Water Management

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Section Editor and Moderator

Nitrate Concentrations in Nursery Drainage Water During Transition from a Full Fertigation Program to a Slow-Release Fertilizer Program: A Real Nursery Experience

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Index Words: Nitrogen, Nitrate, Fertilizer, Water Quality

Significance to Industry: Nutrient enrichment of public surface water bodies throughout the United States has resulted in the US EPA and state governments development- and enforcement of Total Maximum Daily Loads (TMDLs) for nutrient-impaired water bodies. Previous work has indicated that significant amounts of nutrients can be leached from pots and production areas during normal irrigation and fertigation operations (1). Nitrate concentrations in nursery runoff or drainage water reported by others has ranged from 1.6 ppm to 304 ppm (2,3). With increased pressures from state and federal regulatory agencies, nursery managers will need to reduce nutrient export from production areas to natural water bodies. Results from the study reported here document the reduction in nitrate concentrations within production area drainage water at a foliage plant nursery during their transition from 100% reliance on fertigation to a slow-release fertilizer-based fertility program.

Nature of Work: For the results reported, water samples were collected over a 191 day period bracketing the transition period for the fertilization changes. Water samples were collected from a drainage sump that receives runoff water from two production areas. The production area ground surfaces were covered with woven landscape fabric underlain by polypropylene plastic, creating a water-impermeable surface. The production areas were sloped so that all drainage and runoff water was directed to concrete roadways, which themselves sloped to the drainage sump system. One of the production areas was 4 acres in size, with *Raphis spp*. occupying approximately 95% of the area and various other species occupying the remaining space. The second production area was 3.5 acres, occupied with approximately 80% *Ficus spp*., 10% *Dracena spp*., and 10% *Zamia spp*. Both production areas were covered with an automated shade cloth system.

Initially, all plant fertility requirements were met using fertigation. During fertigation periods, plants received a 7-3-7 (N-P-K) urea based formulation, or a 6-3-9 or 7-2-7 nitrate-based fertigation formulation. Plants were irrigated and fertigated according to plant needs and standard production protocols at the nursery. At approximate day 112 of this study, the fertilization for the entire area was changed to a 20-4-12 slow-release

formulation. Irrigation management remained the same according to plant needs and standard practice.
Nursery drainage water was pumped from the sump using a Beckett W1150 large waterfall and stream pump suspended in a floating, net-covered PVC cage that provided pre-filtering of large plant and organic materials. Water was pumped continuously (152 gal/hr) from the sump as part of another research project. Composite samples were collected using two ice-cooled American Sigma autosamplers at 15 minute intervals during each 16-24 hour sampling period. Samples were immediately placed on ice after collection and transported to the laboratory where they were analyzed for nitrate using an ion chromatograph and U.S. EPA Method 300.0 (4).

Results and Discussion: A summary of the nitrate concentrations during this monitored period is shown in Figure 1. During the fertigated period, nitrate concentrations ranged from 2.4 to 1425 mg/L nitrate. The mean and median concentrations were 194 and 145 mg/L, respectively. Following the change to the slow-release fertilizer formulation, the minimum, maximum, mean and median concentrations were 0, 654, 19.7, and 4.1 mg/L, respectively. Using the EPA drinking water standard (44.3 mg/L nitrate or 10 mg/L nitrate-nitrogen) (5) as a reference point, 84% of the samples collected during the fertigated period had nitrate concentrations greater than 44 mg/L. In contrast, only 4% of the samples collected following the transition to the slow-release formulation exceeded 44 mg/L.

These results illustrate the effectiveness of using slow-release fertilizer formulations for reducing nitrate export from production areas relative to fertigation. Phosphorus was not monitored during this study, but similar results should be expected. Nursery production managers located in nitrogen-limited watersheds with state or federal mandated nitrogen regulations should consider the use of slow-release fertilizer formulations for reducing nitrogen enrichment of drainage water, especially if they discharge into off-site water systems. In addition to reducing nitrate discharges from the production area, fertilizer costs were also reduced significantly.

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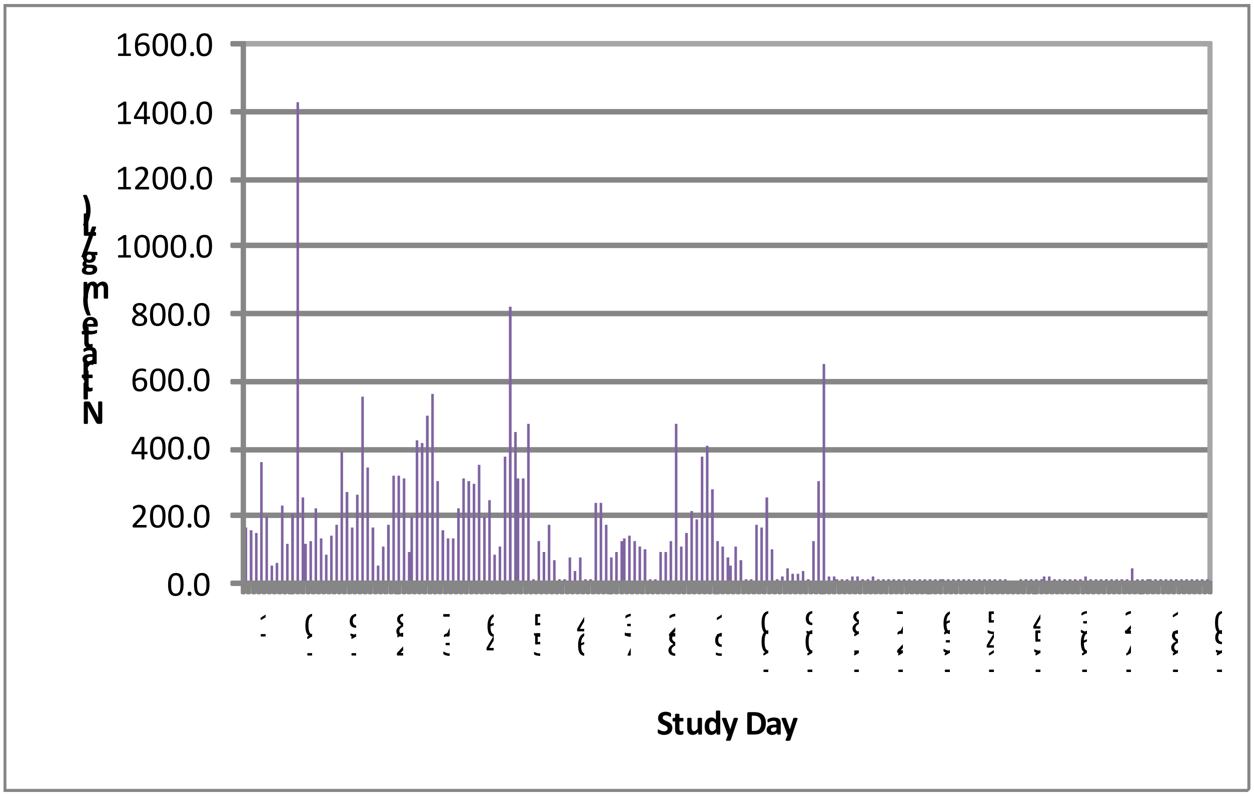

Figure 1. Nitrate concentrations (mg/L) in drainage water from a 7.5 acre foliage plant production area. On days 1- 112 (approximately) the production areas were fertigated using 7-3-7, 6-3-9, or 7-2-7 (N-P-K) formulations. A slow release-fertilizer formulation (20-4-12) was used during days 113-190.

Does oxygen status influence floating wetland nutrient uptake?

