during harvest and increased number of species that can be produced bare root. Further, because of reduced weight and bulk, container-produced bare root whips can be shipped greater distances than similar sized container-grown stock. Therefore, containerized bare root whip production is not limited to regional markets.

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Cyclic Irrigation and Media Affect Container Leachate and Ageratum Growth[1]

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Abstract

Two experiments were conducted with container-grown *Ageratum houstonianum* Mill. 'Blue Puffs' to compare cyclic and continuous irrigations. In experiment 1, leachate volumes were reduced about 54% with 0.4 cm (0.16 in) cyclic irrigation treatments applied with either a 30 min or 2 hr resting phase compared to continuous irrigation of 0.4 cm (0.15 in). Total N leached was about 47% less with the cyclic treatments compared to continuous irrigation. In experiment 2, container leachate volumes and N leached were higher from a pine bark:sand medium, while plants were smaller compared to a pine bark:peat medium. Growth index and root distribution were similar with cyclic and continuous irrigation.

Index words: water quality, interval irrigation, intermittent irrigation, pulse irrigation.

Species used in this study: ageratum (*Ageratum houstonianum* Mill. 'Blue Puffs').

Significance to the Nursery Industry

There are increasing demands to improve the quality of runoff water in container nursery production areas. These experiments demonstrate the influence of media and irrigation practices on container leachate volume and subsequent NO_3-N + NH_4-N loss. Media with greater water holding capacities and higher CEC can improve water quality of container leachate by reducing leachate volume and NO_3-N leached. These data also demonstrate cyclic irrigation can reduce container leachate volumes and leachable forms of N as compared to current irrigation practices, while producing plants of similar size and quality. Cyclic irrigation could become a practical alternative in addressing future environmental regulation. This concept could be incorporated into irrigation management without substantial investment using equipment currently available at many container nurseries.

Introduction

Nurseries in the southeastern United States utilize large volumes of water to meet irrigation demands of container-grown plants in pine bark-based media (4, 15). Overhead

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sprinkler irrigation is the most common application method for producing plants in containers 20 liter (#5) and smaller (1). Rathier and Frink (17) reported about 9.9 million liters (2.6 million gal) of water are needed to produce an acre of plants in a growing season. Environmental awareness has forced nursery producers to evaluate production practices that will reduce water use and irrigation runoff, and improve runoff water quality. Alternative irrigation systems, such as trickle, ebb and flow, and capillary mat, are more efficient than overhead sprinkler irrigation; but only feasible when used to irrigate high value greenhouse crops and large container nursery stock (1, 11).

Milled pine bark is a primary component of container media for growing nursery stock in the southeastern United States. Many amendments have been evaluated for their influence on porosity (total and air) and water holding capacity (3, 8, 16). Physical properties of pine bark media are such that aeration is increased at the expense of water holding capacity (18) and nutrient retention. Increased emphasis on reduced water use suggest that media with higher water holding capacities, such as those containing peat, may play an important role in reducing nutrient leaching (4, 15).

Limited research has been conducted evaluating water use, conservation or recycling with overhead sprinkler systems in container nurseries. Karmeli and Peri (13) reported the benefits of cyclic irrigation with overhead sprinklers on traditional agricultural crops. Cyclic irrigation is defined as a series of two-phase irrigation cycles, 1) the operating phase of the irrigation system, and 2) the phase during which the system is at rest. In practice, cyclic irrigation does not necessarily change the amount of water applied in an irrigation cycle, but extends the time of irrigation application, thereby decreasing the irrigation rate. The objective of this research was to compare irrigation (cyclic vs continuous) and media effects (experiment 2 only) on container leachate volume, nitrate-N (NO_3-N) and ammonium (NH_4-N) levels in the leachate, and growth of 'Blue Puffs' ageratum.

