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Effects of Cyclic Micro-irrigation and Substrate in Pot-in-pot Production[1]

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Abstract

This study was conducted to evaluate production techniques for increasing irrigation application efficiency [(water volume applied – water volume leached) / water volume applied] for large container trees. Three irrigation treatments (single, three cycle and six cycle) and three substrate treatments [pinebark, pinebark:coir (4:1 by vol), and pinebark:peat (4:1 by vol)] were evaluated for effects on irrigation application efficiency and growth of *Acer rubrum* 'Franksred' in a pot-in-pot production system in Auburn, AL. Substrate pH, electrical conductivity and leachate total inorganic nitrogen (N) content were measured. Cyclic irrigation reduced total N lost by a minimum of 89% when compared to a single irrigation application. Irrigation application efficiency increased with cyclic irrigation compared to a single irrigation application and for the pinebark:coir substrate compared to the pinebark. Growth was greater when irrigation was applied in six cycles than in a single irrigation application. Trees grown in pinebark:peat substrate had greater shoot dry weight than those grown in the pinebark substrate.

Index words: irrigation application efficiency, cyclic irrigation, container-grown trees.

Species used in this study: *Acer rubrum* 'Franksred' (Red Sunset™).

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Significance to the Nursery Industry

With increasing emphasis on the quantity of water used, producers should consider management practices that improve irrigation application efficiency of pot-in-pot container-grown trees. Cyclic irrigation is a proactive method to improve water quality by reducing runoff and nutrient loss from containers. Also, cyclic irrigation may lead to increased growth in production of specimen trees. Many nurseries can apply cyclic irrigation methods without changing existing equipment.

Introduction

Selection of irrigation systems, schedules, and growth substrate are major parameters affecting plant growth. A more efficient alternative to the standard practice of overhead irrigation is cyclic irrigation through a spray stake in an individual container (5, 6). Spray stake irrigation can cause excessive leaching if not properly monitored, due to the high application rates of emitters. Spray stake application efficiency can be increased by using cyclic irrigation (7). With cyclic irrigation, a plant's daily water allotment is subdivided into more than one application with prescribed intervals between applications. With conventional irrigation practices, the daily water allotment is applied in a single application.

Cyclic irrigation may improve irrigation application efficiency by allowing time for water to move through the micropore system of a container substrate (6). Irrigation application efficiency improved up to 38 % with cycled irrigation over one-time applications (10). Growers using cyclic irrigation can expect greater plant utilization of applied nitrogen (N) and reduced water and nutrient loss from containers (5). Fare et al., working with overhead irrigation, reported a 47% reduction in N leached from cyclic treatments compared to a single application (3).

Pot-in-pot production, introduced around 1990 (8), is a nursery production method that combines some of the benefits of both field and container production. A 'socket' pot is permanently placed in the ground and a container plant is then placed inside the 'socket' pot. Limited research has been done to determine potential benefits of cyclic irrigation in pot-in-pot production (9).

This study was conducted to determine if cyclic micro-irrigation and pinebark substrate amended with coconut coir or peat to increase water holding capacity would reduce container effluent in a pot-in-pot production system. Substrate and irrigation were evaluated for their effects on growth of *Acer rubrum* 'Franksred' (Red Sunset™).

Materials and Methods

Seventy-two bare root liners, 1.5 to 1.8 m in height (5–6 ft), of *Acer rubrum* 'Franksred' (J. Frank Schmidt & Son's Co., Boring, OR) were planted in 56.8 liter (#15) containers (Nursery Supplies Fairless Hills, PA) in April 1997 in full sun. The experimental design was a randomized complete block with eight blocks. Three substrate combinations were used: 100 percent pinebark; 4:1 (by vol) pinebark:peat; and 4:1 (by vol) pinebark:coconut coir. Substrate physical properties (Table 1) were determined using the North Carolina State University porometer (4). Substrates were amended with 3.5 kg/m^3 (7.7 lb) dolomitic limestone. Trees were topdressed with 337 grams (11.8 oz) of 15N–3.9P–9.1K (15–9–11) plus minors (O. M. Scotts Co., Inc., Maryville, OH). Initial height (from substrate to the top of uppermost bud) and trunk diameter measured 15 cm (6 in) above substrate level were taken after trees were planted, and final growth measurements were taken at the termination of the study on September 23, 1997.