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Index Words: Nitrogen, Phosphorus, Water quality, *Juncus effusus*, Soft rush, Aeration, Constructed wetland

Significance to Industry: The green industry is "cleaning up" its reputation as a waste contributor by educating the public as to the benefits of plants such as air and water purification, noise filters, and carbon sinks, while continuing to implement more innovative and reliable water treatment technologies. In the present environment of progressively increasing public and governmental scrutiny focused on water availability and cleanliness, it is critical that the nursery industry implement treatment technologies to support good environmental stewardship practices whether the runoff water is recycled for on-site reuse or exported off-site. This research shows that aeration enhanced soft rush root growth serving to provide more surface area for microbial habitat. However, aeration did not enhance nitrogen or phosphorus uptake by soft rush. It appears that an oxygenated water column enhances plant growth but does not improve nutrient removal by soft rush. Mixed plantings should be used when establishing floating wetlands to enhance nutrient remediation.

Nature of Work: Constructed wetlands, both surface and subsurface flow, are often used to cleanse nutrient enriched wastewater. Nurseries are often prevented from fully utilizing this technology by the need to maximize production area (wetlands often require a large treatment area) and the high costs associated with constructed wetland startup. Floating wetlands are an emerging treatment technology that can be easily positioned in existing infrastructure to provide similar treatment capacity to constructed wetlands, but without the high costs associated with construction and implementation. Floating wetlands place large root surface areas in contact with the water column. This surface area is critical because it provides habitat for nutrient metabolizing microbes, aids in direct filtration of particulate matter from the water, and enhances nutrient uptake by plant species. Floating wetlands are easy to install and harvest, expanding their utility from simple treatment systems to potential aquatic gardens for landscapes.

Previous research by White et al. (1) suggested that aeration enhanced nutrient uptake and remediation by plants established in floating wetlands. This study was designed to examine one common aquatic species, *Juncus effusus* (soft rush), to determine how aeration, planting density, and percent of surface area covered by a floating wetland influence nutrient remediation and uptake by this plant.

The experimental setup for the floating wetland mesocosms utilized twenty-four 380-liter (100 gal.) Rubbermaid® tanks. Simulated nursery runoff was supplied using a 20-2-20 commercial-grade soluble fertilizer (Southern Agricultural Insecticides, Inc., Hendersonville, NC) with 30 mg/L (ppm) N and 3.0 mg/L (ppm) P supplied to each tank with a 2-day hydraulic retention time. Twelve of the twenty-four tanks were continuously aerated and twelve had no supplemental aeration. Treatments consisted of 50% and 100% surface coverage with plant densities of either 10 plants (50% or 100% coverage) or 20 plants (100% coverage). Water quality parameters monitored included NO_3^-, $NO_2^=$, PO_4, SO_4, and pH. Anion concentrations were determined using a Dionex AS50 ion chromatograph (Dionex Corp., Sunnyvale, CA). Floating wetlands were planted 21 Apr. 2009 and sampled for the first time 27 Apr. 2009, continuing on a weekly basis until 15 Sept. 2009. Soft rush roots and shoots were measured on a bi-weekly basis so that remediation potential could be examined in the context of growth. Data was analyzed using SAS PROC GLM procedure (SAS Institute Inc. Cary, NC).

Results and Discussion: Aeration did not begin to consistently influence dissolved oxygen levels in the water column until late May 2009 (Figure 1); until then, algae blooms may have increased dissolved oxygen concentrations in the water column. Thereafter, dissolved oxygen concentrations in the non-aerated treatment began to reflect more typical water column concentrations. Nitrogen removal as influenced by aeration was poor to non-existent (Figure 2). With aerated treatments, we actually saw consistently greater nitrogen concentrations exported than in the influent, though there were no statistically significant differences between influent concentration and treatment concentration (Figure 2, Aerated). This might be attributable to nitrification processes aided by oxygenated conditions in the water column. Nitrogen removal by the non-aerated treatment was very low (Figure 2, Non-aerated).

Phosphorus removal aided by soft rush established in the floating mats was similar among aerated and non-aerated treatments (Figure 3) with the low density and 50 percent coverage treatment removing slightly less phosphorus than the other treatments. This may be a factor of growth limitation rather than surface area covered since low density plantings with 100 percent surface area coverage removed similar amounts of nutrients to treatments with 100 percent surface area coverage and high density plantings (Figure 3). Because the main phosphorus sink is the soil and clay matrices therein, the limited removal of phosphorus at these higher loading concentrations, in comparison with White et al. (1) was somewhat expected, though these mats may have more utility for polishing wastewater with lower nutrient concentrations.

Plant growth was influenced by aeration or the lack thereof (Figure 4). Soft rush established in the aerated treatments had significantly greater root growth, regardless of other treatment factors, than those plants established in non-aerated treatments. This root growth stimulation may influence nutrient fixation in soft rush, by providing a greater mass for nutrient fixation (1-2). However, it does not appear that a monoculture of soft rush should be used to establish these floating wetlands; instead a mixed culture system approach may prove more efficient and result in greater removal efficiencies (3-4).

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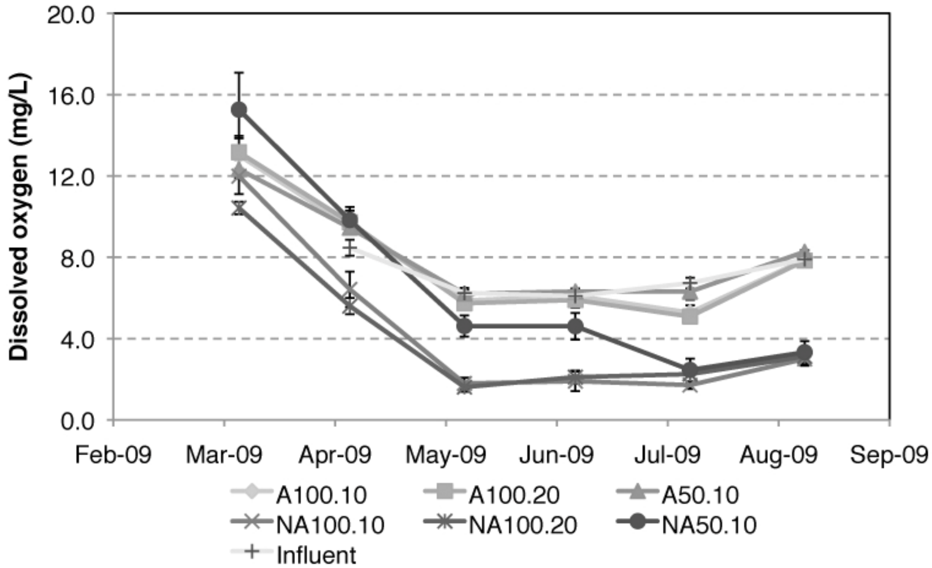

Figure 1. Dissolved oxygen (mg/L) concentration over time in aerated[a] and non-aerated floating wetland treatment systems as impacted by percent surface area covered[b] and planting density[c].

[a]Aerated =A and non-aerated=NA
[b]Percent treatment surface area covered = 50 or 100
[c]Planting density = 10 or 20