Materials and Methods

Experiment 1. Uniform liners of 'Blue Puffs' ageratum in 245 ml (8.3 oz) rose pots were potted into 2.8 liter (#1) nursery containers [6.4 × 6.6 in (16.3 × 16.8 cm)] on February 13, 1991. Plants were grown in a double-layer polyethylene greenhouse where average daily air temperature and relative humidity fluctuated from 17C to 31C (63 to 88F) and 38 to 98%, respectively. Container medium was a pine bark:sand mixture (6:1 v:v) amended with 3.0 kg/m^3 (5 lb/yd^3) dolomitic limestone and 0.9 kg Micromax/m^3 (1.5 lb/yd^3). Plants were topdressed with 5.0 g (0.2 oz) of 12N–2.6P–5.0K (12–6–6, Pursell Industries, Sylacauga, AL). Particle size distribution of the medium was determined with oven-dried medium sieved through U.S. Standard Sieves (Table 1). Medium water holding capacity and drainable pore space were determined from procedures adapted from Gessert (9) and Whitcomb (19).

Plants were hand watered to saturation at potting. On the following day, plants were hand watered, allowed to drain 1 h, and weighed (container capacity). Thereafter, plants were watered with overhead irrigation using a wide, full-cone TeeJet® nozzle (Spraying Systems Co., Wheaton, IL). Irrigation application rate was 9.6 cm/hr. Four irrigation treatments were included: one continuous irrigation applied at 0.5 cm (0.20 in) (1C.5), one continuous irrigation applied at 0.4 cm (0.16 in) (1C.4), two cycles with a total of 0.4 cm (0.16 in) irrigation and a 30 min resting phase (2C.4-30), and two cycles with a total of 0.4 cm (0.16 in) irrigation and a 2 hr resting phase (2C.4-120). Treatments were arranged in a randomized complete block design with three replications of six plants each per experimental unit. Plants were weighed each morning (7 AM) to determine water loss since the previous irrigation. Irrigation was applied to all treatments when the 1C.5 treatment reached 80% of the medium water holding capacity (Table 2). The irrigation volume applied was predetermined to bring the medium to near container capacity in treatment 1C.5. Irrigation was applied between 7 AM and 10 AM. Biernbaum (2) suggested most plants should be watered when 60–70% of the available water is used by the plant or had evaporated. Based on soil moisture release curves (data not shown), 40% of the total water volume was unavailable to the plants. Thus, in these experiments, irrigation was applied when about 50% of the available water was used by the plant or had evaporated from the medium surface.

Container leachate was collected during each irrigation. Each plant was placed in an 18.0 cm (7.1 in) diameter petri dish on a 1.3 cm (0.5 in) tall and 7.6 cm (3.0 in) diameter PVC ring to elevate the container. A shield of clear acetate was attached to the container rim and extended 1.3 cm (0.5 in) below the petri dish rim to prevent irrigation water from entering the petri dish and diluting the container leachate. Container leachate from a one-hour irrigation application was collected and combined from the six pots in each treat-

Table 1. Bulk density, particle size distribution, water holding capacity, and CEC of container media (experiments 1 and 2).

Media	CEC[z]	Bulk density (g/cm^3)	Particle size distribution, (% of dry wt)[y] sieve openings, mm							Water holding capacity (%)[y]
			6.3	4.7	2.8	1.0	0.5	0.250	0.106	
Experiment 1										
Pine bark:sand (6:1)	—	0.45	7.7	14.8	31.1	13.1	24.5	7.3	0.8	26.0
Experiment 2										
Pine bark:sand (6:1)	14.3	0.57	9.3	5.9	23.9	35.7	17.9	2.7	0.9	29.9
Pine bark:peat (4:1)	42.4	0.35	14.5	9.4	26.5	39.8	7.1	0.8	0.5	35.6

[z]CEC = cation exchange capacity, meq/100 g medium.

[y]Water holding capacity = percent of total container volume.

Table 2. Effects of cyclic irrigation on container leachate volume, and N (concn. and total) at 1, 10, and 25 days after potting (experiment 1[z]).

