Water Quality & Management

Samuel O. Dennis
Section Editor and Moderator

Non-Target Deposition of Methiocarb Applied to a Foliage Plant Staging Area

Chris Wilson[1], Peter Strimple[1], Sandra Wilson[1], and Joseph Albano[2]
[1]University of Florida/IFAS Indian River Research and Education Center and the [2]USDA Horticultural Research Laboratory
Fort Pierce, FL 34945

Index Words: Pesticide, Non-target Deposition, Mesurol®

Nature of Work: Deposition of pesticides on non-target surfaces results in material, labor, and financial wastes. Previous studies have shown that broadcast application of granular formulated pesticides can result in significant non-target losses due to pot spacing and plant growth form. Gilliam et al. (1992) reported non-target deposition of granular, broadcast applied herbicides to empty containers ranged from 23-30% when the containers were placed pot-to-pot, and increased to 79-80% when the containers were spaced on 30 cm centers. Mahnken and Sckroch (1992) reported higher herbicide concentrations (relative to per-pot applications) leaving simulated nursery sites that were treated by broadcast applications, and suggested that those higher concentrations were likely due to deposition of the herbicides on ground surfaces surrounding the pots. The objective of this study was to characterize non-target deposition of spray-applied pesticides under typical commercial shadehouse nursery conditions using methiocarb as a surrogate. Methiocarb is the active ingredient in the commercial formulation of Mesurol® 75-W. Mesurol® (Gowan, Yuma, AZ) is an organophosphate insecticide, miticide, and molluscicide, of environmental concern due to its' toxicity to fish, birds, and aquatic organisms.

Two areas within a foliage plant nursery (Kraft Gardens, Fort Pierce, FL) were selected for evaluation. These areas were used for staging plants, Weeping Fig (*Ficus benjamina* 'Monique') and Lady Palm (*Rhapis excelsa*). Species evaluated were of a similar height (Table 1), but varied in structural character. The Weeping Fig was trained to a single trunk, while the Lady Palm, a clustering-type palm, had multiple cane-like trunks/stems and palmate leaves with five to ten segments, divided almost to the base. Each aisle within these blocks was surrounded by two rows (double-row) of plants on each side. These rows were 21.9 m (72 ft) long. Three aisles were chosen within each block of plants. Teflon targets measuring 5.08 x 5.08 cm (2 x 2 in.) were placed at each end of the aisles, and at 5.5 m (18 ft) intervals between the two ends. Targets were also placed at the same distance intervals between one set of the two rows of plants on either side of the aisle.

Mesurol® 75-W was mixed at a rate of 0.45 kg (1 lb.) per 379 L (100 gal.) of spray mixture. Mesurol® applications were made using a PTO-driven Berthoud Super Puma 1000 canon airblast sprayer calibrated to deliver 17.8 L (4.7 gal.) of spray mixture per minute at a ground application speed of 0.1 m/sec. (0.23 mph). Following application, each target was placed in a polyethylene container, transported to the lab, and stored at -18C (-0.4F) until extracted and analyzed. Methiocarb was extracted from the targets and dissolved in monochloroacetic acid buffer (pH 3) by vortexing and sonicating. Extracts were filtered, diluted 1:20, and analyzed using a Waters 2690 high pressure liquid chromatograph (HPLC) equipped with a post column reaction module, reagent managers, and a Waters 474 fluorescence detector.

Results and Discussion: Mean deposition on the targets at each location (aisle vs. within double-row) was calculated for each species (Figures 1 and 2). Ground deposition within aisles and double-rows was generally highest at the edges near the sprayer travel path. Deposition on targets placed within the aisles was generally similar to deposition on those placed between the plant rows at each respective location. Total ground deposition within each aisle-row unit was estimated by averaging adjacent concentrations [i.e. (North edge+18 ft)/2, (18 ft+Center)/2, etc.] and assuming that the calculated average concentration was representative of the deposition within that 18 linear foot section (four total sections = 72 ft) of the aisle-row unit. The average deposition for each 18 ft section was then summed to estimate total ground deposition within the aisle-row units. Ground deposition was expressed in terms of the percentage of the total amount applied to each unit. The total amount of methiocarb applied to each aisle+double-row unit based on the application rate was 5514 mg (0.19 oz) for Weeping Fig and 4666 mg (0.16 oz) for Lady Palm. Based on these estimates, 22% of the calculated mass of methiocarb applied over the aisle spaces, and 22% of the amount applied over the row spaces was deposited on ground surfaces (Figure 3). For *Lady Palm*, 17% of the pesticide applied over the aisle spaces and 12% of the calculated total applied over the double-row spaces was deposited on ground surfaces.

Significance to Industry: Results from this study show that significant amounts of spray-applied pesticides can be deposited on non-target ground surfaces. Depending on the pesticide, these residues may readily move off-site in surface runoff water where they may harm non-target fish, birds, and aquatic organisms. Pesticide applicators should be familiar with the toxicity of the pesticide to non-target organisms as indicated on the label or other sources. Applications of very toxic compounds should be made as far in advance of irrigation or inclement weather as possible. This allows more time for breakdown and aging of residual pesticides, which may reduce the toxic effects of the pesticide to non-target organisms. Pesticide application equipment should be calibrated and well maintained to prevent over application.

Literature Cited:

1. Gilliam, C., D. Fare, and A. Beasley. 1992. Nontarget herbicide losses from application of granular Ronstar to container nurseries. J. Environ. Hort. 10:175-176.

2. Mahnken, G. and W. Sckroch. 1992. Effect of application method on herbicide loss in surface runoff from container production sites. Proc. SNA Res. Conf. 37:45-47.

Table 1. Study area and plant dimensions.

	Ficus benjamina 'Monique'		*Rhapis excelsa*	
	M (Ft)	***STDEV.***	**M (Ft)**	***STDEV.***
Plant Height	1.09 (3.6)	0.03 (0.1)	0.7 (2.3)	0.15 (0.5)
Trunk Length	0.58 (1.9)	0.03 (0.1)	NM	NM
Pot Height	0.24 (0.8)	NV	0.34 (1.1)	NV
Canopy Width	0.58 (1.9)	0.03 (0.1)	0.64 (2.1)	0.09 (0.3)
Pot Spacing	0.64 (2.1)	0.03 (0.1)	0.69 (2.3)	NV
Aisle Width	0.99 (3.25)	NV	0.69 (2.3)	NV
Row/Aisle Length	21.9 (72)	NV	21.9 (72)	NV

NM: *Not measured due to bushiness and multiple trunk character of plants, but is approximately equal to plant height.*
NV: *Considered constant with no variation.*

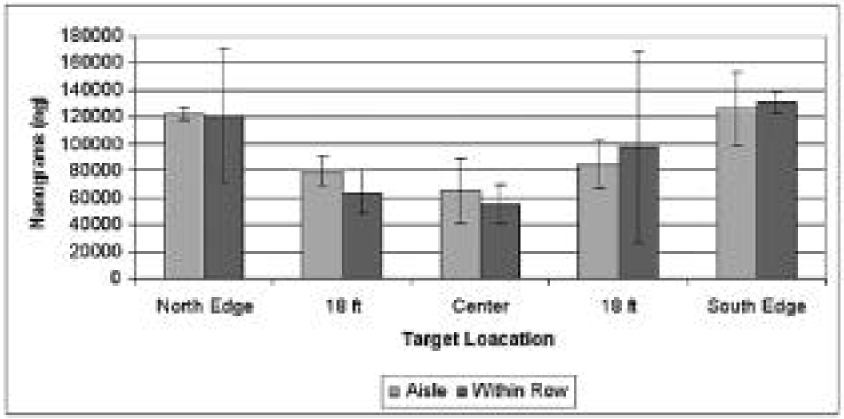

Figure 1. Methiocarb deposition on 5.08 x 5.08 cm (2 x 2 in.) targets within Weeping Fig aisles and double-rows. Bars represent one standard deviation from the mean (*N*=3).

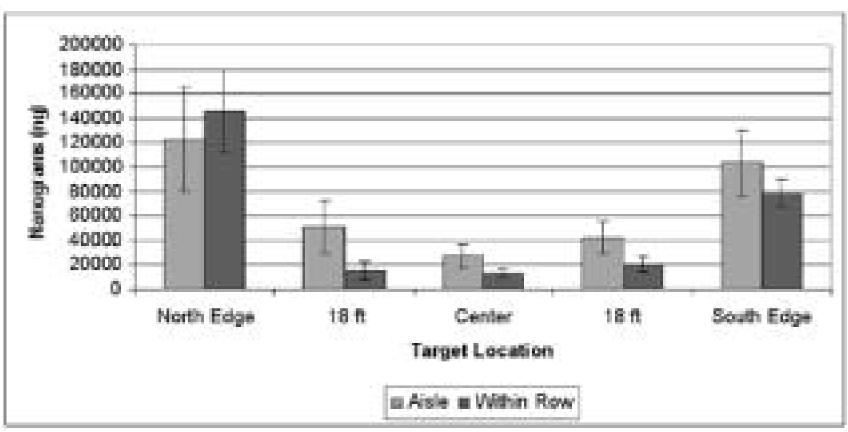

Figure 2. Methiocarb deposition on 5.08 x 5.08 cm (2 x 2 in.) targets within Lady Palm aisles and double-rows. Bars represent one standard deviation from the mean (*N*=3).

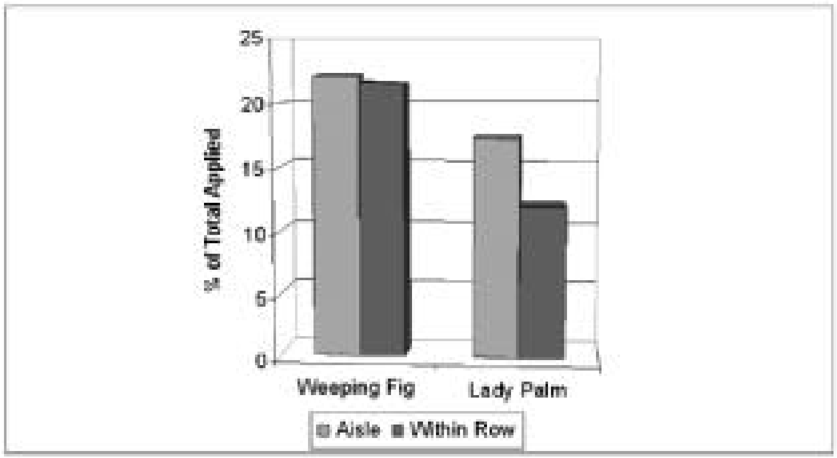

Figure 3. Estimate of percentage of total amount of methiocarb applied that was deposited on non-target ground surfaces.

