with 15 cm (6 in.) of sandy-loam topsoil that supports emergent vegetation that is placed on 0.3 m (1 ft.) square grids. In this system all wastewater is exposed to the atmosphere. Five cells were designed to operate as subsurface-flow, where the wastewater is passed through a gravel media used to support plants. Wastewater in this system is not exposed to the open atmosphere. Three times daily a Rainbird (Glendora, CA) irrigation controller opens a Jandy valve in the 3.75 cm (1.25 in.) PVC drain line from the 7,600 L (2,000 gal.) storage tank for 10 minutes, allowing 30 L (8 gal.) of wastewater to flow into the end of each cell. This forces sedentary water in the cell to move along the 2.5 m (8 ft.) length of the cell where it drains into another two stage settling tank for possible reuse or discharge.

Initial plans called for comparison of free-surface flow vs. subsurface flow systems for the removal of nitrogen from nursery effluent and a comparison of effectiveness and winter hardiness of 5 different species of plant material. Plant material selected for this study included Louisiana Iris (*Iris* sp.), Dwarf Umbrella Palm (*Cyperus haspon* íViviparusí), Dwarf Spider Lily (*Hymenocallis liriosome*) Common Horsetail (*Equisetum hyemale*), and Yellow Flag Iris (*Iris pseudacorus*). Vegetation in a constructed wetland serves as a substrate for microbial growth, transmission of oxygen from leaves to the roots in the subsurface-flow system creates microsites favorable to microbial growth adjacent to the root zone (Reed and Brown, 1992). In the free-surface flow system, transported oxygen is consumed in the soil rooting media. Reaction of the exposed water surface is the major source of oxygen in this system.

Results and Discussion: The Texas A & M University Research Nursery Facility was successfully retrofitted with a recapture and reuse system for irrigation/ rainfall runoff. Problems with plant establishment occurred for both types of wetland cells. *Cyperus haspon, H. liriosome*, and *E. hyemale* all died back with the first frost. *Cyperus haspon* did not recover the following spring in either system. Both *H. liriosome* and *E. hyemale* recovered in the free-surface flow system but not the subsurface flow system where the plant crown was more exposed to cold. Preliminary results (data not shown) demonstrate that free-surface-flow cells were more successful at removing nitrogen from nursery runoff than subsurface-flow cells. This may be attributed to the complete establishment of the plants in the free-surface cells and their ability to transfer oxygen to the anaerobic zones of the wetlands, whereas the subsurface cells were less fully established. Work is underway to expand the number of wetland cells to 24 (12 free-surface-flow and 12 subsurface-flow) so replicated data for each species can be collected. Plans then include establishment of optimal flow rates through each cell for maximum nitrogen removal and assessment of loading capacity.

Significance to the Industry: Conservation of natural resources, such as water, will continue to be vital to the survival of the nursery industry. Natural wetlands, if managed properly, may provide an effective and inexpensive means to address the need to discharge only clean water back into the environment.

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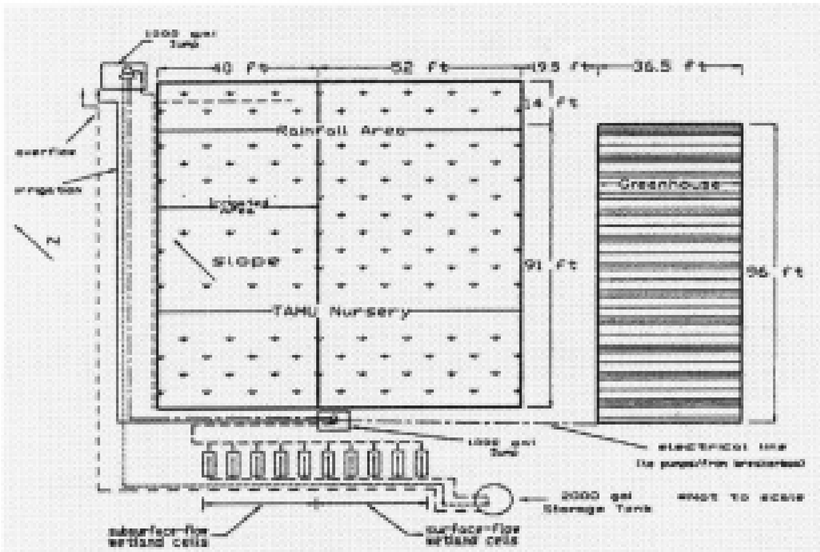