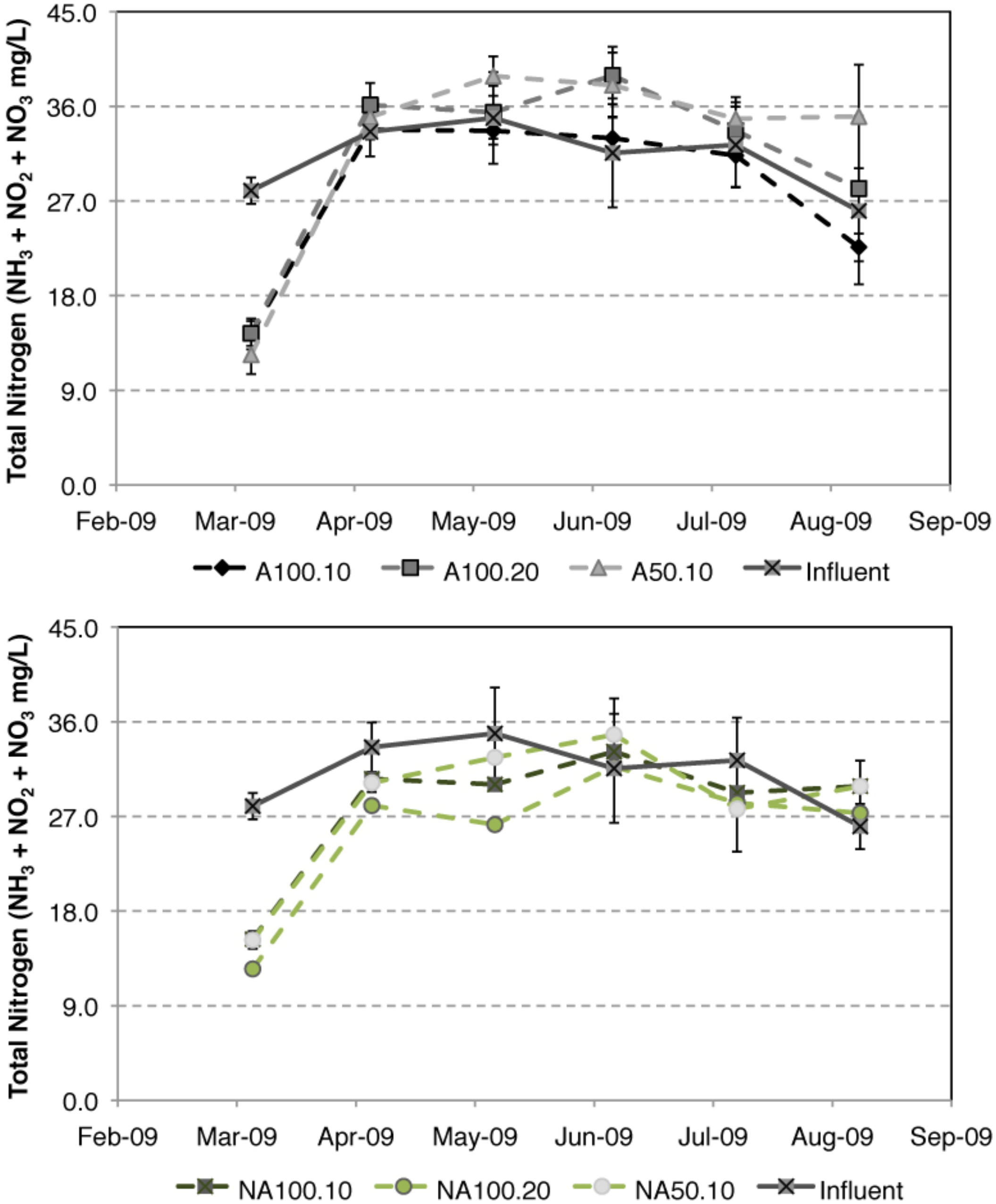

Figure 2. Total nitrogen (mg/L) concentration over time in aerated[a] and non-aerated floating wetland treatment systems as impacted by percent surface area covered[b] and planting density[c].

[a]Aerated =A and non-aerated=NA.
[b]Percent treatment surface area covered = 50 or 100.
[c]Planting density = 10 or 20.

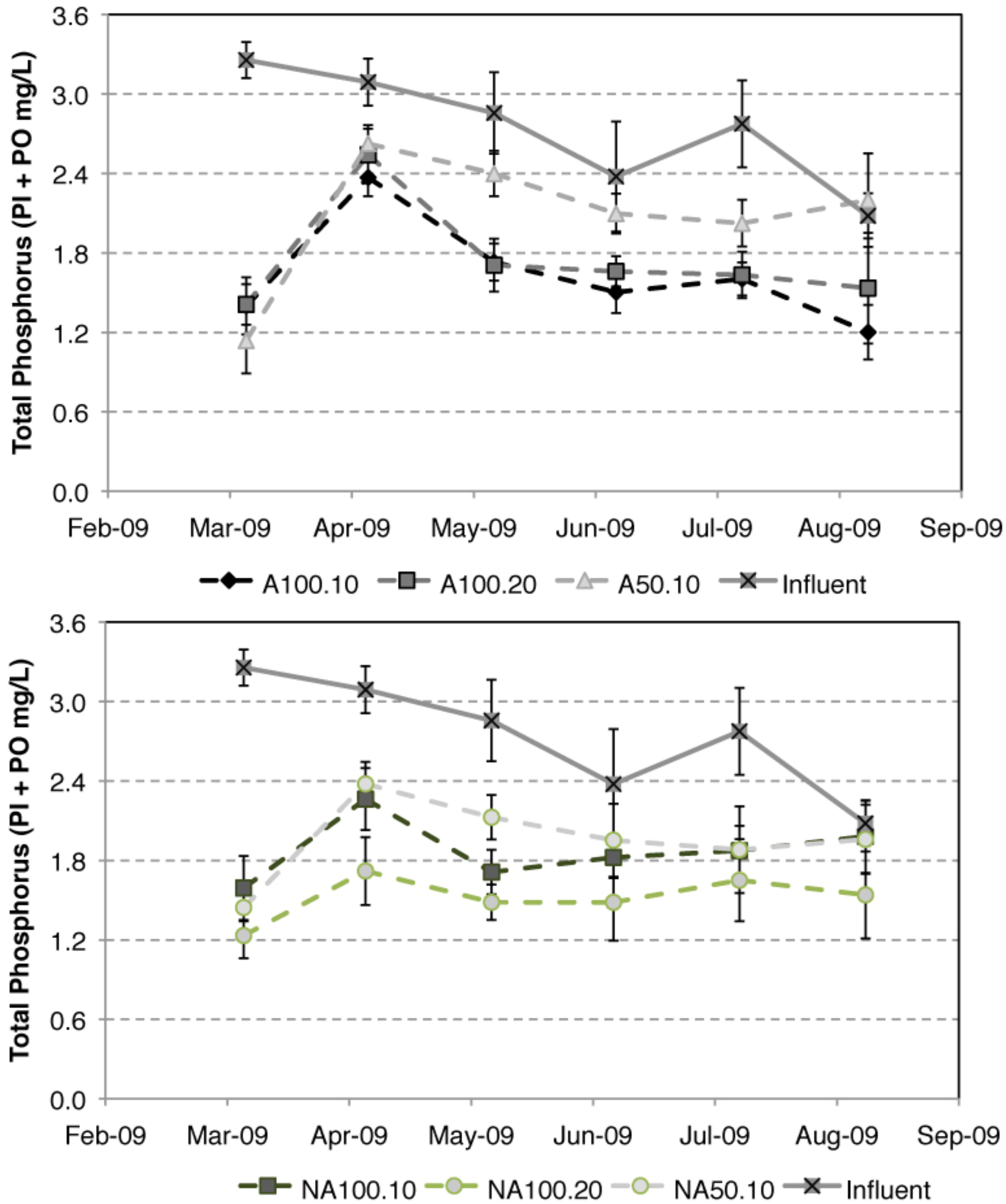

Figure 3. Total phosphorus (mg/L) concentration over time in aerated[a] and non-aerated floating wetland treatment systems as impacted by percent surface area covered[b] and planting density[c].