Modeling Water Use in Container Nurseries: The Importance of Stomatal Response Functions

William L. Bauerle[1] and Christopher J. Post[2]
[1]Department of Horticulture
Clemson University, Clemson, SC 29634-0375
[2]Department of Forest Resources
Clemson University, Clemson, SC 29634

Index Words: Modeling, Irrigation, Water Management

Nature of Work: It is well known that water management is essential for the survival and growth of crops. Just as important, if not more so, is successful water management in limited soil volumes such as containerized plants. Either over watering or under watering plants can have negative consequences. Over watering can lead to leaching of nutrients that effect environmental quality while water deficit can deleteriously affect potential growth. Management practices with nursery crops tend toward excessive water use due to fears of a decline in growth and production. Models to predict potential transpiration confound this fear by potentially over-estimating transpiration rates in water-stressed trees. One possible explanation for the over-estimation is not taking into account the water balance in the soil profile. Another explanation includes the inadequate representation of canopy parameters.

To date, simplified forms of the Penman-Monteith equation are often used to estimate rates of canopy transpiration from atmospheric humidity deficits in aerodynamically well-coupled canopies (Phillips and Oren, 1998). Numerous models have been employed to estimate evapotranspiration (ET) from meteorological data in an attempt to relate the climatic conditions to a reference crop such as the Penman-Monteith well-irrigated short-green grass based equation (Schuch and Burger, 1997). The next step in this scenario is to develop a crop coefficient to compare the water use of a specific crop to that of a reference crop. Lost in this common procedure are a number of plant morphological and physiological features of both the crop canopy as a whole and the individual tree within the canopy. Furthermore, the assumption that adequate water exists in the soil profile can lead to overestimates of transpiration in water-stressed trees (Dye, 1996).

The aim of this paper is to demonstrate the importance of stomatal response functions in modeling water use in response to water deficits under nursery conditions. An integrated model was parameterized from leaf-scale gas exchange measurements and validated against whole plant flux data at ambient atmospheric CO_2. The model is then compared to a popular form of the combination equation; the Penman-Monteith. The validity of the integrated model will be compared to dynamic whole plant measures of transpiration under both well-watered and water stress conditions. Finally, the model will be used to simulate below-potential transpiration rates.

Sixty containerized red maple saplings were spaced 1.5 m center-to-center. Plants were irrigated six times daily to container capacity prior to imposing drought. For each cultivar, treatments consisted of a well-watered control and a drought treatment where water was withheld. Randomly selected plants from each source and treatment combination were chosen for continuous sampling of sap flow. Fourteen sap flow gauges were installed on the trunks of red maple. Of the gauges employed, six were on well-watered control plants and eight were on plants subjected to a drought stress and well-watered recovery cycle. Whole tree sap flow rates were measured simultaneously with microclimate, where meteorological data were collected at 3 m using a Campbell Scientific Weather Station. The station was located on the north side immediately adjacent to the experimental plot and within 0.25 m of canopy level.

Results and Discussion: Figure 1 depicts sap flow of a representative tree in relation to potential transpiration of the Penman-Monteith combination equation (Figure 1) for the period Julian day 245 to 257. The model run illustrated in Figure 1 does not incorporate a soil moisture deficit stomatal response function. Figure 2 illustrates the model run on the same tree with the incorporation of a soil moisture deficit stomatal response function. The departure from measured and estimated sap flow illustrates the need for stomatal response functions in water use modeling. Although irrigated trees appeared somewhat to parallel potential transpiration when the stomatal response function was not incorporated, soil moisture deficit increased in trees subjected to water deficit, forcing sap flow to decline and become disconnected from environmental variables that drive transpiration. Lastly, in measurement trees subjected to water deficit, model estimates at soil moisture deficits above 0.85 were not reliable (Figure 2).

The results indicate that when soil water is extractable, measured and modeled transpiration follows that of atmospheric demand and only in that instance may a crop coefficient potentially predict transpiration. In contrast, when soil water becomes limiting during progressive drought, transpiration is not only reduced, but diverges from atmospheric driving variables. One factor responsible for the divergence is soil moisture, making its inclusion essential in modeling. Surprisingly, our measurements indicated that water loss continued even under severe water deficit. Cuticular conductance is one possible explanation for this. However, in its present state, the model does not consider the effect of cuticular transpiration on evapotranspiration and, therefore is not applicable to severe soil water stress conditions. Transpiration can vary between plants at the same site (e.g. Hatton and Wu, 1995), however, integrated models are spatially explicit and allow for assessment of positional variation in evaporation. Of course further work is required to evaluate containerized plants in different conditions and to check whether modeling the water balance in the soil profile would then permit prediction of the fraction of potential transpiration taking place both spatially and temporally.

Significance to industry: The need for complex models increases as the scale diminishes from the region to the forest allowing for within canopy allocation of parameters appropriate to different foliage (Whitehead, 1998). Incorporation of detailed process information, common to the bottom-up approach, facilitates prediction under conditions other than those in which the model was derived. Furthermore, stomatal response functions constrain the model under a given set of conditions, allowing appropriate estimation.

Crop coefficients are commonly used to estimate water use in woody ornamentals (Schuch and Burger, 1997). However, they were originally developed for uniform canopies such as alfalfa, whereas containerized plants have more similarities to isolated stands of vegetation. Moreover, “universally valid” crop coefficients are nonexistent, even in fully developed canopies, because the values are subject to solar radiation, air temperature, air vapor density, and wind speed (Annandale and Stockle, 1990). An integrated one-step approach that include stomatal response functions further refine water balance models and predict evapotranspiration directly from Penman-Monteith. Integrated leaf level simulation models of CO_2 and H_2O exchange have been successfully parameterized and applied to a deciduous forest (e.g. Harley and Baldocchi, 1995; Baldocchi and Harley, 1995). No model is perfect in all situations and errors must be expected. An integrated biological process model can synthesize the complex and non-linear forcing of environmental variables on biological systems, as well as predict container nursery water use without the uncertainties of crop coefficients.

Literature Cited:

1. Annandale, J.G. and Stockle, G.O., 1990. Sensitivity analysis of evapotranspiration crop coefficients fluctuation with climate. Trans. ASAE, 90: 2645.

2. Baldocchi, D.D. and Harley, P.C., 1995. Scaling carbon dioxide and water vapour exchange from leaf to canopy in a deciduous forest. II. Model testing and application. Plant, Cell and Environment, 18: 1157-1173.

3. Dye, P.J., 1996. Response of Eucalyptus grandis trees to soil water deficits. Tree Physiology, 16: 233-238.

4. Harley, P.C. and Baldocchi, D.D., 1995. Scaling carbon dioxide and water vapour exchange from leaf to canopy in a deciduous forest. I. Leaf model parametrization. Plant, Cell and Environment, 18: 1146-1156.

5. Hatton, T.J. and Wu, H.I., 1995. Scaling theory to extrapolate individual tree water use to stand water use. Hydrological Processes, 9: 527-540.

6. Schuch, U.K. and Burger, D.W., 1997. Water use and crop coefficients of woody ornamentals in containers. Journal of the American Society for Horticulture Science, 122(5): 727-734.

7. Whitehead, D., 1998. Regulation of stomatal conductance and transpiration in forest canopies. Tree Physiology, 18: 633-644.

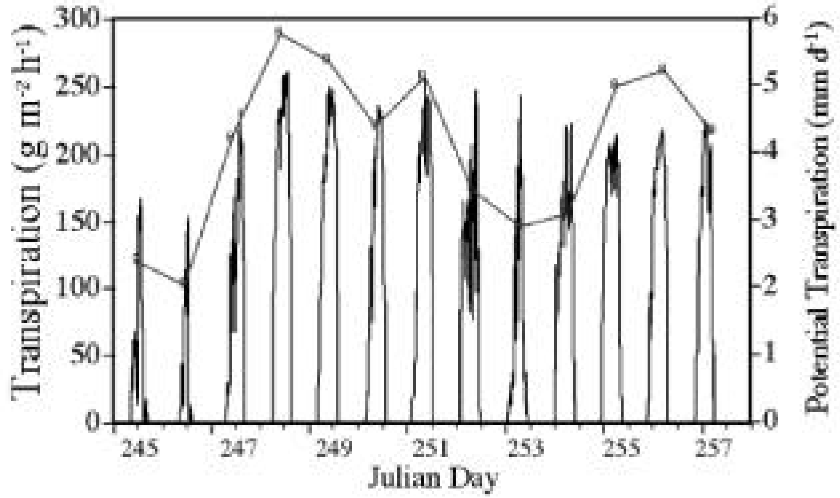

Figure 1. Model estimate (solid black line) and potential transpiration

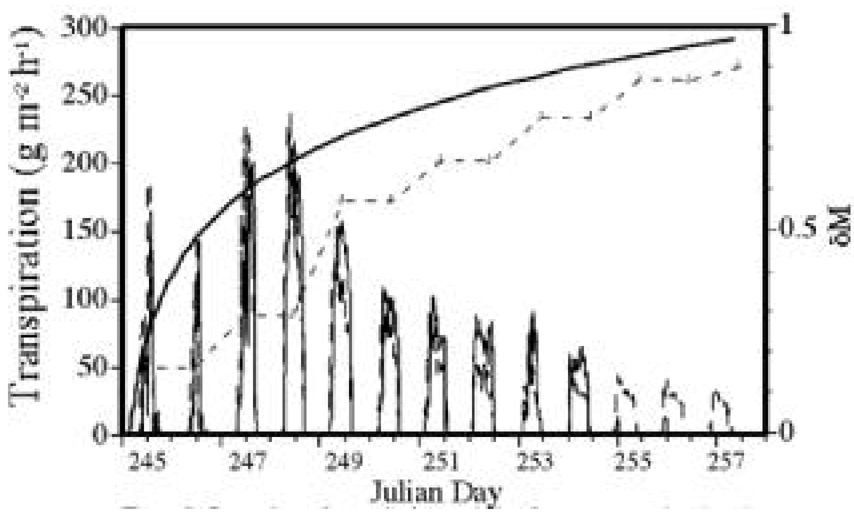

Figure 2. Comparison of transpiration evolution for a representatlive drought stressed individual tree (broken line) to estimate transopration using the canopy transpiration model (solid line) from Julian day 245 to 257. The daily soil moisture deficit is depicted by solid circles connected by a broken line. The non-linear curve indicates the soli moisture deficit stomatal response function in the model.

Sawdust Effect on Soil pH Under Low Water Application

[1]Sam O. Dennis, [2]Sunnie A. Aburime,
[3]Richard Buggeln and [1]Simeon K. Rotich
[1]Cooperative Agricultural Research Program,
Tennessee State University, Nashville, TN 37209
[2]Department of Engineering,
Clark Atlanta University, Atlanta, GA 30314
[3]Center for Industrial Services,
The University of Tennessee, Knoxville, TN 37996

Index Words: Sawmill, Wood Fibers, Organic Carbon, Organic Matter

Nature of Work: Wood fibers such as sawdust accumulate at sawmills and are sometimes sold at marginal cost to farmers. If sawdust is properly utilized it can, under many conditions, be of great value to growers. Sawdust is high in organic carbon and can, therefore, increase soil organic matter with time. Most nursery soils are greatly in need of organic matter. Organic matter can increase the water holding capacity of soils as well as serve as the main source of food and energy for soil organisms (Tan, 1999). However, there is an old wives tale among some growers that "sawdust makes the soil acid." Sawdust application to soil can cause nitrogen deficiency in plants because of the high Carbon/ Nitrogen ratio of sawdust materials. The apparent symptoms resulting from nitrogen deficiency can be mitigated with proper nitrogen and water management. The question becomes, why do growers think this is a pH effect? It is worth mentioning that, in many instances, the soils in question are acidic to start with. The goal of this study is to generate sufficient data to show that the wives' tale has factual or no factual foundation. Chances are the basis for the grower's "mantra" is the historical perspectives of early uses of wood fibers (e.g., oak bark was formerly used to tan leather and bark contains tannic acid). The study was conducted in the laboratory using soil columns constructed from polyvinyl chloride (PVC) tubes (10-cm i.d. X 20-cm long). Four different soil types designated in this study as A, B, C, D were used to pack the soil columns to a bulk density of 1.25 gm/cm^3. Two different types of sawdust were used in the study. One was a one-year-old sawdust (Osd) while the other was a one-day-old sawdust (Nsd).

