Flood Irrigation of Container-grown *Euonymus* and *Thuja* as Affected by Fertilizer Rate and Substrate[1]

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Abstract

Euonymus fortunei [(Turcz.) Hand.-Mazz.] 'Emerald Gaiety' and *Thuja occidentalis* L. 'Little Giant' were grown outdoors in #1 (3 liter) containers for one season on waterproof, crushed stone beds flooded and drained from below the stone. Plants were grown in a bark substrate (2/3 pine bark:1/3 sphagnum peat) or a peat substrate (1/3 pine bark:2/3 sphagnum peat) with either a high or medium rate of incorporated, controlled release fertilizer [17N–2.6P–10K (Sierra 17–6–12)] [6.0 or 4.0 kg/m^3 (10.0 or 6.7 lbs/yd^3)]. For both species, the high fertilizer rate resulted in less top dry weight, and higher substrate electrical conductivity (EC) and NO_3-N. Foliar N levels were also higher with the higher fertilizer rate. Compared with bark, the peat substrate resulted in less top dry weight of *Thuja* (not *Euonymus)* and higher substrate EC, NO_3-N and water retention, and foliar N levels. Substrate EC levels in the upper one-third [5 cm (2 in)] of the container were nearly twice those in the lower two-thirds [10 cm (4 in)], reaching 7.1 dS/m with the high fertilizer rate in peat. In comparison to plants under overhead irrigation (high fertilizer rate only), flooded plants grew as much as (*Euonymus*) or more (*Thuja*) in the bark substrate but both species grew less in the peat. Substrate EC and NO_3-N with flood were either similar or lower in bark, but similar or higher in peat compared to overhead. The amount of roots and their distribution appeared similar for both types of irrigation.

Index words: ebb and flow irrigation, subirrigation, controlled release fertilizer, growing media, *Euonymus fortunei*, *Thuja occidentalis*.

Significance to the Nursery Industry

As the nursery industry becomes more conscious of water and nutrient conservation, alternatives to overhead sprinkler irrigation become increasingly attractive. This study indicates that flood irrigation is a feasible technique for watering container-grown stock. Flood irrigation has the potential to reduce fertilizer rates and enable the recirculation of water and nutrients, as is common in the greenhouse industry. We found that with flood irrigation, one-third less controlled release fertilizer (medium rate) resulted in similar (*Thuja*) or larger (*Euonymus*) plants compared to the high rate recommended for overhead irrigation. Since controlled release fertilizers for containers are expensive, lower application rates would help to reduce production costs. However, a flood system would require growers to redesign their growing facilities.

Introduction

Environmental issues have become extremely important as the nursery industry enters the 21st century. Water quality and quantity have emerged as top priorities for nurseries (30). As a result, growers have begun to address water conservation by reducing water use and runoff, increasing irrigation system uniformity and recirculating water (18, 24). Techniques such as cyclic (pulse) irrigation (13, 20), substrates with greater water retention (2), and waterproof soil liners (25) have been used/recommended to decrease water use with overhead irrigation systems.

Low irrigation application efficiencies (5) and the potential for nutrient leaching with overhead irrigation (6, 26) have led to an interest in subirrigation. The feasibility of subirrigation of container-grown nursery stock standing on plastic-lined sand beds has been demonstrated by a number of researchers in Europe and North America (9, 16, 27). Advantages of sand bed subirrigation compared to overhead irrigation include reduced water use (9, 27, 28), reduced fertilizer rates (8, 27, 28), no leaching of nutrients from the container (9, 16), a more even distribution of water among variable pot sizes (27, 29), less substrate compaction (11), reduced foliar diseases (9, 27), less weed seed germination on the substrate surface (9), and, in some instances, increased growth (8, 16, 28). Disadvantages of sand bed subirrigation include rooting-out into the sand (27, 29), increased construction costs (9, 29), accumulation of nutrient salts (16, 21, 28), and root disease transfer among pots (29).

Flood (ebb and flow) irrigation is a form of subirrigation common in greenhouse production (15) but rarely used by nursery container growers. Preliminary investigations using several woody species indicated both positive and negative growth effects with flood irrigation (3, 4). Negative effects were attributed to water stress and fertilizer placement. An additional advantage of flood irrigation over sand beds is that contact between the container and the wet bed surface is not necessary, thus eliminating the possible growth reduction on sand beds when using a fabric weed control barrier (2). Also, there is little rooting-out with flood irrigation because the bed surface dries.