[a]Aerated =A and non-aerated=NA
[b]Percent treatment surface area covered = 50 or 100
[c]Planting density = 10 or 20

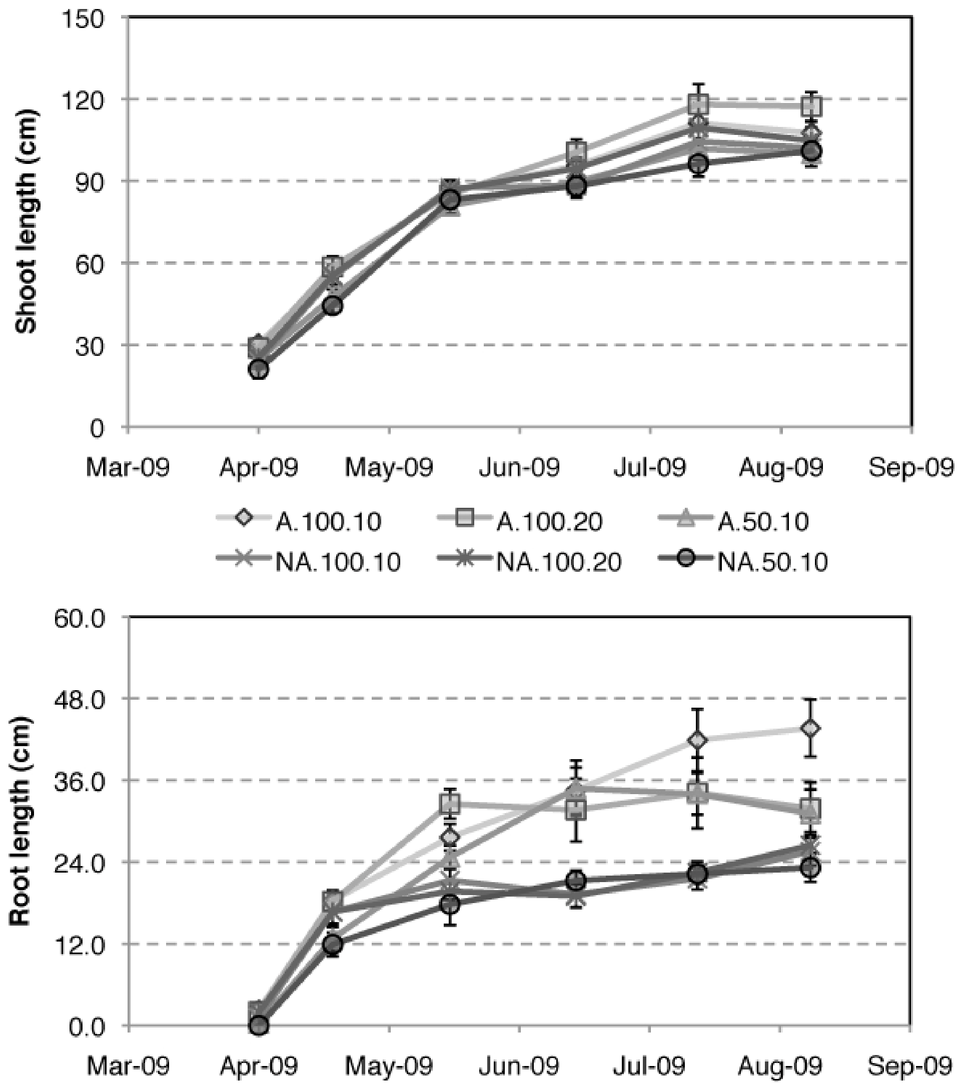

Figure 4. Shoot and root growth of *Juncus effusus* over time in aerated[a] and non-aerated floating wetland treatment systems as impacted by percent surface area covered[b] and planting density[c].

[a]Aerated =A and non-aerated=NA
[b]Percent treatment surface area covered = 50 or 100
[c]Planting density = 10 or 20

Response of *Zinnia marylandica* Cultivars to Salinity

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Index Words: bedding plants, Maryland zinnia, reclaimed water, water reuse

Significance to Industry: Zinnias, whose Mexican heritage is reflected in their bright colors, prolific bloom and ability to handle hot, dry summer conditions are one of the most widely cultivated species and is prized among garden ornamentals in the United States (1). As salt-affected land spreads rapidly all over the world, the demand for salt tolerant ornamentals increases. With the rapidly increasing population and industrial development, the availability of fresh water is limited. Alternatively, reclaimed water plays an important role in irrigating landscapes (2,3). Therefore, selecting plant varieties with greater tolerance to salt stress is of increasing importance. This study investigated the response of six zinnia cultivars to elevated salinity. The results, based on growth and survival rate, indicated that the selected Zinnia cultivars are moderately sensitive to salt stress.

Nature of Work: Seeds of the Zinnia (*Zinnia marylandica*) cultivars, 'Zahara Yellow', 'Zahara White', 'Zahara Scarlet', 'Zahara Rose Starlight', 'Zahara Fire', and 'Zahara Coral Rose' were sown on 13 Aug. 2009 into 72-cell trays filled with a Sunshine Mix No. 5 (SunGro Hort., Bellevue, WA) and placed under a misting bench. Seedlings were transplanted on 31 Aug. to 4-inch plastic pots filled with Sunshine Mix No. 4 (SunGro Hort.). Plants were grown in the greenhouse and sub-irrigated with nutrient solution until treatments were initiated on 8 Sept. During the experimental period, the average air temperature in the greenhouse was maintained at 28.9 ± 2.5 °C (mean ± standard deviation) during the day and 23.0 ± 0.6 °C at night. The average daily light integral (photosynthetically active radiation) was 16.7 ± 3.9 $mol·m^{-2}·d^{-1}$.

Saline solutions were prepared by adding appropriate amounts of sodium chloride (NaCl), magnesium sulfate ($MgSO_4·7H_2O$), and calcium chloride ($CaCl_2$) at 87%, 8%, and 5%, respectively, on a weight basis to a nutrient solution which was made by adding 0.5 $g·L^{-1}$ of 20N-8.6P-16.7K (Peters 20-20-20; Scotts) to tap water (3). Five salinity levels of 1.4 $dS·m^{-1}$ (nutrient solution, control), 2.5, 4.0, 6.0, and 8.0 $dS·m^{-1}$ electrical conductivity (EC) were created. The main ions in the tap water were Na^+,

Ca^{2+}, Mg^{2+}, Cl^{-}, and $SO_4{}^{2-}$ at 184, 52.0, 7.5, 223.6, and 105.6 mg·L^{-1}, respectively. The composition of saline solutions was similar to that of the reclaimed municipal effluent of the local water utilities. The EC for each treatment was confirmed before irrigation every time. Treatments were initiated on 8 Sept. and ended on 4 Oct. Plants were sub-irrigated as needed. Irrigation intervals varied with treatments and weather conditions.

Upon termination of the experiment, plant height and time to flower were recorded. Shoot DW was determined after oven-drying at 70 °C. The experiment used a split-plot design with irrigation water as the main plot and species as the subplots with 6 replications. Since there was an interaction between treatment and cultivar, data were analyzed separately by cultivar. Treatments at EC of 6.0 dS·m^{-1} and 8.0 dS·m^{-1} were excluded in the analysis because no plants survived. A two-way ANOVA using PROC GLM was performed. To distinguish the differences among the treatments, Student-Newman-Keuls multiple comparison was performed. All data were analyzed using SAS software (Version 9.1.3, SAS Institute Inc., Cary, NC).

Results and Discussion: Salinity treatment and cultivars had interactive effects on plant height, shoot DW and time to flower, indicating that zinnia responses to salinity differed among cultivars. No plants survived, regardless of cultivar, at EC of 6.0 and 8.0 dS·m^{-1}. Mortality started to occur around 20 days after initiation of the treatment for all cultivars.

Plant height for all cultivars decreased as the EC of irrigation water increased, except for ‘Zahara Yellow’ whose height was similar among the treatments (Fig. 1). Compared to the control, plant height of ‘Zahara White’, ‘Zahara Scarlet’, ‘Zahara Rose Starlight’, ‘Zahara Fire’, and ‘Zahara Coral Rose’ at 4.0 dS·m^{-1} was reduced by 20.6%, 22.7%, 28.6%, 27.6% and 37.5%, respectively. Shoot dry weight (DW) of all cultivars decreased as EC increased (Fig. 2). At EC of 4.0 dS·m^{-1}, shoot DWs of ‘Zahara Yellow’, ‘Zahara White’, ‘Zahara Scarlet’, ‘Zahara Rose Starlight’, ‘Zahara Fire’, and ‘Zahara Coral Rose’ were reduced by 52.2%, 49.3%, 53.6%, 50.9%, 55.4% and 57.3%, respectively, compared to control. There was no difference in shoot DW of ‘Zahara White’ between control and 2.5 dS·m^{-1}.