A 1.27-cm layer of sawdust was applied to the surface of the soil. Water was applied with a customized water application device (Harrison 2002, Unpublished data) at the rate of 50 ml per day, three times a week throughout the experiment. The pH (soil/water ratio 1:2) of the soils was taken at 30, 60, and 90 days after the initial soil pH was taken. The pH and the organic matter of the two sawdust samples used in the experiment was determined. The experimental setup of the study is shown in Figure 1.

Results and Discussion: Some chemical properties of the sawdust used in the experiment are shown in Table 1. The effects of the old sawdust and the new sawdust on soils' pH are shown in Table 2 and 3 respectively. There is little or no quantitative data in published literature on the effect of sawdust on soil pH. Our results show that the effect of sawdust on soil pH in our study was dependent on initial soil pH and the initial pH of the sawdust. Figure 2 tends to indicate that it will take 185 days and 142 days for soil with old sawdust (Osd) and soil with new sawdust (Nsd) respectively, to increase the soils' acidity to the initial pH of the old sawdust. However, there is much gradual change in pH in soil type A with Osd due to the nearness of their initial pHs. The lower effect of the new sawdust on soil type A, could be due to a neutralization reaction within the first 30 days. Additionally, new sawdust is relatively higher in lignin (Brady and Weil, 2002) and decomposes slower than the old saw dust, thus resulting in a slight or no change in the pH of soil type A.

Significance to Industry: Wood fibers such as sawdust can be used as soil amendments and mulches by nursery crop growers and landscapers to manage acid tolerant ornamentals, such as Azaleas. The nitrogen deficiency associated with the use of sawdust can be mitigated when an additional source of nitrogen is applied with the sawdust. Studies of this nature tend to shed some light on the old wives tale that "sawdust makes the soil acid."

Literature Cited:

1. Brady N. C, and R. R. Weil. 2002. Practical nutrient management. In The nature and properties of soils, P. 697. Prentice Hall, Upper Saddle River, NJ.

2. Tan K. H 1994. Organic constituents In Environmental soil science. P. 52. Marcel Dekker, Inc. New York, NY.

3. Harrison R. E. 2002. Cooperative Agricultural Research Program, Tennessee State University, Nashville TN.

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Figure 1. Experimental setup of soil columns and water application device.

Table 1. Some chemical characteristics of the sawdust used in the experiment

Sawdust Type*	pH	% Organic Carbon	% Organic Matter**
Old	4.53	5.12	8.81
New	7.78	3.65	6.28

* Old sawdust (Osd) is 1 year old. New sawdust (Nsd) is 1 day old
** % Organic matter =Organic carbon X 1.72

Table 2. Effects of sawdust (old) on soil pH used in the experiment

Soil Type	Initial pH Day 0	pH Day 30	pH Day 60	pH Day 90	R^2**
A	5.03a*	4.90a	4.86a	4.78a	0.955
B	5.70a	5.52a	5.40a	5.24a	0.995
C	6.65a	6.26a	6.15a	6.06a	0.872
D	6.28a	6.10a	5.93a	5.79a	0.997

* Means within row followed by the same letter are not significantly different at p=0.05 by Duncans
** Coefficient of Linear Regression for curves in Figure 2

Table 3. Effects of sawdust (new) on soil pH in the experiment

Soil Type	Initial pH Day 0	pH Day 30	pH Day 60	pH Day 90	R^2**
A	5.03a	5.03a	4.92a	4.75a	0.860
B	5.70a	5.68a	5.55a	5.34a	0.726
C	6.65a	6.34a	6.25a	6.05a	0.962
D	6.28a	6.10a	6.00a	6.02a	0.793

* Means within row followed by the same letter are not significantly different at p=0.05 by Duncans
** Coefficient of Linear Regression for curves in Figure 2.

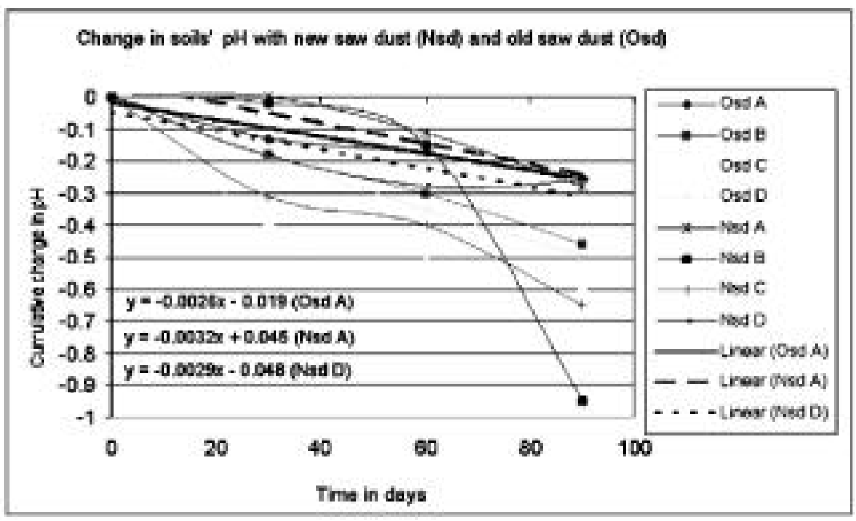

Figure 2 Cumulative Change in Soils' pH with Time

Sulfurous Generator Offers Control of pH and Alkalinity

Mark J. Arena
Clemson University Extension Service
Moncks Corner, SC 29461-3762

Index words: Sulfur, SO_2, Acidification

Nature of work: Understanding water quality thoroughly is a prerequisite to successful plant production. The pH and alkalinity of irrigation water are dominant factors affecting the media solution, the water solution in the pores of growing media (Baily, 1996). Traditionally, either one or both of the following is used to manage these two chemical properties of water: 1) acid injection treatment of the water and/or 2) adjusting the lime rate in the potting mix. The importance of controlling these two parameters is primarily nutrient availability.

Currently, most nurseries that manage these chemical properties use an acid injection system for control. Typically, they inject liquid sulfuric (H_2SO_4), phosphoric (H_3PO_4), or nitric acid (HNO_3) to improve the pH and alkalinity to a desirable level. This is accomplished through a chemical reaction that reduces the amounts of bicarbonates (HCO_3^-), and carbonates ($CO_3^=$) in the water. This system, as in all systems, has its advantages and disadvantages. One advantage is the convenience of this system. If used with a computer, these parameters can be automatically monitored, adjusted and controlled electronically. Disadvantages are the cost and possible safety concerns.

An alternative to the acid injection system is the Aqua SO_2 Generator which is used regularly in the golf course industry (www.aquaso2). This system is starting to gain popularity among nurseries due to its operational and economical advantages over the liquid acid injector system.

Results and Discussion: Baucom's Nursery opened a new operation in Summerville, SC in 1996. Once plant production started, they discovered pH and alkalinity problems. Unfortunately, the water was high in both and required treatment in order to produce quality plants. While researching their options they learned about a sulfur generator that was being used at the Ocean Golf Course on Kiawah Island, SC (O'Brien, 1996). Further investigations lead to the purchase and installation of a SO_2 Generator, Irrigation Pond Inclusion System. For the last six years Baucom's has successfully managed their irrigation water with this unit.

Significance to Industry: The SO_2 Generator offers nursery and greenhouse producers an option for managing water quality issues. Also, it may be considered for cost savings and employee safety. Cost savings will vary depending on the system used and other factors. Baucom's estimated a twenty thousand dollar savings on the unit and installation and report a significant savings on raw materials; prilled sulfur pellets. Also, the pellets are safe to handle.

Literature Cited:

1. Baily,D.A. 1996. Alkalinity, pH, and Acidificationp.69-92. In:Water, Media, and Nutrition for Greenhouse Crops. Ball Publishing, Batavia, Ill.

2. Aqua SO_2, Inc., www.aquaso2

3. O'Brien,P.M. 1996. The Magic of Sulfur. The Best Turf Tips of 1996. May/June Issue.

Production of *Spathiphyllum* Using Three Irrigation Methods

Henry Bryant and Tom Yeager
PO Box 110670, University of Florida, Gainesville, FL 32611

Index words: Overhead Sprinkler, Capillary Wicks, Capillary Mat

Nature of Work: Demand for public supply of fresh water in Florida is expected to increase in the future. For example, in the St. Johns River Water Management District of northeast Florida, public water use is expected to increase 58% by 2020; however, agricultural water use is not expected to increase (Vergara, 1998). In view of this, nurseries will need efficient irrigation systems to increase production space with current water allocations. The capillary wick irrigation system is an efficient alternative in which plants can absorb all water applied. The wick irrigation system has been used by Henley (1998) to grow several container greenhouse crops, although plant growth was not compared to plants grown with traditional overhead sprinkler irrigation. The objective of this study was to compare growth response of S*pathiphyllum* Schott. 'Ty's Pride' irrigated by overhead sprinkler, capillary wick, or capillary mat.

Multiple branched tissue culture liners of S*pathiphyllum* were planted with Metro Mix® 500 (Nov. 9, 2001) in 6-inch diameter containers (1.5 liter). The Metro Mix® 500 for each container was amended with 11.1 grams of Tri-Pro Multicote 17-5-11 (Haifa Chemical Co., Haifa Israel) twelve-month controlled-release fertilizer and moistened to uniform wetness. Plants were placed in a triangular spacing (11 x 11 x 18 in.) on each of three greenhouse benches. Each bench was 4 x 5 ft. and provided for irrigation treatments of 1) overhead sprinkler, 2) capillary wick, or 3) capillary mat. The bench for overhead sprinkler treatment was covered with black 6-mil plastic over Styrofoam™ with a one-forth inch quarter round wood molding glued on three edges. Black 6-mil plastic was placed over the Styrofoam™ and molding that served as containment for the irrigation water. The bench was sloped slightly so irrigation runoff could exit one side of the bench where the black plastic was folded at an angle to channel the irrigation runoff into a collection reservoir. Irrigation water was provided for 30 min. (0.36 inch) twice per week by one Spectrum 360™ Jet (Antelco Corp., South Australia) sprinkler (20 psi) placed in the center of bench at a height of 20 in. Irrigation uniformity was 82% as determined by Christiansen's coefficient (Haman et al., 1997). Bench for capillary wick plants was fitted with level corrugated fiberglass with every third channel blocked by gluing foam inserts at each end. Black 6-mil plastic was placed over fiberglass and one-inch slits were made in plastic where plants rested and wick protruded container bottom into fiberglass channel below plastic. Each plant had a __ in. wide by 8 in. long wick (DeBellco, New Berlin, Wis.) inserted with a wire rod approximately four inches up into the substrate through a drainage hole in container. A Chapin (Chapin Watermatics, Watertown, N.Y.) lead emitter was positioned in each fiberglass irrigation channel and supplied 0.33 gal. per min. (20 psi). For about five months, seven channels were filled twice per week (one gal. total each irrigation) then irrigated each day for the last week of experiment. Another bench constructed similarly to bench for overhead irrigation was fitted with a Bottom Up irrigation mat (Bottom Up Irrigation Pty Ltd., Australia). Irrigation drip tape down one side of the mat supplied 0.12 gal. per min. of water at 10 psi. The bench was sloped slightly to collect irrigation runoff in a reservoir on the side opposite the drip tape. For about two months, the mat was irrigated for 60 min. twice per week and subsequently irrigated twice per week with three 15-min. irrigations separated by 30 min. without irrigation. The latter irrigation schedule was applied three times per week during the last week of experiment.