Treatment[y]	Container leachate (ml)[x]	NO_3-N (mg/liter)[w]			NH_4-N (mg/liter)[w]			Total N[v] (mg/pot)			GI (cm)[u]	Shoot dry wt (g)	Total root dry wt (g)
		1	10	25	1	10	25	1	10	25			
1C.5	48.2	0.3	30.2	2.7	1.3	15.0	3.0	0.08	2.2	0.28	20.6	12.4	5.2
1C.4	47.7	0.3	32.9	6.6	1.7	9.4	8.6	0.10	2.0	0.73	20.5	12.0	5.2
2C.4-30	27.8	0.5	39.1	5.3	2.0	19.2	8.2	0.07	1.6	0.38	19.9	11.4	5.4
2C.4-120	16.5	0.9	30.2	5.2	1.4	12.9	8.5	0.04	0.7	0.23	18.9	9.1	3.7
LSD	13.3	0.9	19.7	2.9	1.9	13.1	3.1	0.07	0.7	0.13	1.1	3.0	1.7
Contrast (probability)													
1C.5 vs. 1C.4	0.974	0.929	0.754	0.017	0.672	0.372	0.005	0.060	0.668	0.001	0.923	0.712	0.868
1C.4 vs. 2C.4-30 & 2C.4-120	0.001	0.250	0.809	0.227	0.956	0.197	0.784	0.173	0.006	0.001	0.031	0.167	0.282
2C.4-30 vs. 2C.4-120	0.098	0.320	0.319	0.888	0.508	0.285	0.857	0.353	0.029	0.029	0.086	0.072	0.048

[z]Potted February 13, 1991.

[y]Treatment: 1C.5 = one cycle with 0.5 cm continuous irrigation; 1C.4 = one cycle with 0.4 cm continuous irrigation; 2C.4-30 = two cycles with a total of 0.4 cm irrigation and a 30 min resting phase; 2C.4-120 = two cycles with a total of 0.4 cm irrigation and a 2 h resting phase.

[x]Average of volumes collected at each irrigation.

[w]Days after potting.

[v]Total N (NO_3-N and NH_4-N).

[u]GI: growth indices = [height + $width_1$ + $width_2$ (perpendicular to $width_1$)] / 3.

ment to determine leachate volumes. At five-day intervals, container leachates were analyzed for pH, electrical conductivity (EC), NO_3-N and NH_4-N (data shown for days 1, 10, and 25). Immediately after collection, leachate pH was measured with an Orion ion analyzer (Model 940, Orion Research, Inc., Boston, MA.), and EC was measured at 25C (77F) with an YSI conductance meter (Model 35, YSI, Inc., Yellow Springs, OH). Leachate pH was between 6.2 and 6.4 during the experiment and was not affected by irrigation treatments (data not shown). Leachate samples were filtered and refrigerated at 4C (39F). Within four weeks samples were analyzed for NO_3-N and NH_4-N with an ammonia analyzer (Wescan 360, Alltech Associates, Deerfield, IL). Total N was determined by adding NO_3-N and NH_4-N concentrations and multiplying by average leachate volume.

One plant/treatment/replication was harvested for fresh and dry shoot and root weights during the middle of the experiment to adjust for plant growth and to recalibrate the watering needs for the increased plant mass. Growth indices {[height + $width_1$ + $width_2$ (perpendicular to $width_1$)] / 3} of the remaining plants (five plants per experimental unit) were determined at 25 days after potting. Shoots were cut at soil level, oven-dried at 57C (135F) for 48 hr, and weighed. The experiment was repeated with minor modification. Main effects were partitioned for orthogonal contrast. Due to similar results only the first experiment is presented.

Experiment 2. A second experiment similar to the first was conducted with the following exceptions. Plants were potted on May 5, 1992. Two media were evaluated, a pine bark:sand medium (BS) (6:1, v:v) or a pine bark:peat medium (BP) (4:1, v:v). Two irrigation treatments were applied: one continuous irrigation with 0.4 cm (0.16 in) (1C.4) and two cycles with a 30 min resting phase with a total of 0.4 cm (0.16 in) water (2C.4). The respective media designations are BS1C.4 and BS2C.4 for pine bark:sand medium and BP1C.4 and BP2C.4 for pine bark:peat medium. Potted plants were weighed each morning to determine gravimetric weight loss. Irrigation was applied when container capacity reached 80% in treatment BS1C.4. Root growth was determined by dividing the rootball into 3 sections: upper third = top of rootball to a depth of 5 cm (2.0 in); middle third = 5 cm (2.0 in) to 10 cm (4.0 in) depth; and the lower third = 10 cm (4.0 in) to 15 cm (5.9 in) depth (bottom of the rootball). Roots were separated from the medium, washed, oven-dried and weighed. Root dry weights in the three sections were combined to determine total root dry weight.