Figure 1. TAMU nursery layout

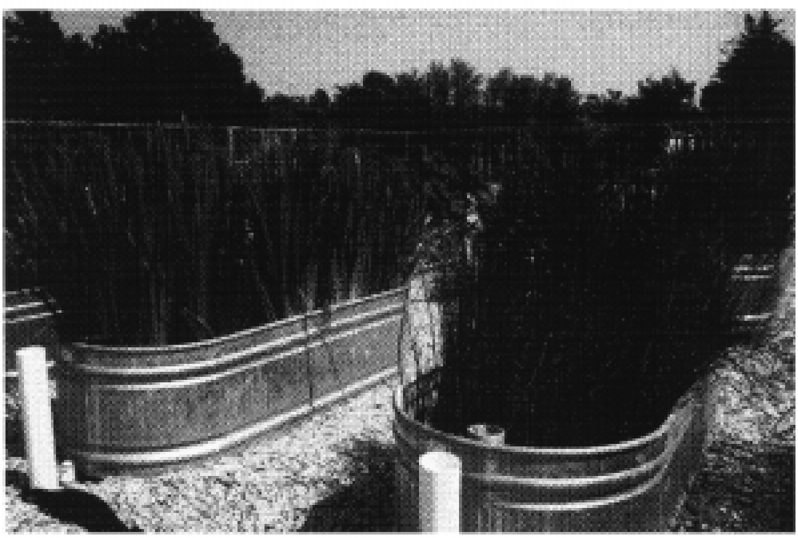

Figure 2. Cuntructed wetland cells, Iris pseudacorus in left forground, Equisetum hyemale in right forground

Effects of Texel Geodiscs on Evaporation From #1 and #7 Containers

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Nature of Work: While chemical weed control with herbicides is a standard industry practice for growers of container nursery stock, reducing herbicide, application, and hand weeding costs are of concern to all growers. Landscape fabrics have been used in the past as physical barriers to weed growth in containers (1). The Texel Geodisc (Texel USA Inc., Henderson, NC) is a needlepunched, nonwoven polypropylene fabric treated on one side with copper from Spin Out (Griffin Corporation, Valdosta, GA) which is designed to fit on the surface of the container medium to control the growth of weeds. Since the Geodisc is a porous physical barrier, it may also reduce water loss from containers by reducing evaporation from the surface of the media. Therefore, the purpose of this study was to look at the effects of Geodisc weed barriers on evaporative losses from #1 and #7 containers under south Georgia nursery conditions.

On 17 July 1996, containers (#1 - 6 5/8" x 6 1/2" and #7 - 13 1/12" x 11 1/2") were filled with the same volume of media (8:1 pinebark:sand (v/v)) and were placed on polypropylene ground cloth. Containers were blocked by container size with a 6" spacing between container walls. Each container size had five replicates with the following treatments: 1) control, and 2) surface of media covered with a Geodisc. Containers received approximately 1/2" irrigation on a daily basis from solid set sprinklers except when evaporation measurements were being taken. Water loss due to surface evaporation from the container medium was determined over a 24 hr period beginning at 9 AM EST on the following dates in 1996: 20-21 August, 22-23 August, 9-10 September, and 12-13 September. Climatological data for measurement dates is shown in Table 1. Data was analyzed using analysis of variance and the Waller-Duncan K-ratio T-test where appropriate.

Results and Discussion: As there were no interactions between treatment and date, only main effects are presented in Table 2. For the #1 containers the control lost 22% more water over a 24 hr period compared to containers with a Geodisc. A similar trend was seen for the #7 containers with the control losing 27% more water through evaporation compared to the Geodisc-covered containers. Water use of floricultural crops has been reduced 20% to 50% when evaporation barriers or pot covers were used (2).

Water loss from #1 containers averaged across treatments ranged from a low of 2.3 oz./day to a high of 4.1 oz./day (Table 2). For the #7 containers, water loss ranged from 16.1 oz./day to 18.8 oz./day. The range between high and low values for water loss across dates was greater for #1 containers (78%) in contrast to #7 containers (17%). Differences in water loss among dates were not readily evident based on available climatological data.