Greenhouse temperatures were controlled to 70^{o} F at night and 85^{o} F during the day with 78% light exclusion. Quantity of irrigation water applied was recorded from meter after each irrigation event along with runoff volume measured manually. Plant height, widest width, and perpendicular width were determined on Jan. 29, 2002 [(81days after potting (DAP)] and Apr. 22, 2002 (164 DAP) for all plants (24, 25, and 25 plants for overhead, wicks, and mat, respectively). A growth index was calculated as height plus average width. Overall plant quality was also noted.

Results and Discussion: Growth indexes for plants irrigated with overhead sprinkler, wicks, and mat were similar 81 and 164 DAP (Table 1), and there were no noticeable differences in plant quality. The largest amount of irrigation water was applied with overhead irrigation (338 gal.), followed by mat (246 gal.), and wicks (46 gal.) (Table 2). Overhead irrigation applied for each event was sufficient to moisten substrate; whereas, irrigation volume applied per irrigation event for the wicks was based on volume to fill fiberglass channels, and volume applied to mat was based on wetting mat (Table 2). The frequency of irrigation events for wicks and mats was adjusted according to plant water need as determined by visual observation.

The wick irrigation system had no runoff (Table 2). Runoff collected per irrigation event for mat was twice that collected for overhead, 4.6 gal. compared to 2.3 gal., respectively. Runoff from mat was 87% of water applied compared to 30% for overhead irrigation. This indicates the need to adjust mat irrigation water delivery so that irrigation wets the mat slowly and uniformly. The use of frequent irrigation applications of small volumes may result in adequate mat wetness with minimal runoff. The water retained in mat [0.7 gal. (applied minus runoff)] or placed in wick channels (0.9 gal.) was about seven times less water than retained (applied minus runoff) by plants that received overhead irrigation. Thus, wick and mat irrigation systems resulted in more efficient use of water in containers than overhead irrigation.

Data from this study indicates that overhead sprinkler, capillary wicks, or capillary mat irrigation results in similar growth indexes of greenhouse-grown *Spathiphyllum* after 164 days. However, the wick irrigation system resulted in 86% less water applied compared to overhead sprinkler irrigation and 81% less water applied compared to mat irrigation. Additionally, wick irrigation did not result in runoff.

Significance to Industry: Plant production in Florida could be confronted with reduced water supplies in the future due to increased demand resulting from population increase. Thus, water-conserving capillary irrigation delivery systems should be evaluated for use in container plant production. In our evaluation, greenhouse-grown *Spathiphyllum* plants irrigated with capillary wick protruding from each container or containers resting on capillary mat, received about one-eighth and six-eighths, respectively, the amount of water as plants irrigated with an overhead sprinkler. The size and quality of all plants were similar after five months, indicating that water-conserving capillary watering systems are viable alternatives to overhead irrigation.

Literature Cited:

1. Haman, D. Z., A. G. Smajstrla, and D. J. Pitts. 1997. Uniformity of sprinkler and microirrigation systems for nurseries. Univ. Fla. Extension Bulletin 96-10.

2. Henley, R. W. 1998. The deep-channel wick-in-pot subirrigation system for greenhouse–grown potted plants. So. Nursery. Assoc. Res. Conf. 43:506-509.

3. Vergara, B. A. 1998. Water supply assessment 1998. St. Johns River Water Management District, Palatka, Florida.

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Trade names and companies are mentioned with understanding that no endorsement is intended or discrimination for similar companies or products not mentioned.

Table 1. Growth indexes 81 or 164 days after potting (DAP) for *Spathiphyllum* grown in 6-inch containers with Metro Mix® 500 in a greenhouse and irrigated with overhead sprinkler, capillary wicks, or capillary mat (mean ± standard deviation).

Irrigation method	81 DAP	164 DAP
Overhead	37 ± 3	58 ± 4
Wick	36 ± 4	56 ± 8
Mat	35 ± 3	58 ± 4

Table 2. Total water applied, water applied per irrigation event, and water lost to runoff 164 days after potting for *Spathiphyllum* grown in 6-inch containers with Metro Mix® 500 in a greenhouse and irrigated with overhead sprinkler, capillary wicks, or capillary mat.

Irrigation Method	Total Applied (gal.)	Water applied per irrigation event (average gal.)	Runoff collected per irrigation event (average gal.)
Overhead	338	7.6	2.3
Wick	46	0.9	0
Mat	246	5.3	4.6

Survey of Container Nursery Irrigation Practices in Georgia

M.P. Garber, J. M. Ruter, and J.T. Midcap
University of Georgia, Department of Horticulture
Tifton and Athens, GA

Index Words: Water, Drip Irrigation, Best Management Practices, BMPs

Nature of Work: Container ornamental nursery production is one of the fastest growing segments of American agriculture. The state of Georgia has four of the top 100 container nurseries (Georgia Green Industry Association, 2002) in the U.S. and the state supplies plant material throughout the United States.

The production of container ornamentals in the United States has evolved during a period of generous availability of irrigation water. Severe drought conditions in many regions of the U.S. in recent years has raised issues such as water availability, efficiency of use, and value derived from this natural resource.

A 2001 survey was conducted of 102 container ornamental nurseries in Georgia that were members of the Georgia Green Industry Association. Completed surveys were received from 26 firms, for a 26% response rate, a sufficiently high rate to make generalizations about the Georgia container nursery industry. Also, three of the four nurseries that rate in the top 100 in the USA, according to annual sales revenue, responded to the survey. Data were tabulated and analysis of response conducted using PROC FREQ, PROC MEANS, PROC GLM (SAS, 1999).

Results and Discussion: The efficiency of use of water applied to container nurseries is influenced by factors such as container density and method of application (Beeson and Knox, 1991). Mean container density, at final spacing, ranged from about 56,000 per production acre (140,000/ha) for #1's, to about 1740 per production acre (4350/ha) for #25's. These densities translate into container spacings that are comparable to industry standards, such as 12" (4.7cm) on-center for #1's and 24" (9.4cm) on-center for #3's, the two most common container sizes used in Georgia and other states in the Southeast.

The #3 container spacing indicates that each plant requires about 576 square inches (88 cm^2) of nursery surface while the container occupies about 64 square inches (9.8 cm^2) of nursery area. This implies that the maximum interception efficiency of water applied by overhead irrigation would be about 11% for #3 containers and 25% for #1 containers. Containers represent a very small percentage of the required production bed area, therefore the efficiency of water use would be greatly influenced by the method of application.

Container nursery producers in Georgia were asked to indicate the percentage of production, by container size, that was irrigated by overhead/broadcast method versus directed or drip/spray methods. Essentially all of the smaller containers (liners, #1, #3 and #5) are irrigated by overhead methods. Directed application of irrigation water (drip/spray) was practiced with the larger containers. Directed application was utilized in #7 containers (49%), #15 (85%) and #25 (75%). The use of directed irrigation is highest with containers of lowest density. The use of directed irrigation with larger containers is a desirable practice since the larger containers intercept the lowest percentage of applied overhead irrigation. However, the industry primarily utilized overhead application methods for #1, #3 and #5 containers, the largest segment of the product mix and production bed area.

Nurseries apply about one acre-inch (102.8 m^3) of water by overhead irrigation per irrigation event for #1 and #3 containers, while about one-half acre-inch (51.4 m^3) is applied per irrigation event for #5, #7 and #15 containers. The average amount of irrigation applied via overhead sprinklers ranged from 0.3 to 1.3 inches (0.1 - 0.5cm) per application in Alabama nurseries (Fare et al, 1992).

The amount of water applied by directed irrigation (drip/spray) increased with container size and was reported in gallons per application, verus acre-inches for overhead. The mean level of directed irrigation applied per irrigation event to each #3, #7, #15 and #25 container was 0.4, 1.1, 1.5 and 1.7 gallons (1.5, 4.2, 5.8, and 6.6 liters), respectively. The frequency of irrigation varied, although not significantly, among container sizes.

The summer irrigation frequency was about three times that of the winter season. The mean weekly application frequency was 3.2 in the winter season and 9.0 in the growing season. There was substantial range in frequency of application among nurseries. The wide range in frequency of irrigation events could be due in part to variation in utilization of cyclic irrigation. With cyclic irrigation, there is a higher frequency of irrigation events but a smaller amount of water applied with each event. Information on amount of water applied and frequency of irrigation events could be utilized to (a) compute peak irrigation demand, and hence irrigation system specifications for nurseries, (b) irrigation capacity or well size and pumping requirements, and (c) estimate total annual irrigation water applied in nurseries.

Significance to Industry: The long standing assumption that water will always be available in generous supply is probably invalid. Most states in the USA, particularly Southeastern and Northeastern, have recently experienced significant water shortages. The implication for container nurseries, and other ornamental producers, is that the industry must learn to better manage this precious natural resource. To accomplish this, the nursery industry will need more and better information on how much water is currently used to grow crops, how the water is managed, and how much water is required to grow crops.

This survey of Georgia nurseries provides baseline data for the first two issues, how much water is used by container nurseries and how efficiently is the water used. This information would provide guidance for industry water conservation efforts and university research and extension programs. The information in this study could be used by growers in other states to determine their relative water use, application methods, and procedures to reduce water use and improve runoff water quality.

During the course of this study, it became apparent that the information provided on quantity of water applied were estimates made by nursery operators. Very little quantitative monitoring of water use is occurring. Georgia is probably not unique in this respect. As a necessary first step to better manage water resources, the container nursery industry should consider quantitative measurement of water applied. This should be done by application method and container size, where feasible. It will be difficult for the container nursery industry to document progress in reducing water use in the absence of baseline data on amount of water applied. Quantitative measurement would also help document the necessary quantity of water required, an important factor in dealing with water regulators.

Literature Cited:

1. Beeson, R.C. and G.W. Knox. 1991. Analysis of efficiency of overhead irrigation in container production. HortScience 26(7):848-850.

2. Fare, D.C., C.H. Gilliam, and G.J. Keever. 1992. Monitoring irrigation at container nurseries. HortTechnology 2(1):75-78.