No differences were observed in time-to-flower for ‘Zahara Yellow’, ‘Zahara Scarlet’, and ‘Zahara Rose Starlight’ (Fig. 3). For ‘Zahara Fire’ and ‘Zahara Coral Rose’, flowering at 4.0 dS·m^{-1} was delayed for 3 and 2 days, respectively, compared to control. However, the response of time to flower in ‘White’ was different. Nevertheless, the difference in time to flower was small and may be insignificant commercially. Elevated salinity reduced flower size in all cultivars but did not affect the number of flowers per plant (data not presented).

A number of bedding plants were found to be moderately tolerant to salinity (4). However, this study indicated that the selected six zinnia cultivars were moderately sensitive to salinity based on their growth response and mortality at EC of 6.0 and 8.0 dS·m^{-1}. Therefore, these zinnia cultivars should not be used for landscapes with poor-quality irrigation water or on soil with high salinity. Further study is underway to confirm the results and to determine the salinity threshold of zinnia by irrigating plants from the substrate surface instead of sub-irrigation.

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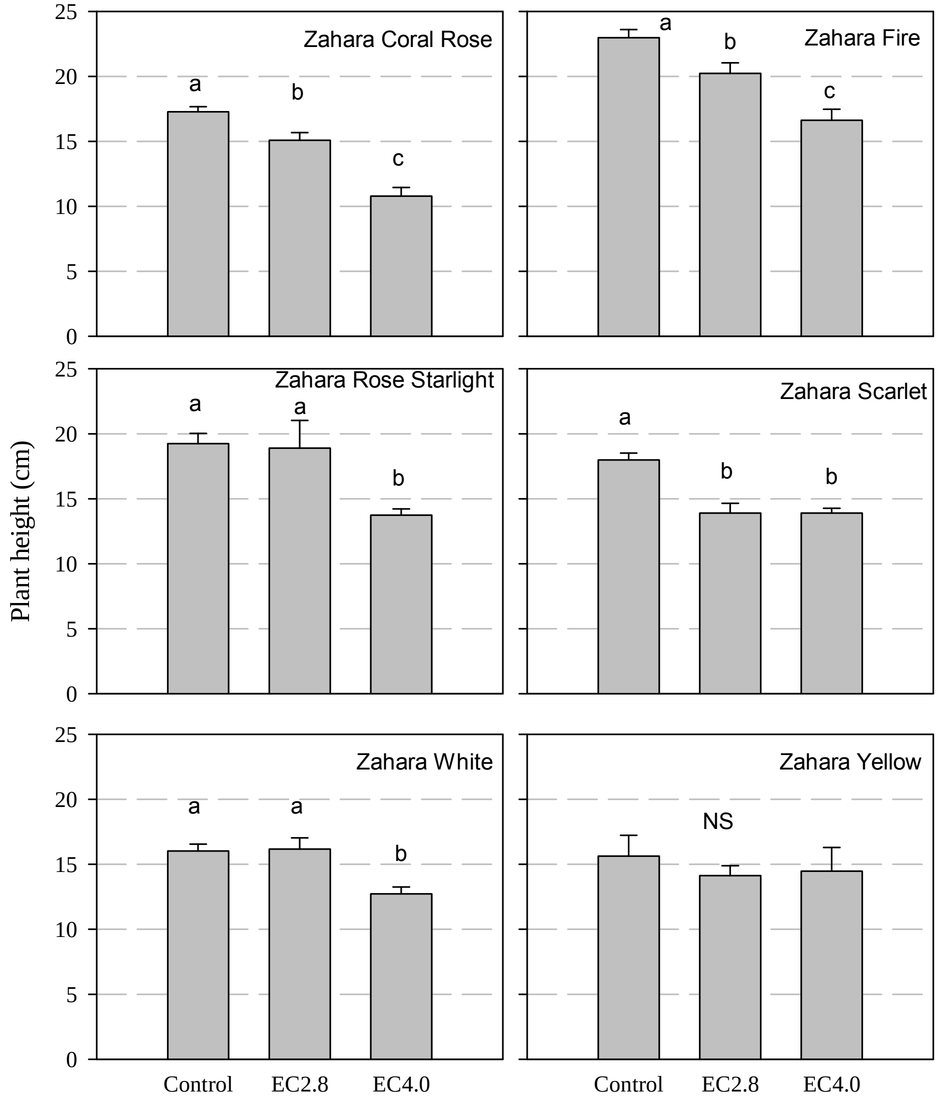

Figure 1. Effect of salinity treatment on height of the six selected *Zinnia marylandica* cultivars. Means followed by the same letters are not significantly different as indicated by Student-Newman-Keuls multiple comparison at *P* = 0.05. Vertical bars represent standard errors.

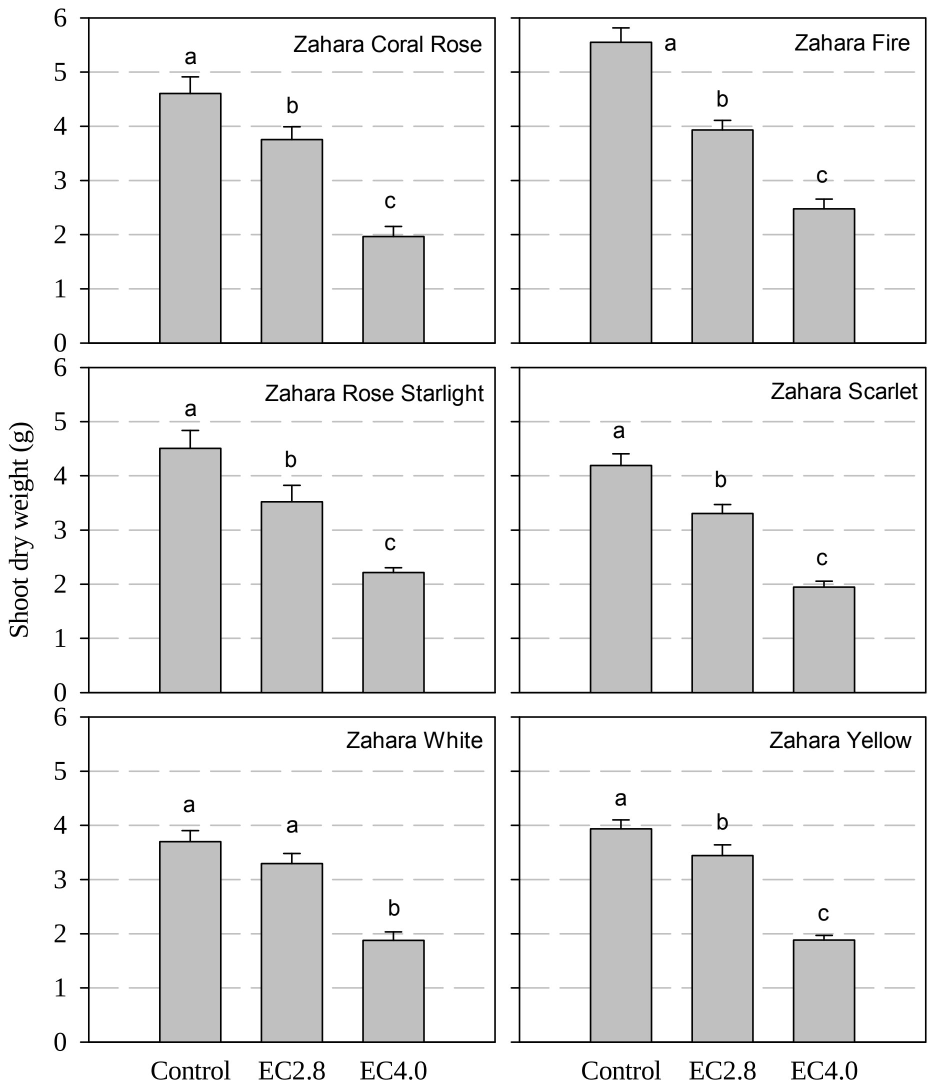

Figure 2. Effect of salinity treatments on shoot dry weight of the six selected *Zinnia marylandica* cultivars. Means followed by the same letters are not significantly different as indicated by Student-Newman-Keuls multiple comparison at *P* = 0.05. Vertical bars represent standard errors.

