Pot-In-Pot Production and Cyclic Irrigation Influence Growth and Irrigation Efficiency of 'Okame' Cherries[1]

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Abstract

A study was conducted with *Prunus* x *incamp* 'Okame' to evaluate the effects of a pot-in-pot production system (PIP) compared to a conventional above-ground system (CAG) and cyclic irrigation on plant growth and water loss. Plants were grown in #7 (26 liter) containers with a pinebark:sand (8:1 by vol) substrate. Cyclic irrigation provided the same total volume of water, but was applied one, three, or four times per day. Final plant height and stem diameter, shoot and root dry weight, total biomass, and root:shoot ratio all increased for plants grown pot-in-pot compared to above-ground. Multiple irrigation cycles increased stem diameter, shoot dry weight and total biomass compared to a single irrigation application. Multiple irrigation cycles also decreased the root:shoot ratio. Mean daily water loss (plant transpiration + evaporative loss from the substrate) was influenced by production system, irrigation, and date. Mean daily water loss was 30% higher for pot-in-pot grown plants compared to above-ground. Cyclic irrigation resulted in a two-fold decrease in average leachate volume and a 27% increase in overall irrigation application efficiency compared to a single application. Production system had no affect on leachate volume or irrigation application efficiency. Substrate pH increased when cyclic irrigation was used. Production system and irrigation had no affect on soluble salts. Nitrate-N concentrations were less in the leachate of plants grown pot-in-pot compared to above-ground.

Index words: pot-in-pot production, cyclic irrigation, production systems, water use efficiency.

Significance to the Nursery Industry

The results of this study showed that pot-in-pot production and cyclic irrigation increased the growth of 'Okame' cherry. Pot-in-pot production increased plant height and stem diameter about 10% over a five-month growing period. Growing plants pot-in-pot increased final shoot and root dry weights by 27% and 44%, respectively, compared to plants grown above-ground. Cyclic irrigation increased shoot dry weight 40% compared to a single irrigation event. Production system (above-ground versus pot-in-pot) had no effect on the amount of water leached or irrigation application efficiency, whereas cyclic irrigation reduced leachate volume by one-half and improved irrigation application efficiency by 27%. Decreased nitrate-N in the leachate from plants grown pot-in-pot, coupled with reduced leaching from cyclic irrigation should help reduce the risk of groundwater contamination.

Introduction

Pot-in-pot (PIP) production is increasing in popularity in the southeastern United States (5, 9, 10). This new production method is being adopted by in-field nurseries and growers of larger container-grown trees. In a PIP system, a holder or socket pot is permanently placed in the ground with the top rim remaining above grade. The container-grown plant is then placed within the holder pot for the production cycle. Recent studies have shown that PIP production can be less costly than conventional above-ground or in-field production methods (5, 6, 8).

Cyclic or intermittent irrigation (daily water allocation applied in more than one application) has been shown to reduce water and nutrients leaching through containers compared with conventional overhead irrigation practices (2, 3, 4, 7, 11). Microirrigation reduced irrigation volumes to one-fourth that used by overhead sprinkler systems for several species while producing similar-sized plants in 10-liter (#3) containers (2). Water consumption was shown to be 1/4 to 1/16 the level of overhead systems, depending on container size, for *Quercus virginiana* Mill. produced using cyclic microirrigation (6). Cyclic irrigation has reduced leachate volume in several studies (3, 4, 7, 11). Total NH_4-N losses were decreased when cycled irrigation was used compared to a single irrigation event (11). Total N leached was 43% higher for containers receiving irrigation as a single application compared to cyclically (7). In one study irrigation method had no effect on leachate NO_3-N and NH_4-N concentrations (7) whereas leachate concentrations of NO_3-N from cyclic irrigation were generally less than from continuous irrigation treatments (3). Little research has been conducted on the affects of cyclic irrigation on plants grown PIP. Therefore, the objectives of this study were 1) to compare the growth of plants grown PIP and CAG (conventional above-ground) with and without cyclic irrigation, and 2) to determine the influences of cyclic irrigation on irrigation efficiencies of plants grown PIP or CAG.

Methods and Materials

Uniform liners of *Prunus* x *incamp* 'Okame' were transplanted from 2.8 liter (#1) containers to 26 liter (#7) containers in April 1995. Potting substrate consisted of milled pine bark and sand (8:1 by vol) amended with micronutrients (Micromax, The Scotts Company, Marysville, OH) at 0.6 kg/m^3 (1.0 lb/yd^3) and dolomitic limestone at 3.0 kg/m^3 (5.0 lb/yd^3). Plants were topdressed with 21N–1.3P–10K + minors (Graco Perm-Green 21–3–12 + minors, six month formula, Graco Fertilizer Company, Cairo, GA) at the rate of 150 g (5.3 oz) per container April 30, 1995. Nitrogen in the fertil-

[1]Received for publication December 29, 1997; in revised form April 13, 1998. This research was supported by **The Horticultural Research Institute, 1250 I Street, N.W., Suite 500, Washington DC 20005**. Technical assistance of Bruce Tucker and statistical assistance of Ben Mullinix is appreciated. Donation of plants and supplies by Piedmont Growers, Graco Fertilizer Company, and The Lerio Corporation is gratefully acknowledged.
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izer was derived from resin-coated urea, methylene urea, urea formaldehyde, and diammonium phosphate. Holder pots were placed in the ground with the top of the pot remaining 2.5 cm (1 in) above grade.