Three irrigation treatments were used: application of a given volume in a single application at 10:00 a.m., the same volume divided into three applications at 10:30 a.m., 1:00

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p.m. and 3:30 p.m., or the same volume divided into six applications beginning at 8:00 a.m. with 90 minutes between cycles. Initial irrigation volume, April to mid June (period one) was 2340 ml (2.5 qt); from mid June to mid July (period two) the volume was increased to 4300 ml (4.5 qt); and to 5500 ml (5.8 qt) from mid July on (period three). Irrigation was applied through maxi-jet spray stakes (Maxijet Inc., Dundee, FL) with a Bowsmith model HPC6 pressure compensating emitter (Bowsmith Inc., Exeter, CA) at a rate of 400 ml (13.5 oz) per minute. Multiple irrigation lines down each block allowed irrigation treatments to be randomized. Total leachate volume was collected from four replications of all treatments on a biweekly basis throughout the study. A watertight container was placed between the 'socket' pot and growing container prior to irrigation to collect leachates. Soluble salts and pH readings were taken from all containers monthly using the Virginia Tech Extraction Method (VTEM) (11).

Subsamples [100 ml (3.4 oz)] from the VTEM were collected and frozen for N analysis at the end of the study. Total inorganic-N analysis was conducted with a Timberline Model 380 Inorganic Nitrogen Analyzer (Timberline Instruments, Boulder, CO) with the addition of an in-line reduction cartridge for nitrate (NO_3) + nitrite (NO_2) determination (1, 2). Leachate volumes were collected one day prior to VTEM collection. Total inorganic-N concentrations determined from the VTEM were used to calculate total inorganic-N lost per container (volume × concentration).

Results and Discussion

For the three substrates tested, total airspace was higher for pinebark at 21.8% over pinebark:coir at 16.9% (Table 1). Water holding capacity was greatest for pinebark:peat and pinebark:coir (Table 1). There were no differences in total porosity between substrates. Pinebark:peat had the lowest bulk density (Table 1).

Irrigation application efficiency was highest for pinebark:peat among substrate treatments for period two while pinebark and pinebark:coir were similar (Table 2). During period one and two, irrigation application efficiency was greatest for the six-cycle treatment followed by the three-cycle and single, respectively, (Table 2). Irrigation application efficiency was affected by a irrigation × substrate interaction for period three (Table 3). During period three, both cyclic treatments had the greatest irrigation application efficiency among all substrates. These results are consistent with prior research showing increased irrigation application efficiency with cyclic irrigation (5, 9, 10). Within the single irrigation treatment, pinebark:peat had the highest irrigation application efficiency followed by pinebark:coir and pinebark, respectively. While not compared statistically, irrigation application efficiency appeared to increase as the season progressed, possibly due to increasing plant needs and environmental conditions.

Tree growth was affected by substrates and irrigation treatment (Table 4). Shoot dry weight was about eight percent greater with plants grown in pinebark:peat compared to plants grown in pinebark. Plants grown in pinebark:peat had a 17% and 12% greater height increase than those grown in pinebark:coir and pinebark, respectively.

Plants grown with cyclic irrigation had the greatest shoot dry weight among irrigation treatments with plants in the three-cycle and six-cycle having 23% and 17% greater shoot

Table 1. Airspace, water holding capacity (WHC), total porosity (TP) and bulk density (BD) of container substrates.

Treatment	Substrate physical properties[z]			
	Airspace[y]	WHC[x]	TP[w]	BD[v]
Pinebark	21.8a[u]	42.8b	64.6a	0.292a
Pinebark:peat (4:1)	19.2ab	47.4a	66.6a	0.254b
Pinebark:coir (4:1)	16.9b	47.3a	64.2a	0.298a

[z]Substrate physical properties determined using the North Carolina State University Porometer.

[y]Airspace: Percent volume filled with air after substrate is saturated and allowed to drain for 60 minutes.

[x]Water holding capacity: Percent volume filled with water after substrate is saturated and allowed to drain for 60 minutes.

[w]Total porosity: Percent volume of the substrate comprised of pore space.

[v]Bulk density: Ratio (g/cm^3) of mass of dry solids to bulk volume of substrate.

[u]Mean separation within columns by Duncan's multiple range test, $P = 0.05$. Values are a mean of 5 observations.

Table 2. Effects of cyclic irrigation and substrate on irrigation application efficiency when applied to *Acer rubrum* 'Franksred' in a pot-in-pot production system[z].