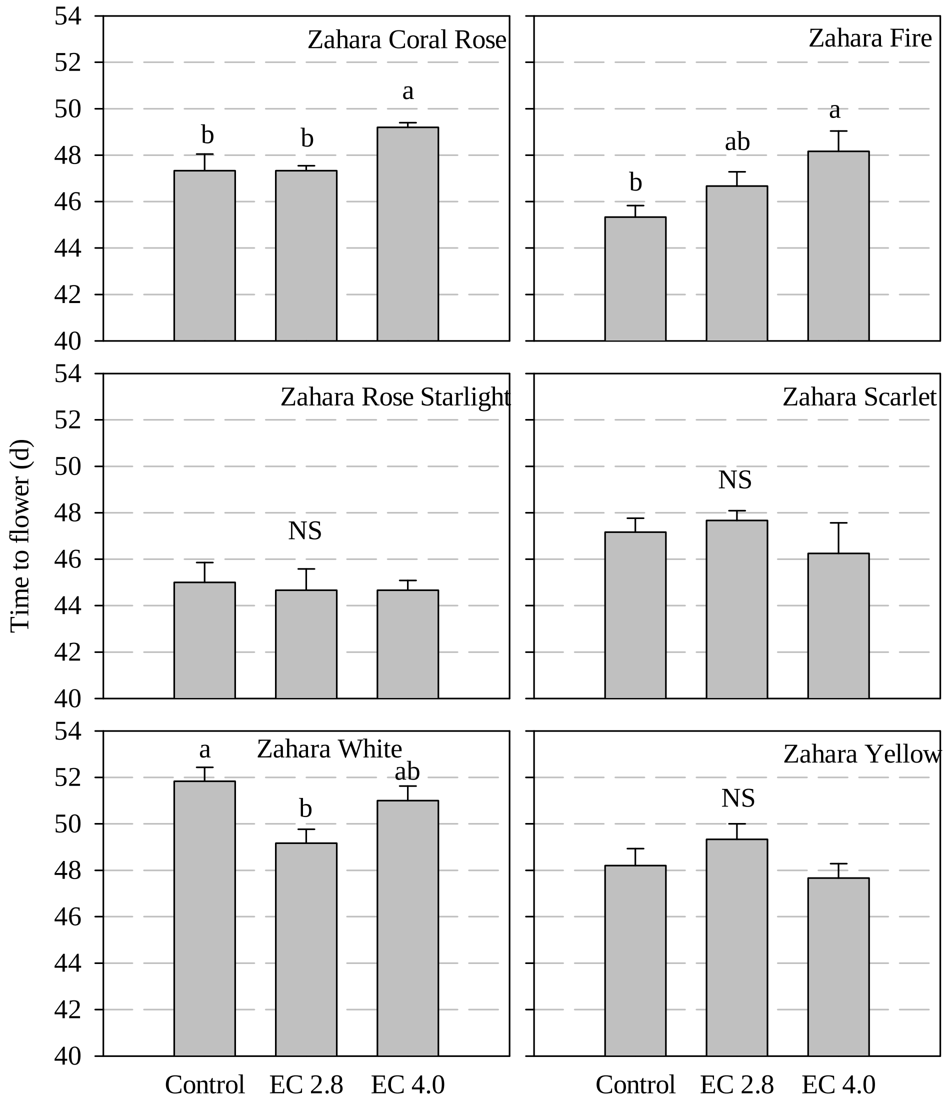

Figure 3. Effect of salinity treatments on days-to-flower of the six selected *Zinnia marylandica* cultivars. Means followed by the same letters are not significantly different as indicated by Student-Newman-Keuls multiple comparison at *P* = 0.05. Vertical bars represent standard errors.

Growth Response of Selected Bedding Plants to Three Irrigation Levels

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Index Words: drought tolerance, landscape irrigation, water conservation

Significance to Industry: Bedding plants are used extensively in landscapes in the United States. Rapid population growth has increased the demand for fresh water supply in many areas. Urban landscape water conservation is a critical issue. Identifying low water use bedding plants is of increasing importance. The results from this and previous studies indicated that the selected bedding plants are drought tolerant and may be irrigated at 50% potential evapotranspiration (ET_0) without losing aesthetic characteristics.

Nature of Work: In addition to climate and soil conditions, landscape plant performance is dependent on irrigation management. Substantial variations exist in the literature for minimum water requirements and performance of landscape plants. For example, Henson et al. (1) reported that the minimum amount of irrigation for acceptable landscape performance ranged from 0% to 100% ET_0 among 17 herbaceous ornamental plants grown in three locations in Colorado with five irrigation levels. However, similar work by Cox and Klett (2) in Colorado with 45 indigenous western plants (mostly herbaceous perennials) exhibited no significant differences between irrigated and non-irrigated treatments, possibly due to different climate conditions. The objective of this study was to quantify the growth response of selected bedding plants to three irrigation levels in a semi-arid environment.

The following nine species and cultivars were selected for this study: *Capsicum annuum* ‘Black Pearl’, ‘Calico’, and ‘Purple Flash’, *Catharanthus roseus* ‘Titan’ and ‘Pacifica’, *Helenium amarum* ‘Dakota Gold’, *Helichrysum petiolatum* ‘Silver Mist’, *Plumbago auriculata* ‘Escapade Blue’, and *Zinnia maritima* ‘Solcito’. Seeds of each bedding plant species and cultivar were sown on 4 March 2008 in 72-cell trays filled with a germination mix (Sunshine Mix No. 5, SunGro Hort., Bellevue, WA). Seedlings were grown in 500-mL pots filled with similar potting mix, except with more and coarser perlite (Sunshine Mix No. 4, SunGro Hort.) in the greenhouse. On 23 May 2008, seedlings were transplanted to raised beds in the field with dimensions of 1.5 x 6 x 0.2 m and filled with blue point loamy sandy soil. Three irrigation treatments were created by irrigating the beds for different amounts of time. The three irrigation levels were 20 to 50%, 50-85%, or 100 to 150% ET_0. The corresponding volumetric soil moisture contents ranged from 5 to 10%, 7 to 13%, or 10 to 18% (Fig. 1). Irrigation treatments were initiated from the middle of June (three weeks after transplanting) to the end of August.

Plant height and two perpendicular canopy widths were measured monthly to calculate the growth index: Growth index = ((height + (canopy width1 + canopy width 2)/2)/2. Upon termination of the experiment, shoot dry weight (DW) was determined after oven-drying at 70 °C to constant weight. Data were analyzed separately by species. The experiment used a completely randomized design with three replications and two or three subsamples depending on species and cultivars. To determine the differences among the three irrigation levels, Student-Newman-Keuls multiple comparison at P = 0.05 were conducted using SAS software (Version 9.1.3, SAS Institute Inc., Cary, NC).

Results and Discussion: Regardless of irrigation level, all species/cultivars had excellent visual appearance, although some plants were smaller when irrigated with less water. Final shoot dry weight of plumbago (*Plumbago auriculata*), vinca 'Titan' and 'Pacifica' (*Catharanthus roseus*), helenium (*Helenium amarum*), and the two ornamental peppers (*Capsicum annuum*) 'Calico' and 'Purple Flash' were not affected by the irrigation treatment (Table 1). The ornamental pepper 'Black Pearl', licorice plant (*Helichrysum petiolatum*), and zinnia (*Zinnia maritima*) had less shoot dry weight under the lower irrigation level. Irrigation level did not affect the growth indices in the ornamental peppers 'Calico' and 'Purple Flash', and *Helenium* (Table 2). However, the size for all other species and cultivars was reduced as irrigation level decreased. Except for the ornamental peppers 'Calico' and 'Purple Flash', all species/cultivars have been tested in previous years (3). In addition to their excellent performance under limited irrigation, they are moderately salt tolerant (4). Therefore, these species/cultivars are good candidates for landscapes in semi-arid regions and may be irrigated with as low as 50% ET_0 without losing aesthetic appearance.