Results and Discussion

Experiment 1: Plant response. Plants grown with cyclic irrigation were of acceptable quality except 2C.4-120 (authors' observations). Plants grown with cyclic 2C.4-120 had less growth indices compared to plants in treatment 1C.4 (Table 2). When the resting phase was extended to 2 hr, water holding capacity of the medium was not recharged as it was with the other treatments. During the last few days of the test, several plants in this treatment (2C.4-120) reached incipient wilt by mid-afternoon, but recovered turgor during the night. Plants grown in the cyclic treatment 2C.4-120 had lower, although not significant, shoot dry weight compared to plants in treatment 2C.4-30 (9.1 g vs. 11.4 g).

Total root dry weight was lowest when the resting phase was extended to 120 minutes (Table 2). All other treatments were similar in total root dry weight. Root distribution of plants in all treatments was primarily in the upper third of the rootball regardless of irrigation treatment (data not shown). Plants irrigated with 2C.4-120 had less dry root weight in the upper third of the rootball and less total root dry weight than other treatments. In this treatment (2C.4-120), some channelling of water through the medium occurred; but root growth in the top third of the container was more affected by overall drying of the medium surface than pockets of dry medium. This implied that the resting phase length could be critical in the production of plants with cyclic irrigation. As the resting phase is lengthened, the possibility of the media reaching container capacity is decreased.

Experiment 2: Plant response. Growth index was similar when comparing cyclic irrigation and traditional irrigation (Table 3). Growth index was generally 5% larger for plants grown in a BP medium compared to a BS medium (Table 3). This growth difference could be attributed to the higher water holding capacity and the higher cation exchange capacity (CEC) of the pine bark:peat medium compared to the pine bark:sand medium (Table 1).

Experiment 1: Container leachate. Cyclic irrigation reduced container leachate volume. Container leachate from cyclic irrigation treatments 2C.4-30 and 2C.4-120 averaged 27.8 ml (0.9 oz) and 16.5 ml (0.5 oz)/pot, respectively, which was a 54% reduction compared to the 1C.4 continuous irrigation treatment (Table 2). Forty-one percent less leachate was collected when the resting phase between cycles was extended from 30 min to 2 hr. These data concur with Daughtry's (5) field observations that cyclic irrigation could reduce container leachate volume and with Karam and Niemiera (12) who reported 32% less water leached with cyclic irrigation compared to continuous irrigation. Container leachate volumes were similar with traditional irrigation when 0.5 (1C.5) cm (0.2 in) or 0.4 (1C.4) cm (0.16 in) was applied (Table 2).

Experiment 2: Container leachate. Container leachate was less with cyclic irrigation than with continuous irrigation (Table 3) in both BS and BP media. Container leachate volume was reduced by 14% and 40% in BS and BP media respectively, when cyclic irrigation was compared to continuous irrigation application. These data agree with previous work (7) where container leachate volume was reduced 34% with cyclic irrigation (plants grown in a pine bark:peat medium) compared to continuous irrigation. Container leachate volumes were 45% less from the BP medium than from the BS medium. These data indicate that container media with greater porosity could subsequently have less container leachate due to the water holding capacity of the media (Table 1). These data concur with a report of reduced container leachate with cyclic irrigation (7) and agree with Biernbaum (2) who reported container media can impact container leachate volume.

Table 3. Effects of cyclic irrigation and media on container leachate volume, total N leachate at 1, 10, and 25 days after potting, and growth (experiment 2[z]).

Treatment[y]	Container leachate (ml)[x]	Total N[w] (mg/pot) 1	10	25	GI (cm)[v]
Pine bark:sand (6:1)					
BS1C.4	37.0	4.4	7.5	1.0	21.5
BS2C.4-30	32.2	2.6	5.7	0.6	21.4
Pine bark:peat (4:1)					
BP1C.4	24.1	2.6	4.4	0.2	21.8
BP2C.4-30	14.3	1.2	3.0	0.2	23.1
LSD	7.7	1.8	3.7	0.7	1.5
Significance					
Media	0.001	0.026	0.043	0.020	0.059
Irrigation	0.016	0.024	0.168	0.383	0.283
Media × Irrigation	0.329	0.640	0.865	0.257	0.209

[z]Potted May 5, 1992.