The experiment was a factorial combination with two container production systems (PIP and CAG), three cyclic irrigation treatments, and ten single-plant replications for growth data. A factorial combination of two container production systems (PIP and CAG), three cyclic irrigation treatments, three sampling dates, and ten single-plant replications was used for leachate and water loss analysis. Cyclic irrigation treatments included 3100 ml (105 oz) of water applied once per day (1×) at 8:00 AM, 1033 ml (35 oz) applied three times per day (3×) at 8:00, 12:00, and 4:00 PM, and 775 ml (26 oz) applied four times per day (4×) at 8:00, 11:00, 1:00, and 4:00 PM. Irrigation was applied using 160° low volume spray emitters at 0.72 liter/min (0.19 gal/min) at 25 psi (Roberts Irrigation, San Marcos, CA). Standard errors for irrigation application ranged from ± 12.1 ml (1×) to ± 2.7 ml (4×). Applied irrigation water had a pH of 7.6 ± 0.1 and an alkalinity of about 2.8 me/liter $CaCO_3$ (140 ppm). The experiment was conducted outdoors under full sun at the University of Georgia Coastal Plain Experiment Station, Tifton.

Mean daily water loss (DWL = plant transpiration + evaporation from the surface of the substrate) was determined 32, 85, and 122 days after initiation (DAI) of the study. Containers were allowed to drain for 1 hr after the 8:00 AM watering and were weighed. Irrigation for all treatments was cut off overnight to allow for water loss over a 24 hr period to be measured. Daily maximum air temperatures during the periods when water loss was being determined ranged from a low of 32.2C (90F) at 32 DAI to a high of 36.7C (98F) at 122 DAI. Mean net solar radiation received was 493, 544, and 520 ly/day at 32, 85, and 122 DAI, respectively.

Leachate volume was determined 30, 90, and 120 DAI. Containers, which fit snuggly around the base of the planted containers to minimize potential losses due to evaporation, were used to collect all leachate from the PIP and CAG treatments. PVC rings (5 cm depth) were placed between the base of the planted container and the collection container to assure that drainage was not impeded. Cumulative daily leachate volumes were collected within 1 hr of the final daily irrigation regime. Leaching fraction was calculated as: (volume of water leached/volume of water applied). Irrigation application efficiency was calculated as: [(volume of water applied – volume of water leached) / volume of water applied]. Electrical conductivity (dS/m), pH and NO_3-N (mg/l) concentrations from the cumulative leachate collections were determined the following day at room temperature with conductivity and pH meters (Cole-Parmer, Vernon Hills, IL) and an ion-specific electrode (Orion, Boston, MA), respectively after overnight storage in a refrigerator at 1.1C (34F).

Initial plant height (~ 90 cm) and stem diameter (~ 7.0 mm) measurements were taken at the start of the study. At 150 DAI, final plant height and stem diameter measurements were taken. Shoot dry weight and root dry weight were determined after drying in a forced-air oven for 72 hr at 65.5C (150F). Substrate was removed from the root system before drying. All containers were rotated monthly to eliminate possible problems with rooting-out into the surrounding soil. Irrigation use efficiency was calculated using the equation: [total plant dry weight / (volume of water applied – volume of water leached)]. Data analysis for all parameters were evaluated by analysis of variance. All interactions among main effects were nonsignificant.

Results and Discussion

Plants grown PIP were 9% taller than plants produced CAG (Table 1). Stem diameters of PIP plants were 10% greater than CAG plants. For PIP plants, shoot dry weight and root dry weight were 27% and 44% greater, respectively, than plants grown CAG. The increase in shoot and root dry weight resulted in a 35% increase in total biomass. The root:shoot ratio increased 12% when plants were grown PIP.

For growth parameters there were no differences between the 3× and 4× cyclic irrigation treatments (Table 1). Increases in height and stem diameter for the two cyclic irrigation treatments were approximately 10% when compared to the 1× irrigation event. Cyclic irrigation treatments increased shoot dry weight by 40% compared to a single irrigation event (1×). Root dry weight was not affected by cyclic irrigation treatments whereas the root:shoot ratio decreased by 20% compared to 1×.

Table 1. Influence of container production system, pot-in-pot (PIP) or conventional above-ground (CAG), and cyclic irrigation on the mean growth of *Prunus* x *incamp* 'Okame'.