Significance to Industry: Texel Geodiscs were effective in reducing the amount of water lost through evaporation from the media surface in #1 and #7 containers. Use of Geodiscs reduced water loss from #1 containers by 22% and #7 containers by 27%. Geodiscs may be a useful tool for nurseries facing water restrictions or shortages. Further work is warranted looking at the effects of Geodiscs on weed control and plant growth in nursery containers, as well as the possibilities of using reduced irrigation volumes for crop production.

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Table 1. Climatological data.

24 hr. period	Air (°F) (max.)	Air (°F) (min.)	Net evaporation (in.)	Radiation (ly/ (day)	Wind (miles/ (day)
8/20-8/21	92	68	0.25	577	223
8/22-8/23	89	67	0.25	572	271
9/9-9/10	91	77	0.21	526	129
9/12-9/13	88	67	0.20	512	110

Table 2. Water loss from #1 and #7 containers with and without Tex-R Geodiscs.

	Water loss (oz.)	
	#1 container	#7 container
Treatment		
Control	3.9 a	19.3 a
Geodisc	3.2 b	15.2 b
Date		
8/20-8/21	3.8 a	16.1 b
8/22-8/23	2.3 b	16.5 b
9/9-9/10	3.9 a	17.7 ab
9/12-9/13	4.1 a	18.8 a

Means followed by different letters are significantly different (0.05).

Cyclic Irrigation and Pot-In-Pot Production Affect the Growth of 'Okame' Cherry

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Nature of Work: Pot-in-pot (PIP) production is increasing in popularity in the southeastern United States (3,7,8). This new production method is being adopted by in-field nurseries and growers of larger container-grown trees. Recent studies have shown that PIP production can be less costly than conventional above-ground or in-field production methods (3,6).

Cyclic or intermittent irrigation (daily water allocation applied in more than one application) has been shown to reduce water and nutrients leaching through containers compared with conventional overhead irrigation practices (1,2,5,9). Water consumption was shown to be 1/4 to 1/16 the level of overhead systems, depending on container size, for *Quercus virginiana* Mill. produced using cyclic micro-irrigation (4). To my knowledge, no research has been conducted on the effects of cyclic irrigation on plants grown pot-in-pot. Therefore, the objectives of this study were to compare the growth of plants grown PIP and CAG with and without cyclic irrigation.

The experiment was conducted outdoors under full sun at the University of Georgia Coastal Plain Experiment Station, Tifton. Uniform liners of *Prunus x incamp* 'Okame' were transplanted from 2.8 l (#1) containers to 26 l (#7) containers in April, 1995. Potting substrate consisted of milled pine bark and sand (8:1 by vol) amended with micronutrients at 0.6 kg/m^3 (1.0 lb/yd^3) and dolomitic limestone at 3.0 kg/m^3 (5.0 lb/yd^3). Plants were topdressed with 21N-1.3P-10K (21-3-12, Graco Fertilizer Company, Cairo, GA) at the rate of 150 g (5.3 oz) per container 30 April, 1995. Holder pots were placed in the ground with 2.5 cm (1 in) at the top of the pot remaining above grade.

The experiment was a randomized complete block with two container production systems (PIP and CAG), three cyclic irrigation treatments, and ten replications. Cyclic irrigation treatments included 3100 ml (105 oz) of water applied once per day (1x) at 8:00 AM, 1033 ml (35 oz) applied three times per day (3x) at 8:00, 12:00, and 4:00 PM, and 775 ml (26 oz) applied four times per day (4x) at 8:00, 11:00, 1:00, and 4:00 PM. Irrigation was applied using 160o low volume spray emitters (Roberts Irrigation, San Marcos, CA). Standard errors for irrigation application ranged from 12.1 ml (1x) to 2.7 ml (4x).

At 150 DAI, final plant height and stem diameter measurements were taken. Shoot dry weight and root dry weight were determined after drying in a forced-air oven for 72 hr at 65.5C (150F). Substrate was removed from the root system before drying. All containers were rotated monthly to eliminate any possible problems with rooting-out into the surrounding soil. Data analysis for all parameters were evaluated by analysis of variance.

Results and Discussion: Plants grown PIP were 9% taller than plants produced CAG. Stem diameter of PIP plants was 10% greater than CAG plants. For PIP plants, shoot dry weight and root dry weight were 27% and 44% greater, respectively, than plants grown CAG. The increase in shoot and root dry weight resulted in a 35% increase in total biomass. The root:shoot ratio increased 12% when plants were grown PIP.