[y]Treatment: BS1C.4 = pine bark:sand with one continuous irrigation applied at 0.4 cm; BS2C.4-30 = pine bark:sand with two cycles with a 30 min resting phase applied 0.4 cm irrigation; BP1C.4 = pine bark:peat with one continuous irrigation applied at 0.4 cm; BP2C.4-30 = pine bark:peat with two cycles with a 30 min resting phase applied 0.4 cm irrigation.

[x]Average of volumes collected at each irrigation.

[w]Total N (NO_3-N and NH_4-N).

[v]GI: growth indices = [height + $width_1$ + $width_2$ (perpendicular to $width_1$)] / 3.

Experiment 2: Media. Differences in physical properties existed for the two media; however, both media provided acceptable physical properties for container production (Table 1) (10). de Boodt and Verdonck (6) reported the ratio for water/air (% v/v) should be about 1:1 between 15 and 25 cm water tension to provide optimal quantities of water and air in the root zone. In this experiment, both media conformed to this air to water ratio (% v/v).

Another important physical property of a potting medium is water-holding capacity (14); however, water available to the plant is more important (16). A moisture release curve was determined for each medium prior to potting (data not shown). BS medium held less water than BP at moisture tensions ranging from 10 to 100 cm. Irrigation was applied when the BS1C.4 reached 80% of the water holding capacity. Based on the moisture release curve, the BP moisture level was slightly higher than 80% when irrigation was applied.

Experiment 1: Nitrogen leached. Cyclic irrigation or irrigation volume did not affect leachate NO_3-N or NH_4-N concentrations at most sampling dates (Table 2). The highest NO_3-N and NH_4-N concentrations for all treatments occurred at day 10 and decreased during the rest of the experiment regardless of the irrigation treatment. This pattern probably resulted from the typical release pattern of the fertilizer used and increased plant absorption.

Total N (NO_3-N and NH_4-N) leached (volume × concentration) was similar among treatments at day 1 (Table 2). At day 10, total N leached was 42% higher in the continuous irrigation treatment, 1C.4, compared to cyclic treatments, 2C.4-30 and 2C.4-120. This difference was due to reduced leachate volume with cyclic irrigation treatments compared to continuous irrigation application since leachate N concentrations were similar. There was a substantial reduction in total N leached from the pots when the resting phase was extended from 30 min to 2 h. These data agree with Yelanich and Biernbaum (20) who reported higher irrigation volumes can result in higher leachate volumes and leachable NO_3-N from container medium. Total N leached during the experiment is important environmentally. For instance, about 47% less total N leached from the cyclic treatments, 2C.4-30 and 2C.4-120, compared to the continuous application, 1C.4.

Experiment 2: Nitrogen leached. Cyclic irrigation or irrigation volume did not affect NO_3-N or NH_4-N concentrations (data not shown). Cyclic irrigation and media affected total N (mg/pot) in container leachate (Table 3). Total N leached from BS medium was significantly greater than from the BP medium. For example, at day 10 in experiment 2, container leachates from the BS treatments (BS1C.4 and BS2C.4-30) contained 6.6 mg total N compared to 3.7 mg from the BP treatments (BP1C.4 and BP2C.4-30).

Total N in container leachate from cyclic irrigation treatments (BS2C.4 and BP2C.4) was less at day 1 than levels in leachate from noncyclic treatments (BS1C.4 and BP1C.4) (Table 3). Although not statistically significant, 28% less N was leached in cyclic treatments compared to continuous irrigation treatments. In this experiment, leachate volume from the pine bark:peat medium was less than the pine bark:sand medium, which resulted in greater nutrient retention in the medium. Also, the pine bark:peat medium had a greater CEC, 42.4, compared to 14.3 with the pine bark:sand medium. The retention of NH_4-N in the pine bark:peat medium could have been enhanced by the higher CEC which subsequently reduced total N (mg/pot) leached. There was a difference in the amount of total N (mg/pot) leached between experiment 1 and 2. The authors cannot clearly define the basis of the difference, but contribute the time of the year and perhaps container media pre-irrigation water content.

These data demonstrate cyclic irrigation can reduce container leachate volume and total N leached. From a practical standpoint, these experiments indicate that as irrigation volumes increase, container leachate volumes and total N loss will increase. Cyclic irrigation may become an important production practice to reduce total water applied, irrigation runoff and total N leached.

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