The objective of this study was to determine the effects of two fertilizer rates and two substrate types on the growth and quality of two species of container nursery stock using flood irrigation, and to compare flood and overhead irrigation with both substrates.

Materials and Methods

Flood beds. In June 1993, two flood beds, each 5 m (17 ft) wide and 9 m (30 ft) long, were constructed at Sheridan Nurseries Ltd., Georgetown, ON, on a compacted sand base (sloped 0.5%) using 5 × 20 cm (2 × 8 in) lumber as sides. On both beds, the base and sides were covered by a 40 mil thick rubber liner (Terrafix Environmental Technology Inc.,

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Rexdale, ON). In both beds, three sections of 5 cm (2 in) perforated, flexible plastic drain tile were laid the length of the beds equi-distant apart. Three tiles were attached to 3.8 cm (1.5 in) PVC headers at both ends of the bed. To supply water, a 5 cm (2 in) PVC irrigation pipe penetrated the rubber liner and attached to the end of each PVC header. The header at the opposite end drained water from the bed into a catch basin for return to the pond. The supply and drain lines had quarter turn valves to control water flow. After laying the fill/drain tile, beds were filled with 10 cm (4 in) of 12 mm (0.5 in) clear, crushed stone, which was carefully leveled and covered with a woven polyethylene fabric weed barrier (Plant Products Co. Ltd., Brampton, ON).

Species and treatments. Uniform rooted cuttings of *Euonymus fortunei* 'Emerald Gaiety' [8 cm (3.5 in) tall], uniform branched liners of *Thuja occidentalis* 'Little Giant' [15 cm (6 in) tall] were potted into #1 (3 liter) nursery containers in mid June 1993. The blow-molded containers were 19 cm (7.5 in) high with a top and bottom diameter of 16 cm (6.25 in) and 12.5 cm (5 in), respectively. There were four drain holes in the container, one of which was in the center of the bottom. Two substrates were prepared, one containing 2/3 ground pine bark and 1/3 sphagnum peat (v/v) (hereafter called bark), the other containing 1/3 ground pine bark and 2/3 sphagnum peat (hereafter called peat). For each substrate, two fertilizer rates were prepared by incorporating 6.0 kg/m^3 (high rate) or 4.0 kg/m^3 (medium rate) (10.0 and 6.7 lbs/yd^3 respectively) of controlled release fertilizer [17N–2.6P–10K, (Sierra 17–6–12, 3–4 month release)]. The experiment was a 2 (fertilizer) × 2 (substrate) factorial arranged as a randomized complete block design consisting of eight blocks with ten plants per treatment block. Plants of the two species were placed on separate flood beds because of the potential need for different watering regimes. During the season, plants were watered as needed to a container depth of 3 cm (1 3/16 in) for 15 minutes. In late October, two plants from each treatment block were transferred to a polyhouse for overwintering.

Sampling and analysis. Substrate samples from the upper one-third [5 cm (2 in)] and the lower two-thirds [10 cm (4 in)] of the container for both species were collected in early August and early October 1993, and in early April 1994 before the poly was removed from the plants being overwintered in a polyhouse. Sampling consisted of selecting one plant from each block, removing the container and separating the top one third. In the lower two thirds, the substrate was shaken from the roots to collect the sample. Samples from all treatments were analyzed for electrical conductivity (EC), pH, NO_3-N, P and K using the saturated paste extract procedure. Five times, from late July to late August, plants were weighed before and one hour after irrigation to determine water retention of the substrates. Foliar samples were collected from both species in early October and analyzed for N, P and K. In mid October, plants for dry weight determinations were cut at the substrate level, oven dried and weighed. All data were analyzed using the SAS-GLM procedure. Treatment means within species were separated using Fisher's protected LSD test.

Flood vs. overhead irrigation. As a comparison of flood irrigation to the normal grower practice of overhead irrigation, both *Euonymus* and *Thuja* were grown in an adjacent uncovered polyhouse using the bark and peat substrates with only the high rate [6.0 kg/m^3 (10 lbs/yd^3)] of Sierra fertilizer. Plants were potted, sampled, and overwintered similarly to those with flood irrigation and they were watered with impact sprinklers as needed using three 20-minute cycles with 30-minute pauses between each cycle. A total of about 20 mm of water was applied. Data for overhead irrigation were compared to flood irrigation treatments (both substrates at the high fertilizer rate only) using t-tests.