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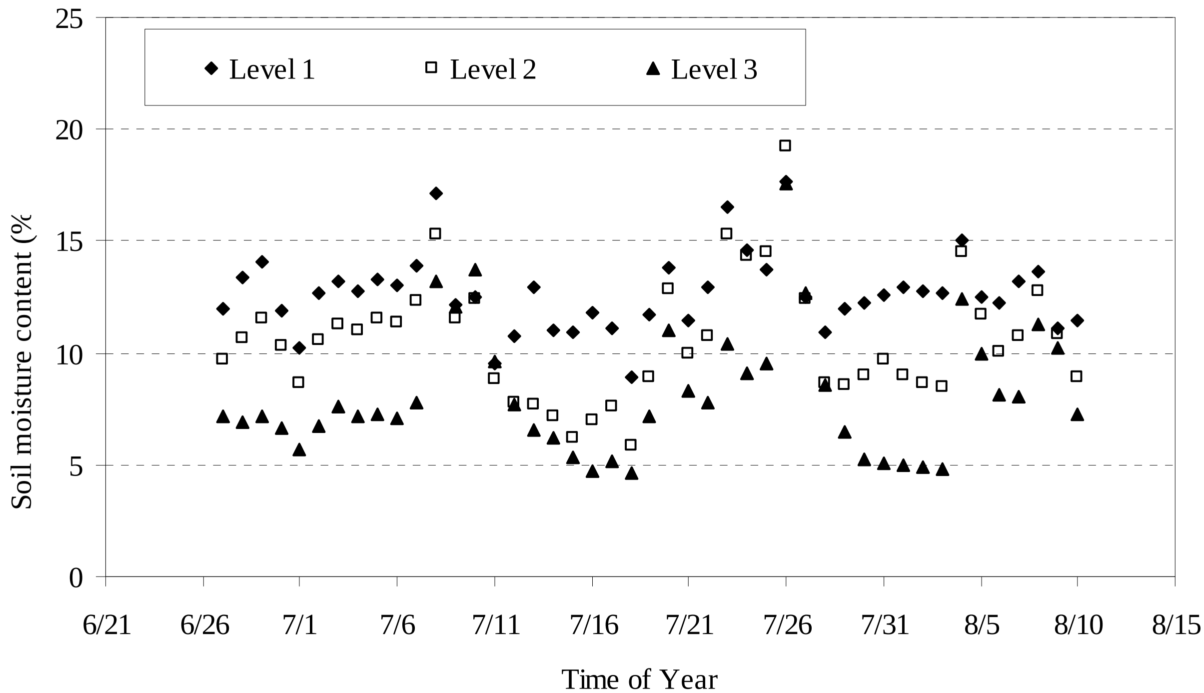

Figure 1. Soil moisture contents for the raised beds in the field irrigated at three levels: 100 to 150% (Level 1), 50-85% (Level 2), or 20 to 50% (Level 3) of reference evapotranspiration (ET_0).

Table 1. Final dry weight of selected bedding plants irrigated at three levels: 100 to 150% (Level 1), 50-85% (Level 2), or 20 to 50% (Level 3) of reference evapotranspiration (ET_0).

	Irrigation level		
Species/cultivar	Level 1	Level 2	Level 3
C. annuum ‘Black Pearl’	846.7 a	916.9 a	304.4 b
C. annuum ‘Calico’	124.8 a	83.2 a	127.5 a
C. annuum ‘Purple Flash’	55.7 a	57.5 a	77.8 a
C. roseus ‘Titan’	172.7 a	214.3 a	176.0 a
C. roseus ‘Rose Halo’	125.3 a	234.3 a	136.3 a
H. amarum ‘Dakota Gold’	541.7 a	587.7 a	546.3 a
H. bracteatum ‘Silver Mist’	316.7 a	253.7 ab	100.0 b
P. auriculata ‘Escapade Blue’	90.6 a	97.8 a	79.7 a
Z. maritime ‘Solcito’	912.0 a	629.6 b	622.3 b

Means followed by the same letters are not significantly different tested by Student-Newman-Keuls multiple comparison at $P = 0.05$.

Table 2. Growth indices of selected bedding plants irrigated with three levels: 100 to 150% (Level 1), 50-85% (Level 2), or 20 to 50% (Level 3) of reference evapotranspiration (ET_0).

	Irrigation level		
Species/cultivar	Level 1	Level 2	Level 3
C. *annuum* 'Black Pearl'	36.4 a	33.8 a	24.1 b
C. *annuum* 'Calico'	22.6 a	22.2 a	22.0 a
C. *annuum* 'Purple Flash'	20.4 a	19.9 a	19.1 a
C. roseus 'Titan'	30.0 a	25.2 ab	23.9 b
C. roseus 'Rose Halo'	22.1 a	24.4 a	21.6 b
H. amarum 'Dakota Gold'	35.0 a	31.5 a	28.7 a
H. bracteatum 'Silver Mist'	24.3 a	24.0 a	16.6 b
P. *auriculata* 'Escapade Blue'	23.3 a	19.4 ab	16.6 b
Z. maritime 'Solcito'	37.9 a	31.3 b	30.4 b

Means followed by the same letters are not significantly different tested by Student-Newman-Keuls multiple comparison at P = 0.05.

Growth of Live Oak with Tensiometer-controlled Cyclic Irrigation

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Significance to Industry: Tensiometer-controlled cyclic irrigation resulted in more than a 50% reduction in the volume of water applied compared to a fixed daily cyclic irrigation schedule. Because tree growth was not negatively affected, these results indicate that the BMP of scheduling irrigation based on substrate moisture is an effective way for container tree producers to conserve water.

Nature of Work: Efficient use of water resources in plant production is important for sustainability. Irrigation water is often thought of as a low cost input, but over-application wastes this valuable resource. Cyclic irrigation has been shown to result in 50% less irrigation water applied without sacrificing live oak growth (1). The use of soil moisture sensors to prevent irrigation when substrate water content is above a critical level could further reduce irrigation volume applied, while still providing sufficient water for plant growth.

This study, conducted at Sun City Tree Farm in Ruskin, FL from May 2006 through February 2008, compared tree growth using switching tensiometers (Irrometer Model "LT", Irrometer Company, Inc., Riverside, CA) to activate irrigation. Irrigation was scheduled solely by a controller. Live oak trees (*Quercus virginiana*, Cathedral Oak®) in #3 containers were transplanted May 2006 in soft-sided porous non-woven polypropylene containers called The Smart Pot® (High Caliper™ Smart Growing System, Oklahoma City, Oklahoma) containing a commercially prepared 6 pine bark: 4 Florida peat: 1 sand substrate (by volume). Containers were 24 inches in diameter and 14 inches tall. The substrate was amended with dolomitic limestone (pH 5.5 – 6.0). Florikan® Blend 15-4-9 controlled-release 12 month fertilizer (Florikan, Sarasota, Florida) was applied during potting by distributing 1 lb of fertilizer around the roots of the transplant as the container was filled with substrate. All trees were subsequently fertilized the same. Trees were placed 5 ft apart in a guy-wire-supported row. Irrigation water was applied via one Chapin spray stake (type P) per container (0.6 qt/min at ≈12 psi; Chapin Watermatics, Inc.,Watertown, New York).