3. Georgia Green Industry Association. 2002. Personal Communications.

4. SAS Institute, Inc. 1999. SAS/STAT User’s Guide, Version 8. SAS Institute Inc, Cary, NC.

Modeling Tree Irrigation Requirements: Where are We and Where are We Headed?

R. C. Beeson, Jr.
University of Florida
Mid-Florida Research and Education Center
Apopka, FL 32703

Index Words: Irrigation, Tree Production, Water Volume

Nature of Work: In March 2001, a project to model tree water use from the liner stage to trees of 4- to 5- inches in caliper was initiated at the University of Florida's Mid-Florida Research and Education Center (MREC). Liners of *Acer rubrum* 'Florida Flame' (red maple), *Quercus virginiana* (Live oak) and *Ilex x* 'Nellie R. Stevens' (holly) were potted in #7 containers. These containers were painted on the inside with Spin-Out (Griffin Corp., Valdosta, GA) and covered on the outside with aluminum foil prior to use. Five plants of each species were transplanted into a 60% pine bark fine: 30% Florida sledge peat: 10% coarse sand substrate amended with micronutrients and dolomite limestone. These were placed in suspension lysimeters and the tops of each container covered to limit surface evaporation. Identical liners were also transplanted into unmodified and uncovered #7 containers and placed around the lysimeter plants simulate a normal production situation. Trees were pruned, staked, spaced and fertilized as needed.

Weights of the trees in the lysimeters were recorded every half hour to determine tree water use. Based on daily tree water use and effective rainfall, containers were irrigated at 1.2 times their maximum daily water use the following evening. The total required irrigation was divided and applied in 3 cycles during the night using micro-irrigation spray stakes. Tree canopy width, height and trunk caliper at 6 and 12 inches and 1-inch below the first major branch were recorded every 3 weeks for the lysimeter trees.

In the spring of 2002, nine new lysimeters were fabricated and installed at MREC that could accurately weigh trees in up to #300 (5 ft diameter) containers. The three best maples were upcanned into Spin Out-painted and foil-covered #25 polyethylene containers in mid-April 2002. The three best live oaks were upcanned into identical containers the first of May 2002, with the 3 best hollies following suite in late May. Nineteen additional trees of each species were also upcanned into unmodified #25 black polyethylene containers and placed around the lysimeters. Trees are micro-irrigated at 1 pm EST and the containers re-saturated to container capacity each night.

During the #7 container stage, Reference Evapotranspiration (ETo) was calculated from a FAWN (Florida Automated Weather Network) remote weather station located less than 300 ft from the experimental site. A new remote weather station was established near the large tree lysimeters for more accurate calculation of ETo at their new location.

Results and Discussion: Tree water use (Actual Evapotranspiration, AET) was quite low (7 to 16 oz., 0.05 to 0.22 inch replacement in a #7 container) for the first several months after transplanting for maples (Fig. 1), and similar for the other two species (data not shown). Based on a concurrent experiment, evaporation from an uncovered container during this time was estimated to have been around 18 oz. or (0.25-inch replacement in a #7 container) daily. Thus irrigation applications would have required the sum of the AET and estimated evaporation [(0.05 to 0.22 inch) + 0.25 inch] to replace daily water loss from uncovered containers. By mid-August, the 12-inch maple liners had increased in height to about 5 ft, with AET rates of around 1 gal (1.7-inch replacement in a #7 container) daily. This was around 2/3 of the plant available water of this substrate in this container. Even after complete leaf drop, maples in covered containers maintained AET rates of around 6 oz. (0.08 inch replacement in a #7 container) per day when maximum temperatures were in the mid- to upper 70 F range. With bud break, AET rates of maples increased 8-fold over just a 10 day period of leaf expansion (Fig. 2).

From these AET rates, trunk calipers and daily ETo variables, models will be developed to estimate a tree's irrigation needs that can be tailored to specific locations. These needs should require only knowledge of ETo and tree caliper. With some modification, these models could also be used to estimate irrigation requirements of trees in landscape settings. Remote weather stations capable of calculating ETo range from $1,000 to $2,500 each, within the affordable range of moderate side to large tree farms. A new model, with a projected price of around $600, will be offered soon from Campbell Scientific in Logan, UT.

Significance to Industry: For better or worse, the nursery industry is being propelled towards incorporating precision agriculture by repercussions from the current drought, upcoming Federal regulations and urbanization. Models developed from this research will permit growers to more accurately determine how much irrigation to apply to a given size tree based on local or immediate microclimate situations. During the growing season, observations suggest that trees are often under-irrigated, resulting in reduced growth, which extends production time and thereby reduces profits. On the flip side, over-irrigation likely occurs during the fall and rainy/cloudy periods during the summer. In addition to helping nurseries become better stewards of their water resources, these models will provide a solid basis to justify irrigation needs during both production and landscape establishment.

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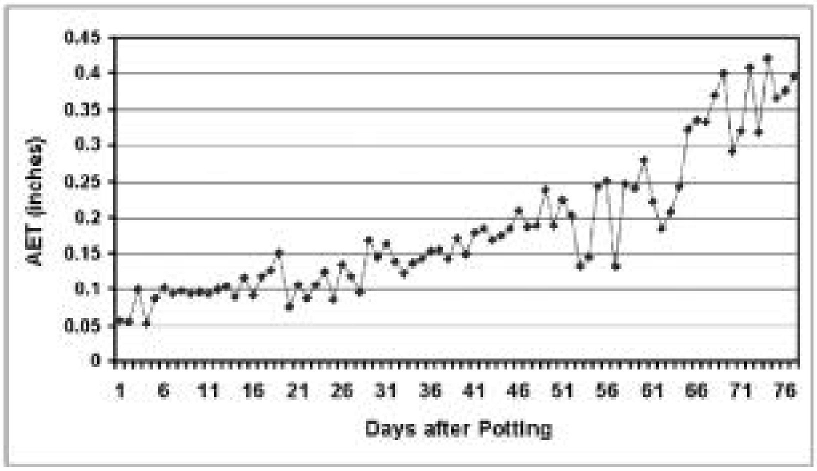

Figure 1. Mean Actual Evapotranspiration (AET) rate in inches per #7 container of newly transplanted cuttings in #7 containers from late March to mid-June 2001. Each point represents five tree replications.

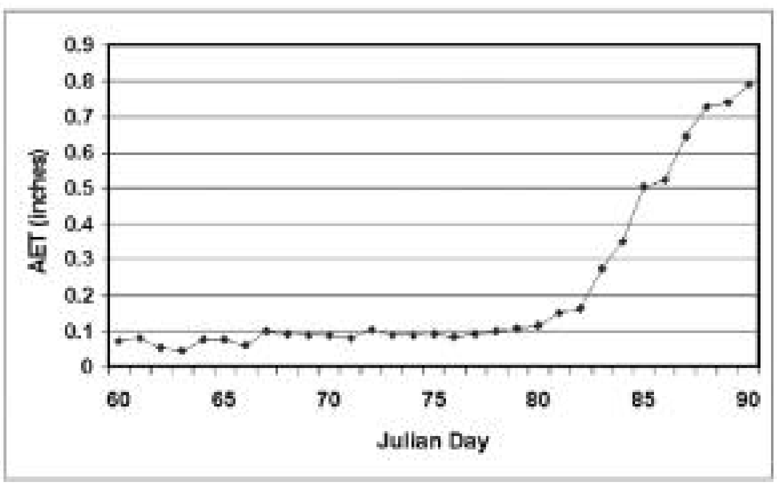

Figure 2. Mean Actual Evapotranspiration (AET) rate in inches per #7 container from March 1-31, 2002. Mean bud break occurred around 82 days into the year. Each point represents five tree species.

Evaluation of Fertilizer and Irrigation Production Systems for Large Containers

Anthony L. Witcher, Edward W. Bush, Drew Bates and Ann Gray
Louisiana State University Agricultural Center
Baton Rouge, LA 70803

Index Words: BMP's, Offsite Runoff, Leachates, Large Container, Irrigation, Fertilizer Placement and U*lmus parvifolia.*

Nature of Work: Demand for large container trees has increased in the last several years because their transplant survival rate is quite higher than field produced trees. Traditionally container-grown trees have been overhead irrigated, yet only 20% of the water applied is actually used by the plant (1). Large containers require significant amounts of space, which leads to increased runoff of unused irrigation water. Concerns of depletion and contamination of water sources by nursery and other industries has initiated programs for water conservation and regulation standards (2). An alternative to overhead irrigation is micro-irrigation, use of spray stakes or drippers, which has been shown to reduce runoff and nutrient loss while maintaining equal or improved plant growth (4). Other studies show that using cyclic irrigation, watering multiple times during the day, can further reduce runoff and leaching of nutrients. Studies of fertilizer placement, topdressing versus incorporation, indicate differences in plant size and amount of contaminates in runoff (3). This experiment will look at the relationship between type of irrigation, irrigation frequency and fertilizer placement in producing large container trees. The objective of this study is to compare two elements within each factor and determine which maximizes growth while minimizing effluent and nutrient loss.

This experiment was conducted at Burden Center in Baton Rouge, LA. Eighty 3-gallon Chinese elms (*Ulmus parvifolia)* were transplanted April 5, 2000 into 20-gallon Lerio containers using a pine bark, peat and sand (3:1:1 by volume) media amended with 8lbs/yd_ dolomitic limestone. Forty containers were topdressed with 1.14lbs of Osmocote 15-9-12 plus minors (12-14 Month) and forty were filled with media incorporated with 18lbs/yd_ of the same product. Half the containers were irrigated by Roberts Spot Spitters® (spray stakes) with a 6gph flow rate @ 15psi, while the rest contained 42" rings with drippers every 6", 3gph flow rate @ 15psi, made from drip tubing manufactured by Drip-In Irrigation Co. Thirty-two containers were placed on 10" tall square stands constructed of 1.5" angled iron, a 24" square rubber mat with a drain attached placed between the container and stand for collection purposes. Trees were arranged in a RCBD with 2 irrigation treatments (spray stake and drip ring), 2 fertilizer treatments (incorporated and topdressed), and 2 irrigation frequencies (one and three times per day) with 10 replications. Trees were irrigated at 6AM for the one time per day (1x) treatment and at 6AM, 12PM, and 6PM for the three times per day (3x) treatment. Effluent and leachates were taken monthly from July to November while a growth index, calculated by averaging height plus caliper measurements, was recorded every two months from June to October. Effluent was collected in 5-gallon containers and weighed to determine percent effluent. Leachates were collected from effluent and analyzed for pH, EC, N, P, and K. Height was taken in inches from the media surface to the apical meristem using a measuring pole. Stem caliper measurements were taken 6" above the media surface to the nearest 1/100 millimeter using a Mitutoyo® digital caliper.