Results and Discussion

Flood irrigation.

Growth and substrate EC, nutrients, and pH (lower two-thirds of container). Top dry weight of both *Euonymus* and *Thuja* was reduced at the high fertilizer rate and for *Thuja* (not *Euonymus)* in the peat substrate (Table 1). The significant interaction of fertilizer rate and substrate for both species was the result of less growth with the high fertilizer rate in peat, but more and similar growth with the medium fertilizer rate in peat and both rates in bark (Table 2). Both EC and substrate N levels in August for *Euonymus* and *Thuja* were greater with the high than the medium fertilizer rate and with the peat than bark substrate (Table 1). In October, there was a significant interaction of fertilizer rate and substrate for EC and N (except N for *Euonymus*) (Table 1), the result of higher EC levels in peat than bark at both fertilizer rates (Table 2). Substrate N followed a similar pattern except that levels for the medium fertilizer rate in peat and the high rate in bark were similar (Table 2).

Reduced growth at the high fertilizer rate was the result of substrate EC and N levels being about two times higher at the high than the medium fertilizer rate in both August and October. Leaf tip necrosis was evident on *Euonymus* in August with the high fertilizer rate, a symptom of high EC in the root zone. EC levels approaching 3.0 dS/m are considered higher than desirable (10). With the high fertilizer rate, substrate N levels were above 300 ppm for both species in August and for *Euonymus* in October. Levels above 200 ppm are considered unnecessarily high and those above 300 ppm can cause nutritional problems (10). Generally higher EC and N levels in the peat than bark substrate for both species in August and October (Table 1) were probably the result of a higher cation exchange capacity (7) and less leaching during rainfall (16) in peat and possibly more nutrient release from the Sierra fertilizer in the more moist peat. Moisture relations in the container may affect the nutrient release characteristics of controlled release fertilizers (14, 17). For *Euonymus*, the difference between EC and N levels in peat compared to bark appeared greater in October than in August. Levels tended to be higher for *Euonymus* than *Thuja*. Nutrients may have accumulated in the *Euonymus* substrates, especially peat, as a result of less nutrient absorption by root systems damaged at the high EC levels. Also, the *Euonymus* were smaller and younger plants at potting than *Thuja* thus more prone to nutrient salt toxicity (10).

In April, after overwintering the remaining plants in a polyhouse, EC and N levels followed similar patterns to the previous season, being higher for the high fertilizer rate in peat (data not shown). The EC levels were only somewhat lower in April than in October of the previous season, indicating that most of the release from the Sierra fertilizer was

Table 1. EC and NO_3-N (lower 2/3 of container), and water retention of bark and peat substrates, foliar N and top dry weight for *Euonymus fortunei* 'Emerald Gaiety' and *Thuja occidentalis* 'Little Giant' grown with flood irrigation using two fertilizer rates.

	Substrate						
	August			October			
Treatment	EC (dS/m)	NO_3-N (ppm)	Water retention[z] (g)	EC (dS/m)	NO_3-N (ppm)	Foliar N (%)	Top dry wt (g)
				Euonymus			
Fertilizer rate (F)[y]							
High	2.9	329	279	2.3	341	3.4	9.6
Medium	1.8	201	279	1.3	156	2.8	11.5
Substrate (S)[x]							
Bark	1.7	199	266	1.1	130	2.7	11.1
Peat	2.9	331	293	2.5	366	3.6	10.0
Significance							
F	**	**	NS	**	**	**	**
S	**	**	**	**	**	**	NS
F×S	NS	NS	NS	**	NS	**	**
				Thuja			
Fertilizer rate (F)							
High	2.8	327	267	1.8	219	2.2	29.0
Medium	1.9	212	276	1.1	115	2.0	32.4
Substrate (S)							
Bark	1.5	177	243	0.8	74	1.9	33.2
Peat	3.1	360	300	2.0	260	2.4	28.2
Significanc							
F	**	**	NS	**	**	**	**
S	**	**	**	**	**	**	**
F×S	NS	NS	*	**	**	**	**

[z]Change in weight before and one hour after irrigation, mean of five sample dates.

[y]Sierra 17–6–12 at 6.0 (high) and 4.0 (medium) kg/m^3 (10.0 and 6.7 lbs/yd^3).

[x]Bark = 2/3 ground pine bark, 1/3 sphagnum peat; Peat = 1/3 ground pine bark, 2/3 sphagnum peat.