For growth parameters there were no differences between the 3x and 4x cyclic irrigation treatments. Increases in height and stem diameter for the two cyclic irrigation treatments were approximately 10% when compared to the 1x irrigation event. Cyclic irrigation treatments increased shoot dry weight by 40% compared to a single irrigation event (1x). Root dry weight was increased by 10% for cyclic irrigation treatments whereas the root:shoot ratio decreased by 25%.

Significance to Industry: Results of this study indicate that PIP production and cyclic irrigation can increase the growth of 'Okame' cherry. Pot-in-pot production increased plant height and stem diameter by approximately 10% over a five month growing period. The results were similar when cyclic irrigation was used. Increases in shoot and root dry weight were also evident when the plants were grown PIP or using a cyclic irrigation regime. Future studies will focus on irrigation use and irrigation application efficiencies for PIP and cyclic irrigation systems.

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Use of Fuzzy Logic Irrigation Control System for Geranium Production

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Nature of Work: Container production of landscape plants requires intensive management with a vital dependency on irrigation. As much as 80% of overhead irrigation water falls between or moves through the containers and drains from the container production area (3). Leachates from containers and soluble chemicals on the ground between containers can contain unacceptable concentrations of nitrates and other pesticides (4). Nurseries are evaluating Best Management Practices (BMP's) to prevent movement of these contaminants. A BMP to address this issue is an efficient irrigation control system.

Irrigation control systems for greenhouses and container nurseries should apply water to plants as needed and only replace water that is used by the plants or evaporated from the container substrate. Leaching should be kept to a minimum to increase profitability, productivity and reduce environmental impact from contaminants.

The difficulty for application of traditional feedback control in irrigation systems lies in the nonlinear response and the time delay of the soil moisture sensor (so called soil sensor continuum). Whereas "Fuzzy logic aims at modeling the imprecise modes of reasoning that plays an essential role in the remarkable human ability to make rational decisions in an environment of uncertainty and imprecision" [6]. Therefore, fuzzy logic has been exploited since 1994 to try to develop a more efficient irrigation control system to try to meet this challenge.

The proposed fuzzy irrigation control system consists of the following components: computer, sensors, solenoid valves, transducing circuits and A/D (analog to digital), D/O (digital output) interfacing board, etc. The computer implements the fuzzy control rules and other control algorithms. Soil moisture sensor (Granular Matrix Sensor by Irrometer Inc.)[1,2] changes electrical resistance according to soil water content, which is then converted into voltage by a transducing circuit. A pair of electrodes are combined with another transducing circuit to detect leachate. A temperature sensor is used to calibrate readings from soil moisture sensors. Analog signals from transducing circuits are provided to the computer by an A/D interfacing board. D/O interfacing board is used to send control voltage to solenoid valves, which turn on or off the water supply to the plants. The hardware configuration of the system is shown in Fig. 1.

Fuzzy logic is applied to control irrigation in a manner resembling a human operator. In brief, soil moisture readings are taken at scheduled intervals. The system decides if it should activate irrigation for certain channels now or if it can hold until the next scheduled reading using fuzzy rules. Whenever irrigation is activated, the length of the irrigation event is controlled by fuzzy rules so that the amount of water applied saturates the soil moisture sensor. This is done in small increments to prevent channeling and leaching of water. The final application of water brings the medium to container capacity. A leachate detecting circuit is used to modify the length of the last irrigation segment. A more detailed description of the system operation can be found in [5]. The leachate detecting circuit is a major modification added to this prototype system. The system can now be fully automated without needing human inputs.