Treatment	Irrigation application efficiency (%)	
	Period 1	Period 2
Substrate		
Pinebark	72.1a[y]	86.3b
Pinebark:peat (4:1)	80.2a	92.8a
Pinebark:coir (4:1)	72.2a	87.1b
Irrigation		
Single	59.7c	76.4c
Three-cycle	75.3b	91.2b
Six-cycle	88.0a	96.6a
Significance		
Substrate	NS	*
Irrigation	*	*
Substrate × Irrigation	NS	NS

[z]Irrigation application efficiency = [(water volume applied – water volume leached) / water volume applied].

[y]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

Table 3. Effects of a cyclic irrigation × substrate interaction on irrigation application efficiency when applied to *Acer rubrum* 'Franksred' in a pot-in-pot production system[z].

Substrate	Irrigation treatment		
	Single	Three-cycle Period 3	Six-cycle
Pinebark	68.1bC[y]	94.2aA	98.9aA
Pinebark:peat (4:1)	84.8bA	98.8aA	97.7aA
Pinebark:coir (4:1)	74.6bB	95.9aA	98.6aA

[z]Irrigation application efficiency = [(water volume applied – water volume lost) / water volume applied].

[y]Mean separation within rows (lower case) and columns (upper case) by Duncan's multiple range test, $P = 0.05$.

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Table 4. **Effects of cyclic irrigation and substrate on final growth of *Acer rubrum* 'Franksred' in a pot-in-pot production system.**

Treatment	Shoot dry wt (g)	Trunk diameter[z] increase (cm)	Shoot height increase (cm)
Substrate			
Pinebark	1203.8b[y]	1.72a[x]	109.4b[x]
Pinebark:peat (4:1)	1303.8a	1.81a	122.9a
Pinebark:coir (4:1)	1223.8ab	1.74a	105.3b
Irrigation			
Single	1098.3b	1.51b	103.8b
Three-cycle	1349.2a	1.86a	120.6a
Six-cycle	1283.8a	1.90a	113.3ab
Significance			
Substrate	*	NS	*
Irrigation	*	*	*
Substrate × Irrigation	NS	NS	NS

[z]Diameter 15 cm above substrate surface.

[y]Mean separation within columns by Duncan's multiple range test, $P = 0.05$. Values are a mean of 4 observations.

[x]Mean separation within columns by Duncan's multiple range test, $P = 0.05$. Values are a mean of 8 observations.

dry weight, respectively, than plants grown with a single irrigation application (Table 4). With trunk diameter, plants receiving three-cycle and six-cycle irrigation treatments had a 23% and 26% greater diameter increase, respectively, than plants grown with a single irrigation irrigation. Tree height was also affected by irrigation treatment. Plants grown with three-cycle irrigation had a 16% greater height increase than plants grown with a single irrigation application. These results support a previous study showing an increase in growth of 'Okame' Cherry (*Prunus* x *incamp*) with cyclic compared to a single irrigation application (9).

Irrigation treatment had no effect on substrate pH. Irrigation treatment had an effect on electrical conductivity, with the six-cycle treatment having the highest electrical conductivity for the July and August samples (Table 5). More irrigation cycles and greater efficiency, or reduced leaching fraction allowed salts to accumulate in the substrate. However all electrical conductivity readings were below thresholds where root damage might be expected to occur.

Cyclic irrigation reduced total N leached by a minimum of 89% in June and August when compared to a single irrigation application (Table 5). While N concentration was generally higher in cyclic treatments, reduced leachate volume (i.e., greater irrigation application efficiency) resulted in less N leached. For example with the six cycle irrigation in August the N concentration was 34.6 mg/liter; however, total N leached per pot was 0.2 mg/pot. This is a 99 percent reduction compared to the single irrigation application. These data suggest greater retention of N with cyclic vs. a single irrigation application. This agrees with previous work which showed a decrease in N leached when using cyclic irrigation compared to a single irrigation application (4). Leachate N concentration was greatest for 100 percent pinebark in June at 9.3 mg/liter compared to 5.5 and 6.0 mg/liter for pinebark:peat and pinebark:coir, respectively. There were no other differences between substrates on leachate N (Data not shown).

With increasing emphasis on water quality as well as quantity used, growers should consider changing management practices to improve irrigation application efficiency of container-grown trees. Cyclic irrigation is a proactive method to improve water quality and reduce runoff. Total N leached during production is important environmentally. Reduced leachate volume and increased N retention in the substrate may allow for more effective use of controlled release fertilizer and thereby reduce potential negative impacts on the environment.