Results and Discussion: Results reveal effluent was affected by irrigation type and frequency. Drip rings produced significantly more effluent than spray stakes for every month recorded (Figure 1), although overspray and drift by the spray stakes accounted for differences in effluent by irrigation type. Irrigating three times daily significantly reduces effluent by 15-24% compared to once a day irrigation (Figure 2). Results indicate growth was affected by fertilizer placement and irrigation frequency. Incorporating fertilizer produced statistically larger trees than topdressing in the months of August and October (Figure 3), but a grower would need to examine the pros and cons of each method in deciding the optimum system for their particular operation. Statistically, larger trees were produced by watering 3x compared to 1x (Figure 4), an easy adjustment a grower could make if they had an automated irrigation system. No significant differences for pH were observed between any of the treatments. In all cases EC remained in an acceptable range for vigorously growing plants. Leaching of N and P was significantly higher from the incorporated fertilizer in August and September compared to topdress. K leached significantly more from incorporated than topdressed from July to October. Higher temperatures inside the container could cause this since the fertilizer release rate is dependent on temperature.

Significance to Industry: This study showed cyclic irrigation reduced runoff and increased plant growth compared to a single application. Increased growth was also seen with incorporated fertilizer compared to topdressed. These results provide several production systems for large containers growers could consider.

Literature Cited:

1. Karam, N.S. and A. X. Niemiera. 1992. Low Water Application Rate and Intermittent Irrigation Increase Irrigation Efficiency of Sprinkler-Irrigated Container-Grown Plants. Proc. SNA Res. Conf. 37: 41-44.

2. Tyler, H.H., S.L. Warren and T.E. Bilderback. 1995. Cyclic Irrigation Increases Irrigation Efficiency and Ammonium Retention. Proc. SNA Res. Conf. 40:59-61.

3. Warren, S.L., T.E. Bilderback and H.H. Tyler. 1997. Does Method of Fertilizer Application (Surface or Incorporation) Affect Nutrient Losses of Controlled Release Fertilizers? Proc. SNA Res. Conf. 42:141-143.

4. Witmer, R.K., J.R. Harris, A.X. Niemiera and J. Fanelli. 1998. Frequent Irrigation Increases the Growth of Pot-in-Pot Sugar and Red Maple. Proc. SNA Res. Conf. 43:516-519

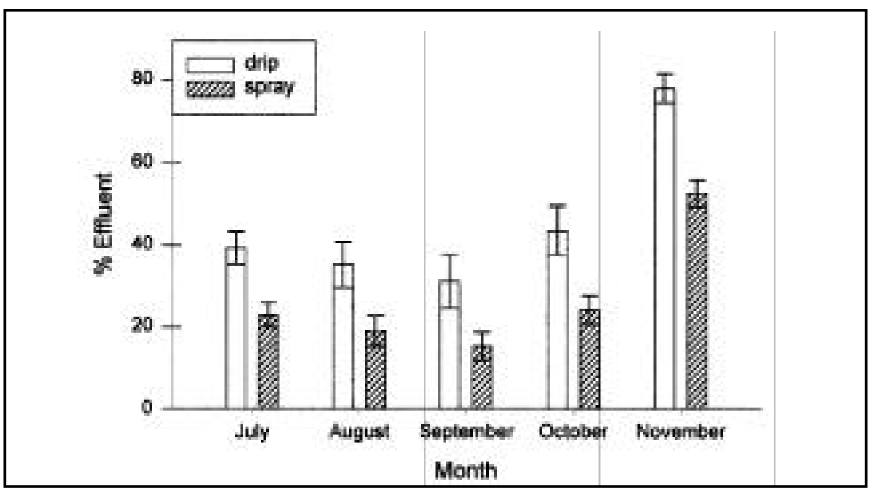

Figure 1. Percent effluent (% Effluent) in Chinese elms under two irrigation types – Drip rings (drip) and spray stakes (spray).

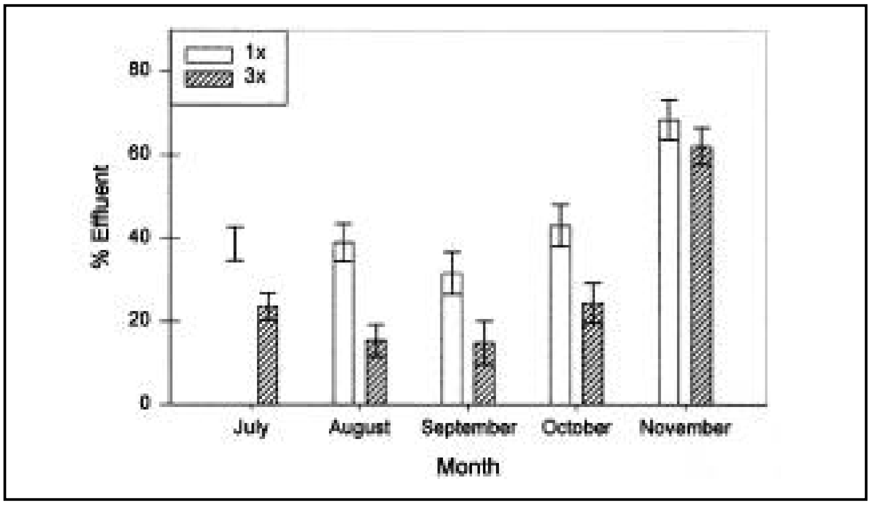

Figure 2. Percent effluent (% Effluent) in Chinese elms under two irrigation frequencies – once daily (1x) and three times daily (3x).

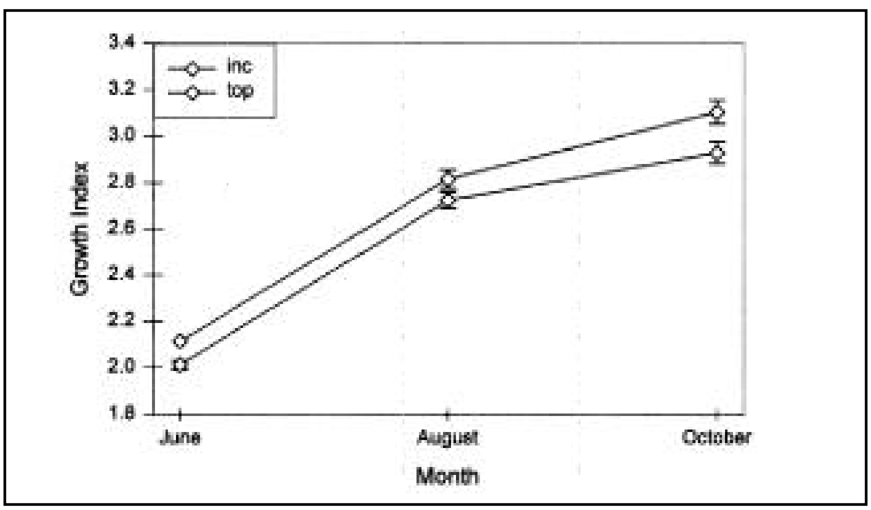

Figure 3. Growth Index of Chinese elm under two fertilizer placement methods – incorporated (inc) and topdress (top).

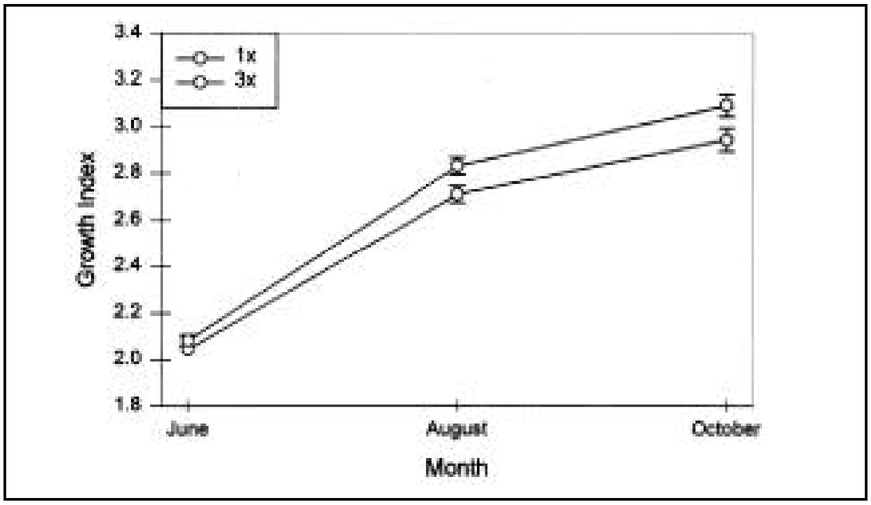

Figure 4. Growth Index of Chinese elm under two irrigation frequencies – once daily (1x) and three times daily (3x).

Irrigating Landscape Bedding Plants And Cut Flowers With Recycled Nursery Runoff

Michael A. Arnold[1], Garry V. McDonald[1], Bruce J. Lesikar[2], Donita L. Bryan[1], Amit Gross[3], and Dennis W. Hoffman[4]

[1]Dept. of Horticultural Sciences, Texas A&M University Mail Stop 2133, College Station, TX 77843-2133

[2]Dept. of Biological and Agricultural Engineering Texas A&M University, Mail Stop 2117 College Station, TX 77843-2117

[3]Environmental Hydrology & Microbiology J. Blaustein Institute for Desert Research Ben Gurion University of the Negev Ben Gurion College 84990, Israel

[4]Temple - Blackland Research and Extension Center Texas A&M University 720 East Blackland Road, Temple, TX 76502-9622

Index Words: Nursery effluent, constructed wetlands.

Nature of Work: Water quality, water availability, and environmental issues associated with runoff are becoming a concern for floral and nursery producers (2, 3, 4). Passing water through constructed wetlands has been shown to effectively reduce nutrient contaminant levels in nursery runoff (1). Elevated salinity was not a concern with single pass water during the spring months, but the potential effects of concentration of salts with water recycled during summer droughts and with multi-pass water remain unanswered (1). Disposal of excess nursery runoff is also an issue, thus alternative uses such as landscape application or production of compatible horticulture crops might represent a viable solution to disposal of this effluent. The objective of this study was to evaluate the efficacy of constructed wetlands remediated and direct nursery runoff as reclaimed water sources for irrigation of landscape bedding plants and cut flowers.

On June 7, 2001, two species of cut flower crops (*Helianthus annuus* L. and *Gladiolus* x *hortulanus* L.) and two bedding plants (*Catharanthus roseus* G. Don and *Zinnia elegans* N.J. von Jacquin) were established in trial beds irrigated with the four water treatments. The statistical design was a randomized complete block design with two blocks of water treatments each with three subplots each containing eighteen plant replications of a given species. The *H. annuus* were established from seeds, *G.* x *hortulanus* from corms, *C. roseus* from transplants, and *Z. elegans* from seeds. Growth and flowering data were gathered initially and at two week intervals for the bedding plants. Plots were fertilized with a complete granular formulation quick release fertilizer (13-13-13) at the inception of the study and monthly thereafter at the rate of 1 lb. of actual N per 1000 ft^2 of bed surface. Pre-irrigation soil samples were collected and analyzed for selected chemical characteristics. Initial and bi-weekly water samples from four water treatments were collected for analysis. The four treatments included direct nursery runoff, nursery runoff water treated via passage through constructed wetland cells containing *Canna* and *Iris* species, a municipal water source, and municipal water with elevated sodium (Na) levels (targeted injection to 3.0 mS). Three replicate water samples from each treatment were collected for analysis of nutrients and sodium levels.