A small scale greenhouse experiment was conducted from March 21 to May 28 to test the effectiveness of the control system. Sixty, four inch seedling geraniums, *Pelargonium X hortorum*, were transplanted to six inch containers using identical media and fertility amendments. Two irrigation treatments, automated fuzzy logic control and manual irrigation, were applied to plants arranged in three blocks with 10 plant replicates for each block and treatment. Water was applied to each container through a pressure compensating emitters with low-pressure shutoff valve (Acuff Irrigation, Gainesville, FL) at a rate of 10 oz/min (300 ml/min). The greenhouse manager manually activated 3 solenoid valves to irrigate the manual treatment on an “as needed” basis and recorded the irrigation events. A fixed schedule of about 5 minutes every other day was used. Three of the 6 solenoid valves in the setup were used in the automated fuzzy irrigation control system to manage and incrementally apply water to the containers in the 3 automated rows. Each of these rows was monitored and controlled by a separate soil moisture sensor embedded in a container and leachate detecting electrodes placed in a pan beneath the container. Small holes in the bottom of the leachate pan allowed leachate to stay briefly for detection purposes but to eventually drain. Three collection pans were put under randomly selected containers in each automated and manual treatment row to collect leachate volumes. Leachate volume from three pans from each treatment were averaged. Five plants from within each irrigation block were randomly selected and a growth index calculated for each irrigation treatment by taking the mean of two perpendicular widths plus the shoot height of each plant divided by 2. Three media samples were taken from each irrigation treatment and analyzed for soluble salts.

Results and Discussion: There was no difference in the growth index of plants in the fuzzy logic irrigation control system (10.7) and manual irrigation (9.7). The automated system applied a total average of 5.9 oz (173 ml) of water at each irrigation event with 4.4 oz (131 ml) leachate

(76%). The manual system applied an average of 42.4 oz (1254) ml to each container every other day with 32.7 oz (968 ml) leachate (77%). The test revealed the need to increase the sensitivity of the leachate electrodes. The mean soluble salts level of three samples from the automated and the manual irrigation treatments were 441 ppm and 237 ppm, respectively.

Significance to Industry: This fuzzy irrigation control system can automatically control water supply to plants and produce plants of equal size with potentially less water than manual irrigation. The leachate sensor needs increased sensitivity to decrease the percent leachate. The decreased water applied to the containers in the automated system tended to reduce soluble salts and the potential for increased efficiency of the fertilizers and reduced concentration of nutrients in the runoff.

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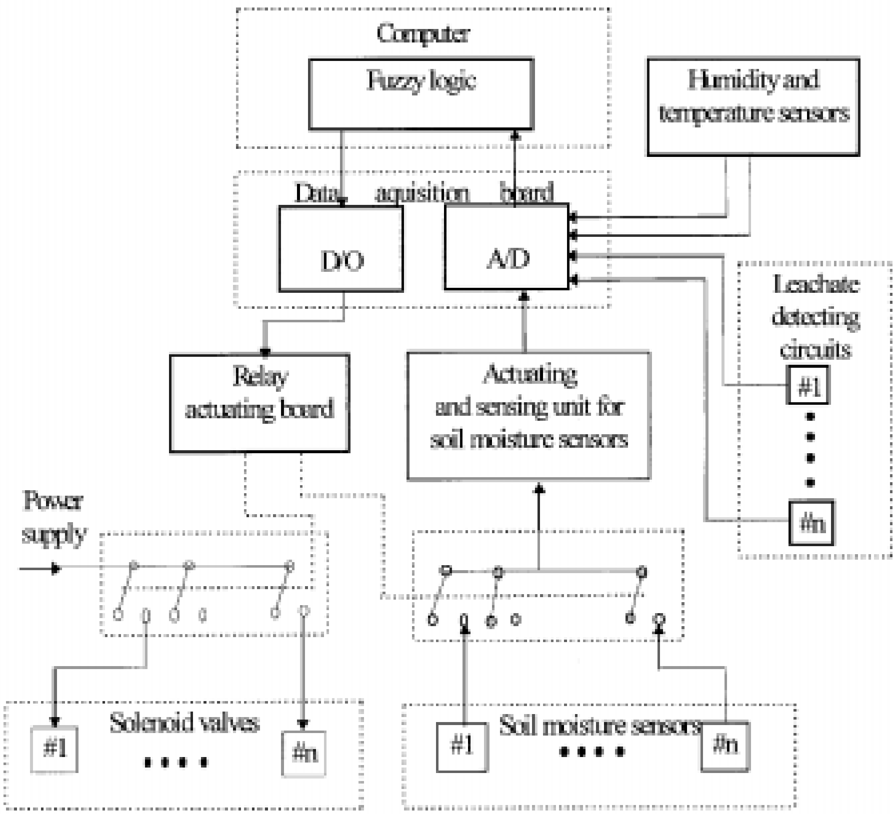

Figure 1. Configuration of fuzzy irrigation control system