	Final height (cm)	Final stem diameter (mm)	Shoot dry wt. (g)	Root dry wt. (g)	Total biomass[z] (g)	Root:shoot[y] ratio
Production system						
PIP	161	23	443	393	836	0.9
CAG	148	21	349	272	621	0.8
Irrigation						
1×	145	21	318	313	632	1.0
3×	161	23	448	348	797	0.8
4×	158	23	421	336	757	0.8
Significance[x]						
Production system	*	**	**	**	**	*
Irrigation	NS	**	**	NS	**	**

[z]Total biomass = shoot dry weight + root dry weight.

[y]Root:shoot ratio = root dry weight / shoot dry weight.

[x]NS, *, ** Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 2. Influence of production system, cyclic irrigation, and date on measured irrigation parameters.

	Daily water loss[z] (ml)	Water leached (ml)	Leaching fraction[y] (%)	Irrigation application efficiency[x] (%)
Production system				
PIP	1925	738	24	76
CAG	1483	684	22	78
Irrigation				
1×	1448	1059	34	66
3×	1818	507	16	84
4×	1845	567	18	82
Date (days after initiation)				
32	1924	793	26	74
85	1518	884	29	71
122	1669	456	15	85
Significance[w]				
Production system	**	NS	NS	NS
Irrigation	**	**	**	**
Date	**	**	**	**

[z]Daily water loss = (plant transpiration + evaporative loss from substrate).

[y]Leaching fraction = (volume of water leached / volume of water applied).

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

[w]NS, ** Nonsignificant or significant at $P \leq 0.01$.

Overall irrigation use efficiency was greater for plants grown PIP (36%) compared to CAG plants (25%). The 11% increase in irrigation use efficiency for plants grown PIP was due to a 35% increase in total biomass (Table 1) combined with the fact that production system had no effect on the amount of water leached during production (Table 2). Cyclic irrigation had no influence on irrigation use efficiency (data not shown).

Mean daily water loss from PIP plants was 30% greater than from CAG plants (Table 2). Since final shoot dry weight was 27% greater for PIP plants, it is likely that the leaf area was also greater, therefore increasing the transpirational water loss from the PIP plants. Production system had no effect on average leaching fraction or irrigation application efficiency (Table 2). Mean daily water loss was greater for cyclic irrigated plants compared to plants receiving a single irrigation event. A single irrigation event averaged a two-fold higher amount of water leached through a container and a higher leaching fraction compared to plants receiving cyclic irrigation. Overal irrigation application efficiency increased by as much as 27% for the cyclic irrigation treatments.

Daily water loss was greatest 32 DAI (Table 2). The amount of water leached and the leaching fractions were lowest 122 DAI, a 93% decrease occurring between DAI 85 and 122. As a result of the decreased leaching fraction, irrigation application efficiency was also greatest 122 DAI.

Substrate pH was influenced by cyclic irrigation, with the 3× and 4× treatments having values of 7.5 an 7.3, respectively; compared to 6.9 for the 1× event. The alkalinity of irrigation water used was greater than the maximum level (2.6 me/l) suggested for production of long-term crops (1). Since the leaching fraction was less for the cyclic irrigation treatments, more water was retained in the substrate. Since water is consistently withdrawn from the substrate by the plant during the course of a day this results in an accumulation of Ca in the substrate. Since less Ca is leached, higher Ca concentrations occur in the substrate over time, thereby influencing the pH of the substrate. Substrate pH was not influenced by production system or date (data not shown).

Production system and irrigation had no effect on soluble salt levels in the leachate (data not shown). Soluble salts were highest at 30 DAI (0.69 dS/m) and decreased to 0.18 dS/m at 120 DAI. Nitrate-N was greater in the leachate from CAG plants (24 mg/l) compared to PIP (18 mg/l). Differences in NO_3-N between production systems could have been due to increased uptake since plants grown PIP had a final biomass 35% higher than plants grown CAG. Nitrate-N was also influenced by date, decreasing from 20 mg/l at 30 DAI to 13 mg/l and 9 mg/l, respectively, at DAI 90 and 120. Irrigation had no effect on NO_3-N concentrations (data not shown). Tyler et al. (11) reported cyclic irrigation treatments on 3.8 liter (#1) containers as having no effect on NO_3-N losses. Fare et al. (3) noted that container leachate NO_3-N concentrations were generally lower in cyclically irrigated plants compared to containers receiving continuous irrigation treatments.

Increased plant growth, coupled with decreased nitrate-N leachate concentrations for plants grown PIP should help reduce risks associated with environmental pollution from commercial nurseries. Cyclic irrigation will also help control the amount of nutrients leaving a container since leachate volume was reduced by one-half. From a growth standpoint there were no differences between the 3× and 4× irrigation treatments. However, it was observed that there were few roots alive at the bottom of the containers and algae was growing on the surface of the substrate when plants were irrigated 4× per day compared to 3×. While recommendations of up to 12 irrigation cycles per day exist, genera which are sensitive to waterlogging in containers may benefit from three or fewer cycles per day (2). Further studies with different species, fertilizers, and irrigation volumes and the PIP production system are suggested.

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