Results and Discussion: Water samples indicated increasing levels of soluble salts in the municipal water (normal irrigation water, indicated as tap in graphs), container nursery runoff, and recycled wetland remediated water as the summer progressed (Fig. 1A). For the municipal water, this is probably a result of the drawing of groundwater from progressively deeper, lower quality, wells as the droughty summer season progressed. Single pass recycled water tended to increase in soluble salts concentration relative to the municipal water and direct nursery runoff late in the summer. Changes in total soluble salts in the nursery runoff and recycled water were due at least in part to elevated Na levels (Fig. 1B). Early in the summer runoff was less salty than the tap or recycled water due to the diluting effects of rainfall to the irrigation runoff. Later in the season an increase in the Na content of the nursery runoff occurred, likely due to evaporative concentration of the captured water relative to the applied irrigation (Fig. 1B). This process was even more evident in the recycled water in which the salts were further concentrated as evapotranspiration occurred during processing in the wetlands (Fig. 1B). Nitrates increased in both the nursery runoff and the recycled water as the season progressed and fertilization of the nursery continued (Fig. 1C). This increased concentration was likely an effect of the evaporative concentration of captured runoff from applied irrigation water (Fig. 3C). The decrease in nitrate concentration of the nursery runoff at week eight was a result of rainfall event that diluted the runoff just prior to sample collection. A single pass through the wetland cells substantially reduced the amount of nitrate in the water, but was inadequate to bring it to an acceptable discharge level of less than 10 ppm (mg/L) (Fig. 3C).

With the exception of the final two observation dates, flowering and growth of surviving Vinca was not meaningfully impacted by the irrigation treatments (Fig. 2 A, B). On these final two observation dates Vinca flowering and growth was reduced relative to plants irrigated with the municipal water source (Fig. 2A, B). This corresponded with the time period in which the Na and total soluble salts content of these irrigation sources were exceeding that of the municipal water source (Fig. 1A, B). Flowering and growth of Zinnia followed a similar pattern (Fig. 2C, D), but with an unexplained spike in flowering of plants irrigated with elevated salt levels on the final observation date despite this treatment being at or near the lowest flowering treatment at all other observation dates. Perhaps the late season spike in zinnia flowering was due to a leaching of the salts as it occurred shortly after the rainfall event that diluted the nursery runoff (Fig. 1C) While differences in growth of surviving plants was minimal for both species in response to the irrigation treatments, survival (Fig. 2E) was much lower with Zinnia than with Vinca, partly due to poor germination in high salt treatments. The most cut sunflowers were produced with the municipal water treatment (79 stems) compared to the other irrigation treatments, direct nursery runoff (50 stems), recycled wetland water (59 stems), and water with elevated salt levels (49 stems), which were similar to each other in production. While these treatments reduced the number of cut flowers produced, the quality of the flowers was generally similar to those from the municipal water source. Flower diameter was slightly reduced with the recycled water (19.3 cm) versus the municipal (20.6 cm), direct nursery runoff (21.3 cm), and elevated salt (21.2 cm) treatments. Quality ratings did not differ significantly ($P<0.05$) among the irrigation treatments for cut sunflowers. *Gladiolus* x *hortulanus* did not produce a saleable crop in any of the treatments, probably due to the mid-summer initiation of the experiment that necessitated holding the corms in cold (40°F) storage for an extended time prior to planting. This work was supported by a grant from the Texas Dept. of Agriculture's Texas - Israeli Exchange Board.

Significance to Industry: Drip application of single pass nursery runoff or direct nursery runoff were suitable for drip irrigating zinnia and vinca in landscape settings. These same treatments were effective for drip irrigating common sunflower as a cut flower crop, suggesting an alternative use for recycled or direct nursery runoff.

Literature Cited:

1. Arnold, M.A., B.J. Lesikar, A.L. Kenimer, and D.C. Wilkerson. 1999. Spring recovery of constructed wetland plants affects nutrient removal from nursery runoff. J. Environ. Hort. 17:5-10.

2. Wilkerson, D.C. 1995. Target 2000: an environmental plan for the floral and nursery industry. Texas A&M Univ. System, Texas Agric. Ext. Ser., College Station, TX.

3. Wilkerson, D.C. and M.A. Arnold. 1994. Thirst for conservation. Amer. Nurseryman 179(2):56-61.

4. Yeager, T., C. Gilliam, T. Bilderback, D. Fare, A. Niemiera, and K. Tilt. 1997. Best Management Practices for Producing Container-Grown Plants. Southern Nurserymen's Assoc., Marietta, GA.

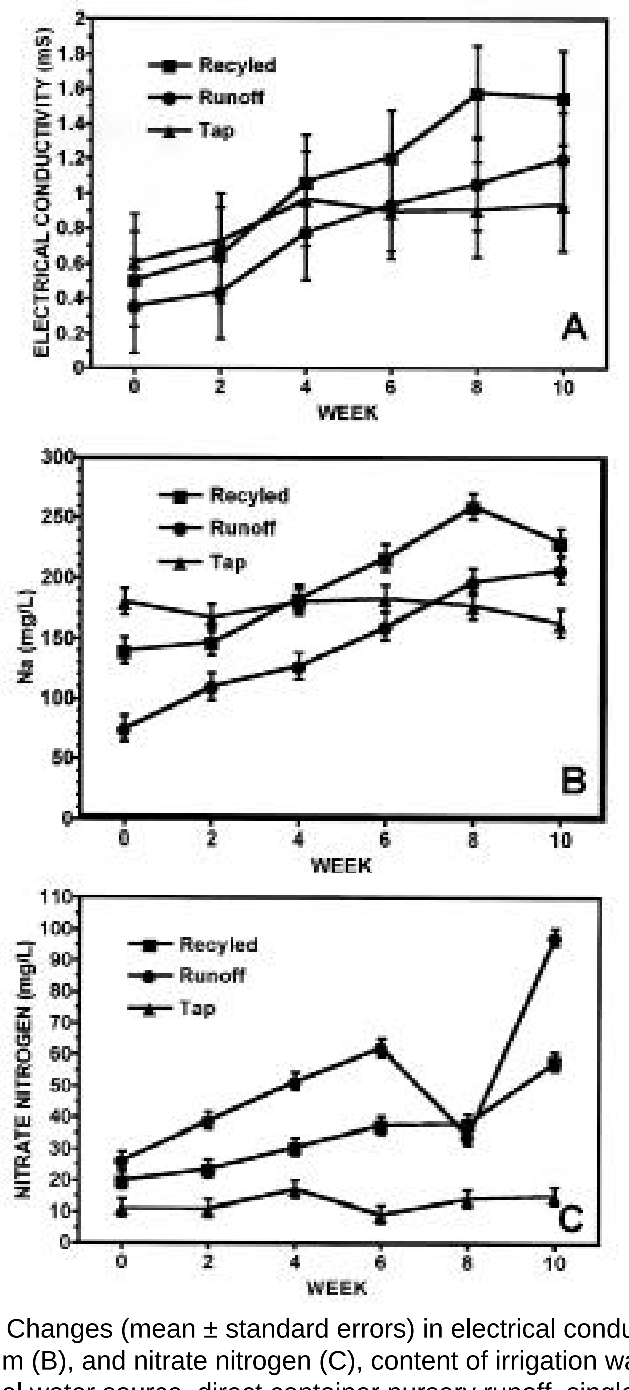

Figure 1. Changes (mean ± standard errors) in electrical conductivity (A), sodium (B), and nitrate nitrogen (C), content of irrigation water from a municipal water source, direct container nursery runoff, single pass recycled water from a constructed wetland, n = 3.

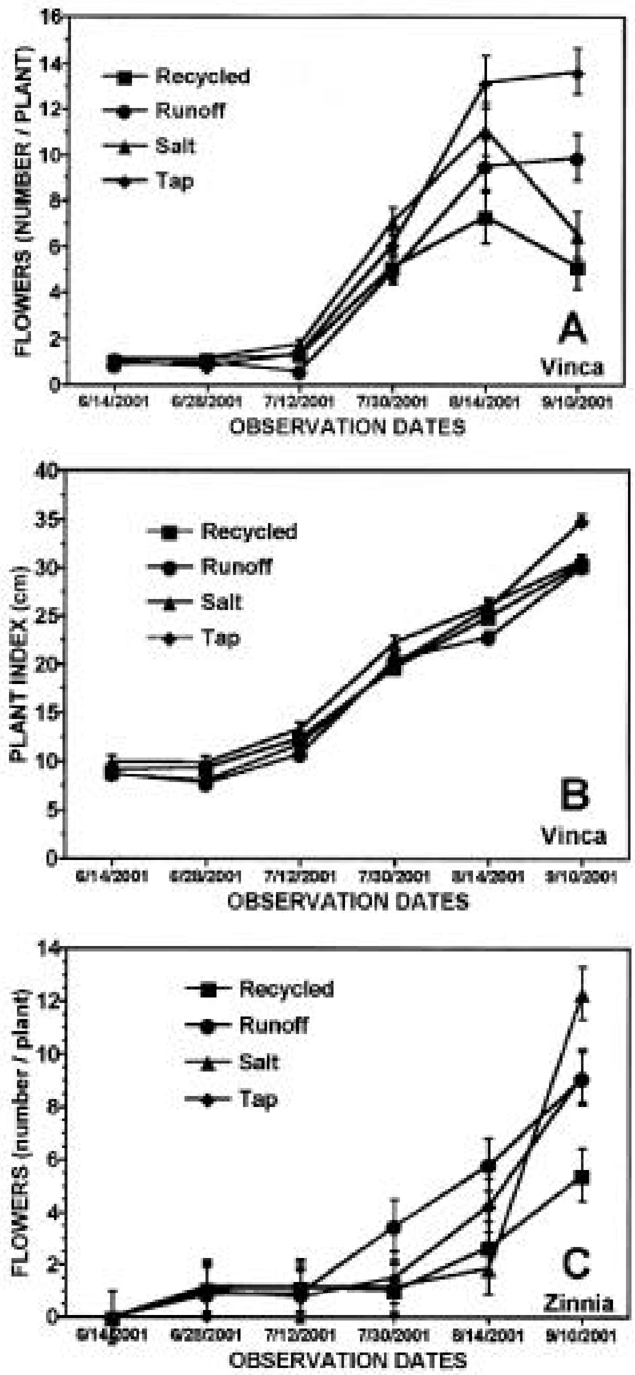

Figure 2. (continued on next page)