A water meter with a non-resettable totalizer was installed in the main irrigation supply line for each of four irrigation zones of the study. Tensiometers were placed in the substrate of one container in each of two replicate irrigation zones (39 trees total). Each tensiometer tip was positioned at the edge of water spray, 7.5 inches deep, and 3 inches from the container sidewall. Tensiometers were interfaced with the irrigation controller so that irrigation was activated only when the substrate moisture tension was greater (drier) than 5 kPa (5 centibars) during any of the three scheduled activation periods during the day. In the other two replicate irrigation zones (40 trees total), an irrigation controller alone activated irrigation each day during three preset times (mid-morning, mid-afternoon, and late afternoon) for a total daily irrigation application of ≈ 2 gal/tree at the beginning of study and ≈ 3.4 gal/tree at the end. Tree heights and calipers (15 trees per irrigation zone) and meter readings were determined on July 24 (Aug. 3 for caliper), Oct. 13, and Dec. 18 of 2006; on Mar 21, Aug. 15, and Nov. 2 of 2007; and on Feb. 25 of 2008. All cultural practices were conducted by nursery personnel; hence, any reduction in height data was due to pruning.

Results and Discussion: Tree height and trunk caliper were not different at each date (Fig. 1) due to irrigation. Tensiometer-controlled irrigation resulted in a 62% reduction (52.1 vs. 19.7 thousand gal) in the total volume of water applied, compared to a fixed schedule of cyclic irrigation events (Fig. 2). Although, tensiometers required monitoring and maintenance to ensure proper operation, our results indicated that controlling irrigation with tensiometers is a viable means of achieving the BMP of initiating irrigation based on substrate moisture (2).

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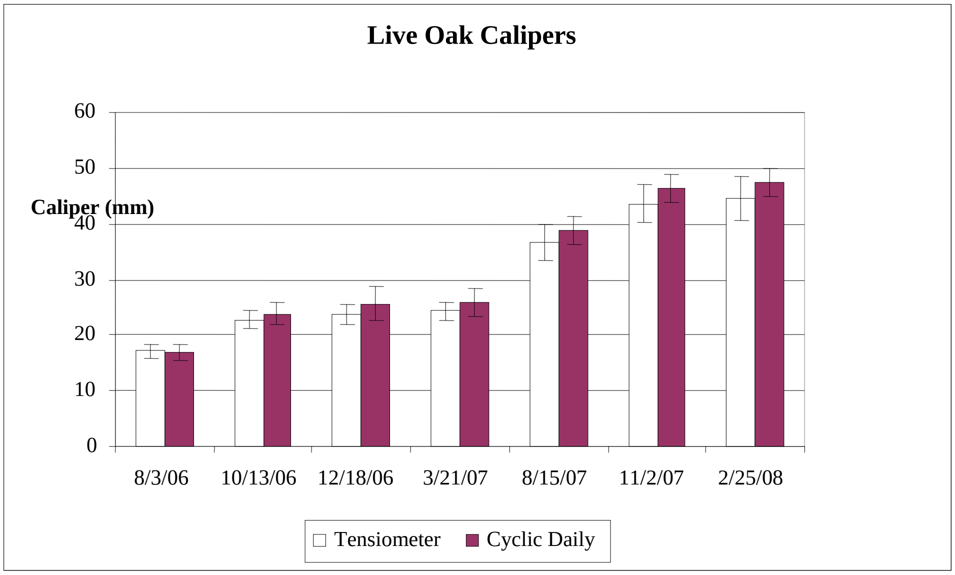

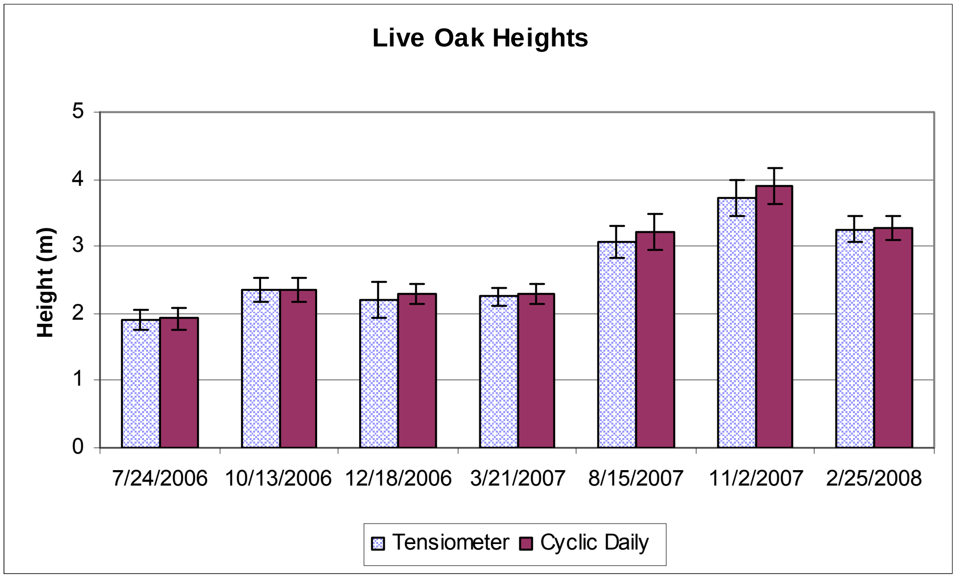

Figure 1. Average heights and calipers (± standard deviations) for live oak trees grown in #30 soft-sided porous non-woven polypropylene containers with a 6 pine bark: 4 Florida peat: 1 sand substrate (by volume) at Sun City Tree Farm, Ruskin, Florida. Cyclic irrigation applications were three times daily or applied when substrate moisture tension was >5 kPa (5 centibars) as determined with tensiometers during any of the three cycle intervals. Measurement conversions are 1 meter (m) = 3.3 feet and 25.4 millimeters (mm) = 1 inch.

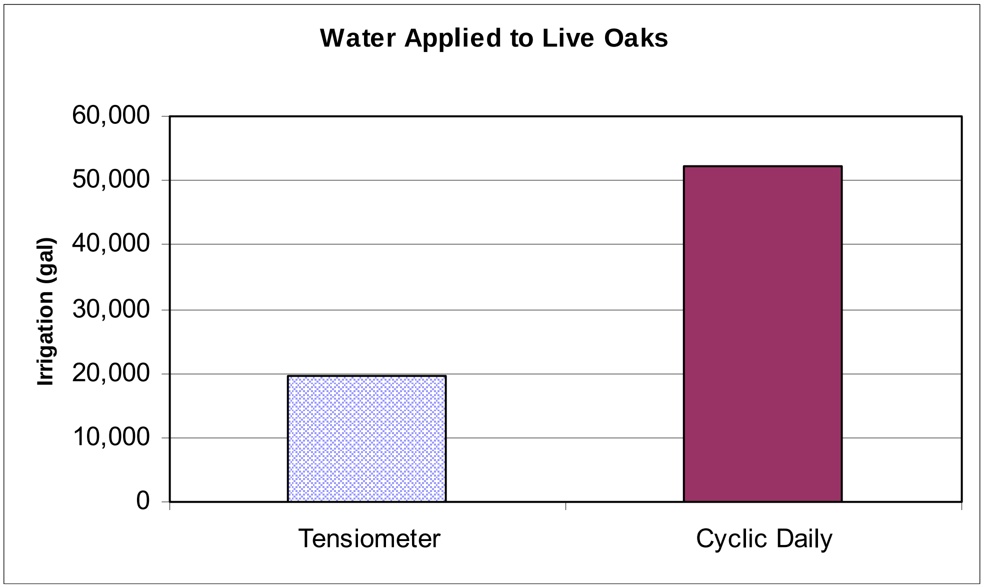

Figure 2. Irrigation water volume (gal) applied to live oak trees grown from July 2006 to Feb. 2008 in #30 soft-sided porous non-woven polypropylene containers with a 6 pine bark: 4 Florida peat: 1 sand substrate (by volume) at Sun City Tree Farm, Ruskin, Florida. Cyclic irrigation was applied three times daily. Tensiometer based applications were applied when substrate moisture tension was >5 kPa (5 centibars) as determined with tensiometers during any of the three cycle intervals.