In summary, both cyclic irrigation and pinebark:peat (4:1 by vol) substrate increase irrigation application efficiency by reducing leachate volume in a pot-in-pot production system. Both six and three cycle irrigation produced increased growth of *Acer rubrum* 'Franksred' compared to a single irrigation application. The pinebark:peat substrate (4:1 by vol) produced increased shoot dry weight over 100% pinebark and pinebark:coir (4:1 by vol). Leachatetrate N concentration increased with cyclic irrigation; however, due to the reduced leachate volume with cyclic irrigation, less N was leached. Furthermore, many growers of large container plants can apply cyclic micro-irrigation methods without major changes in existing equipment.

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Table 5. **Effects of cyclic irrigation on leachate inorganic N, and electrical conductivity[z].**

Irrigation treatment	Inorganic N (mg/liter)			Inorganic N (mg/pot)			Electrical conductivity (dS/m)		
	June	July	August	June	July	August	June	July	August
Single	6.7b[y]	4.6b	18.1a	5.8a	4.7a	24.7a	0.22a	0.21b	0.32b
Three-cycle	3.9b	7.5b	22.3a	0.5b	3.0a	2.8b	0.25a	0.28b	0.44b
Six-cycle	10.3a	28.8a	34.6a	0.0b	1.3a	0.2b	0.24a	0.47a	0.57a

[z]Nitrogen concentration (mg/l) and electrical conductivity (dS/m) from 100 ml sub-samples collected by VTEM, total N lost (mg/pot) was for one irrigation event one day prior to VTEM based on volume of leachate collected (volume × concentration).

[y]Mean separation within columns by Duncan's multiple range test, $P = 0.05$. Values are a mean of 8 observations.

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Evaluation of Ornamental Grasses for the Northern Great Plains[1]

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Abstract

A total of 160 grass or grass-like species/cultivars were evaluated under field conditions for a period of four years. Detailed assessments of survival, growth and development are presented. Horticultural evaluations were completed on all material, providing a basis for making recommendations for utilization of grasses in the landscape in colder regions (USDA zone 3) of the Great Plains. Thirty accessions were identified with very good to outstanding visual appeal. Plants that were rated very high for horticultural value included: big bluestem (*Andropogon gerardii*), feathertop (*Calamagrostis epigejos*), many of the sedges (*Carex* sp.), plumegrass (*Erianthus ravennae*), Hervier's fescue (*Festuca hervierri*), Leman's fescue (*Festuca lemanii*), tall purple moorgrass (*Molinia caerulea* spp. *arundinacea* cv. Skyracer), switchgrass species and cultivars (*Panicum virgatum* cv. Haense Herms, Heavy Metal and Strictum), ravenna grass (*Saccharum ravennae*) and variegated cordgrass (*Spartina pectinata* cv. Aureo-marginata). Eighteen accessions were removed from the test mainly due to their invasive nature (e.g., *Bromus inermis* cv. Skinner's Golden, *Elymus* spp., *Glyceria maxima* and *Phragmites australis*). Of the remaining 142 accessions, 71.8% had at least one plant remaining at the end of the test period (1996).

Index words: grasses, ornamental grass, plant evaluation.

Significance to the Nursery Industry

Information on the overwintering survival and horticultural evaluation of ornamental grasses is essential to gain an appreciation for the potential value of the many different species and cultivars. In this three-year trial (established in 1992), over 160 accessions representing over 80 different species in 43 genera were evaluated. Plants that were rated very high for horticultural value included: big bluestem (*Andropogon gerardii*), feathertop (*Calamagrostis epigejos*), many of the sedges (*Carex* sp.), plumegrass (*Erianthus ravennae*), Hervier's fescue (*Festuca hervierri*), Leman's fescue (*Festuca lemanii*), tall purple moorgrass (*Molinia caerulea* spp. *arundinacea* cv. Skyracer), switchgrass species and cultivars (*Panicum virgatum* cv. Haense Herms, Heavy Metal and Strictum), ravenna grass (*Saccharum ravennae*) and variegated cordgrass (*Spartina pectinata* cv. Aureo-marginata). This study provides a detailed assessment of the potential value for the landscape industry and suggests that a greater diversity of material can be grown even in very cold locations (USDA Zone 3).

Introduction

Ornamental grasses have been increasing in popularity for a number of years (1, 2, 3, 4). The diversity of plant charac-

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