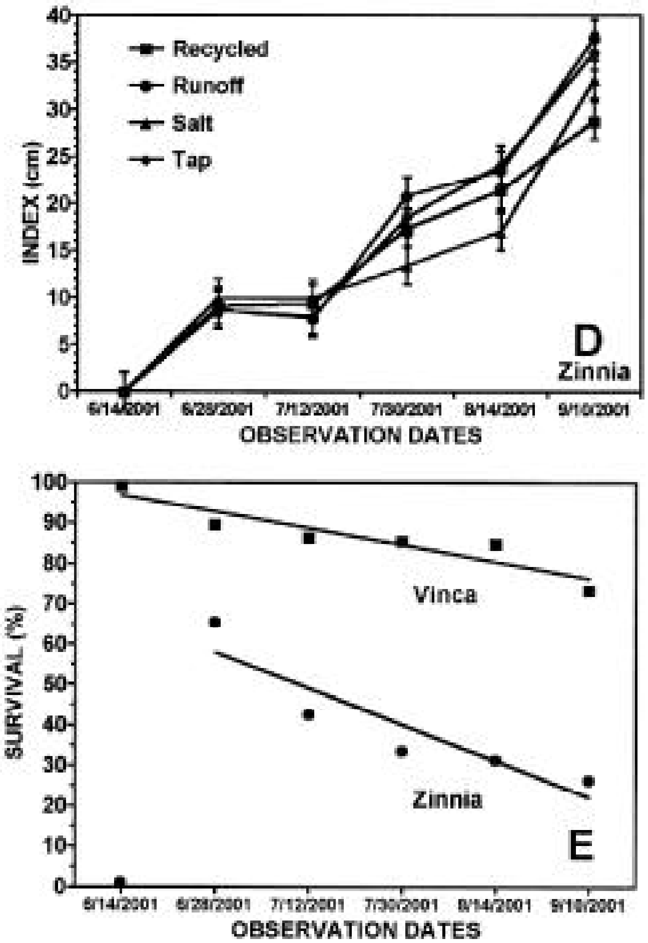

Figure 3. Flowering (A, B, means ± standard errors), plant index (B, D, means ± standard errors), and survival [E, means for zinnia (_) and vinca (_) with best fit linear regressions) responses if vinca (A, B, E) and zinnia (C, D, E) to irrigation with a municipal water source, nursery runoff, recycled water from a constructed wetland, or water with an elevated salt content, n = 108 for plant index and flowering, n = 6 for survival.

Timing of Low Volume Irrigation Affects Plant Growth

**Stuart L. Warren, Ted E. Bilderbach,
Cindy Lambert and Jim S. Owen**

**NC State University, Dept. of Horticultural Science,
Raleigh, NC 27695-7609**

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Nature of Work: Pine bark based container substrates, common in the southeastern United States, have low moisture retention properties; therefore, daily irrigation during the growing season is required to maximize plant growth. Current "best management practices" state that irrigation should occur during the early morning hours (before 1000 HR) to reduce potential of wind blowing the irrigation water from the targeted area and to reduce evaporation of irrigation water (Yeager et al., 1997). A recent survey of Alabama nurseries stated that most nurseries (> 60%) are following this recommendation (Fain et al., 2000). However, previous research indicated that multiple application of water each day resulted in more growth compared to early morning application. Keever and Cobb (1984) reported irrigation during the day (1300 HR or split application at 1000 and 1500 HR) reduced substrate and canopy temperature that they claimed increased top and root growth of Rhododendron x 'Hershey's Red' compared to irrigation at 2000 HR. Beeson (1992) working with four woody ornamentals also reported increased growth when irrigation was applied during the day in contrast to predawn (0600 HR) irrigation. However, he attributed the increased growth to lower daily accumulated water stress. Unfortunately, the times of irrigation during the day were not reported. Thus, irrigating during the day may increase growth by reducing heat load and minimizing water stress in the later part of the day. Therefore, our objective was to evaluate the effects of irrigation timing on plant growth, photosynthesis, and substrate temperature.

The study was a randomized complete block design with 4 replications. Rooted cuttings of *Cotoneaster dammeri* 'Skogholm' were potted into one gallon containers in an 8 pine bark : 1 sand (by vol) substrate amended with 2 lbs/yd^3 dolomitic limestone. Each plant was fertilized at potting with 5.0 g N (0.18 oz) from 17-5-10 (5-6 month, Pursell Technology, Sylacauga, AL).

The daily total volume of irrigation to maintain a 0.2 ±0.05 LF within each treatment was divided into three equal parts and applied at the following times:

A. 0200, 0400, and 0600 HR (predawn)
B. 0600, 0900, and 1200 HR (AM)
C. 1200, 1500, and 1800 HR (PM)
D. 0600, 1200, and 1800 HR (all day)

Leaching fraction was monitored daily. Irrigation was applied via pressure compensated spray stakes {Acu-Spray Stick; Wade Mfg. Co., Fresno, CA [200 ml/min (0.3 in/min)]}.

Substrate temperatures were measured in two locations in one container in every replication (total of 8 thermocouples / treatment) for the entire study. Two copper-constantan thermocouples were positioned in the substrate halfway down the container profile 1 in from the container wall on both the northern and southern exposure. Thermocouples were connected to a 23X micrologger via a AM-32 multiplexer (Campbell Scientific, Logan, Utah). Temperature data were recorded every 5 min and averaged over each 60-min interval. Maximum, minimum, and average temperature along with time of maximum, and time of minimum were recorded every 60 min. Substrate temperatures were averaged over exposure before analysis.

At harvest, tops (aerial tissue) from five randomly chosen containers per plot (total of 20 containers / treatment) were removed. Roots were placed over a screen and washed with a high pressure water stream to remove substrate. Shoots and roots were dried at 150F for 5 days and weighed. Diurnal measurements of net CO_2 assimilation were made on July 20 and August 17, 2000 on one plant from each replication (4 plant / treatment), using a portable photosynthesis system containing a LI-6200 computer and LI-6250 gas analyzer (LI-COR, Lincoln, Nebraska). A diurnal measurement event consisted of measurements during late morning from 1030 to 1130 HR, at midday from 1300 to 1400 HR and late afternoon from 1600 to 1700 HR.

Data were subjected to analysis of variance procedures (ANOVA). Treatments means were separated by LSD, $P = 0.05$.

Results and Discussion: *Leaching fraction and dry weight.* A total of 18.7 L, 26.4 L, 27.5 L, and 26.4 L of irrigation water was applied to predawn, AM, PM, and all day, respectively resulting in LFs of 0.19, 0.15, 0.13, and 0.13, for predawn, AM, PM, and all day, respectively. Plants irrigated with PM had significantly greater top dry weight compared to all other irrigation timings (predawn, AM, and all day) (Table 1). Top dry weight was 71% heavier when irrigated with PM compared to predawn. Root dry weight increased 62% when irrigated with PM (1200, 1300, and 1600 HR) compared to predawn. Plants irrigated with midday, PM, and all day irrigation had similar root dry weights. In general, plants irrigated with PM produced the best results. This study suggests that if presumably sufficient daily irrigation is restricted to early morning hours, growth will be significantly reduced compared to plants grown with irrigation applied during the day.

Photosynthesis. Results from July 20 and August 17 were similar, so only data from August 17 are presented. At 1100 HR, plants irrigated with PM and all day had 48% higher rates of photosynthesis compared to predawn and AM (Table 2). Compared to 1100 HR measurements, photosynthesis of all treatments decreased at 1330 HR. This is probably due to increased canopy and substrate temperature. Only plants irrigated all day had significantly greater photosynthesis than predawn and AM at 1330 HR. This may reflect the two irrigation cycles all day (0600 and 1200 HR) had received by 1330 HR compared to the one cycle for PM irrigation (1200 HR). Thus, plants irrigated PM may have had reduced photosynthesis due to limited water availability. At 1630 HR, photosynthetic levels of plants irrigated predawn, AM, and all day decreased compared to 1330 HR suggesting increasing water and temperature stress. However, plants irrigated with PM had increased photosynthetic measurements compared to 1330 measurements. At 1630 HR, plants irrigated with PM had 86% higher rates of photosynthesis compared to predawn and AM. Both AM and all day had water applied at 1200 but this does not appear to be sufficient to maintain phtosynthetic levels through 1630 HR. Plants irrigated PM received additional water at 1500 HR which appeared to maintain photosynthetic levels. Beeson (1992) reported the greatest differences in shoot water potential between plants irrigated predawn and plants irrigated throughout the day occurred in mid- to late afternoon. Generally by 1300 HR plants irrigated predawn had lower water potential with the difference becoming more pronounced by 1600 HR.

Substrate temperature. Containers irrigated with predawn and AM treatments had similar temperature profiles (data not presented). The time of daily maximum for containers irrigated predawn occurred at 1630 HR (111F). Time of daily maximum and maximum temperature for containers irrigated PM and all day were similar (1530 HR, 104F). Containers irrigated predawn had significantly lower temperatures at 0600, 0700, and 0800 HR compared to PM however, the differences were very small. Container irrigated with PM and all day had significantly lower temperatures from 1800 to 2200 compared to predawn for most days. Compared to predawn, daily maximum temperatures for PM were usually significantly lower by 3F to 5F. This difference in temperature in combination with available water could have a significant impact on photosynthesis (Ruter and Ingram, 1990).

Significance to Industry: Irrigation timing had a significant affect on plant growth, photosynthesis, and container temperature. Plants that were irrigated 1200, 1500, and 1800 HR significantly outperformed plants irrigated during early morning hours. Decreases in plant growth appear to be related to increases in diurnal water stress over the course of the growing season. Growers should avoid letting the container substrate dry out by late afternoon. Our data suggests that growers may want to investigate irrigating at times other than early morning.

Literature Cited:

1. Beeson, R.C. 1992. Restricting overhead irrigation to dawn limits growth in container grown woody ornamentals. HortScience 27:996-999.

2. Fain, G.B, C.H. Gilliam, K.M. Tilt, J.W. Olive, and B. Wallace. 2000. Survey of best management practices in container production nurseries. J. Environ. Hort. 18:142-144.

3. Keever, G.J. and G.S. Cobb. 1985. Irrigation scheduling effects on container media and canopy temperature and growth of ‘Hershey’s Red’ azalea. HortScience 20:921-923.

4. Ruter, J.M. and D.L. Ingram. 1990. ^{14}Carbon-labelled photosynthesis partitioning in Ilex crenata ‘Rotundifolia’ as supraoptimal root-zone temperatures J. Amer. Soc.Hort. Sci. 115:1008-1013.

6. Yeager, T.H., C.H. Gilliam, T.E. Bilderback, D.C. Fare, A.X. Niemiera, and K.M. Tilt. 1997. Best Management Practices Guide for Producing Container-Grown Plants. Southern Nurs. Assoc., Marietta, GA.

Table 1. Effect of irrigation timing on dry weight of

Cotoneaster dammeri 'Skogholm'.

Irrigation timing	----Dry weight (g)---- Top	Root
Predawn	60.7 d[z]	12.8 b
AM	80.3 c	18.0 a
PM	103.5 a	20.7 a
All day	91.0 b	19.7 a

[z]Means within columns followed by the same letter or letters are not significantly different as determined by LSD, P = 0.05.

Table 2. Effect of irrigation timing on net CO_2 assimilation (µmol $CO_2 \cdot m^{-2} \cdot s^{-1}$) of

Cotoneaster dammeri 'Skogholm'.

Irrigation timing	Time 1100	1330	1630
Predawn	5.9 b[z]	5.4 b	4.0 c
AM	5.5 b	4.6 b	4.2 bc
PM	8.7 a	6.5 ab	7.6 a
All day	8.4 a	7.5 a	6.0 ab

[z]Means within columns followed by the same letter or letters are not significantly different as determined by LSD, P = 0.05.