NS, *,**, nonsignificant or significant at $P \leq 0.05$, $P \leq 0.01$, respectively; n = 8 in August, 6 in October.

Table 2. Interaction effects of top dry weight, substrate EC and NO_3-N, foliar N and water retention for *Euonymus fortunei* 'Emerald Gaiety' and *Thuja occidentalis* 'Little Giant' grown with flood irrigation using two fertilizer rates and two substrates.

Fertilizer rate[z]	Substrate[y]	Top dry wt (g)	EC (dS/m)	Substrate $N0_3$-N (ppm)	Foliar N (%)	Water absorption[x] (g)
			Euonymus			
High	bark	11.1a[w]	1.5c	—	2.9c	—
High	peat	8.7b	3.2a	—	3.8a	—
Medium	bark	11.1a	0.7d	—	2.7d	—
Medium	peat	11.8a	1.8b	—	3.1b	—
			Thuja			
High	bark	35.1a	0.8c	206b	2.0c	287b
High	peat	29.1b	2.8a	383a	2.5a	305b
Medium	bark	33.0a	0.8c	129c	1.9c	241c
Medium	peat	33.3a	1.3b	193b	2.2b	334a

[z]Sierra 17–6–12 at 6.0 (high) and 4.0 (medium) kg/m^3 (10.0 and 6.7 lbs/yd^3).

[y]Bark = 2/3 ground pine bark, 1/3 sphagnum peat; peat = 1/3 ground pine bark, 2/3 sphagnum peat.

[x]Data from August, all other data from the October sampling date.

[w]Means in columns within species followed by the same letter are not significantly different ($P \leq 0.05$).

completed during the first growing season. EC and substrate N were higher than expected for a three month controlled release fertilizer, probably because of less nutrient leaching in a flood system.

Substrate P and K levels responded similarly to N, being higher at the high fertilizer rate and in the peat substrate (data not shown). Levels of both nutrients were within an acceptable range for optimum growth (10).

Substrate pH was lower with the high than the medium fertilizer rate (by 0.4 units) and also lower in peat than bark (by 1.1 units) (data not shown). These responses were the result of the acidifying effect of additional nutrient salts at the high fertilizer rate (23) and the lower pH of peat than bark (7). The limited magnitude of the pH differences probably had little effect on growth or nutrient availability (10).

EC levels in upper one-third of container. Substrate EC levels in the upper one-third [5 cm (2 in)] of the container in August were very high, reaching 7.1 dS/m with the high fertilizer rate and the peat substrate (data not shown). Such high levels are considered excessive, resulting in root damage, foliar wilting and even plant death (10). Levels were about twice those in the lower two-thirds [10 cm (4 in)] of the container. High EC levels at the top of the container, which may be 13 times higher than at the bottom (21), were the result of upward capillary movement of water with its dissolved nutrient salts (1, 22). Argo and Biernbaum (1) indicated that, for floricultural crops, this process of surface accumulation removes salts from much of the root zone thus preventing root injury from high salts. However, in an outdoor system, rainfall would leach salts lower into the substrate. In October, EC levels declined compared to August, probably as a result of nutrient absorption by the plants and less release from the Sierra fertilizer.

Foliar nutrients. Foliar N levels for both species were higher with both fertilizer rates in peat, but lower and similar with both fertilizer rates in bark (Table 2). Levels were within the high (*Euonymus*) to adequate (*Thuja*) range for acceptable growth (10, 19). Foliar P levels were similar to those for N (data not shown). Interestingly, foliar K for both species was not affected by fertilizer rate or substrate in spite of the significant difference for K in the substrate (data not shown). This response is unexplained.

Water retention and root distribution. Water retention was greater in the peat than the bark substrate but was not affected by fertilizer rate (Table 1). Increased water retention by the peat substrate is an expected response for a mix containing two-thirds peat (7). The fertilizer rate by substrate interaction for *Thuja* was the result of more water retention in peat with the medium than the high fertilizer rate, but the opposite response with bark (Table 2). This response may have been related to growth differences in the peat substrate at the two fertilizer rates and the possible influence of roots in altering the capillary movement of water.

Observations by the authors were that the visibly saturated wetting front was higher in peat than bark. In peat, the wetting front was about 10 cm (4 in) above the container base (two-thirds its height) while in bark the wetting front was about 7.5 cm (3 in) above the base (one half its height) one hour after irrigation. After 12 hours, the wetting front moved about 3 cm (1 3/16 in) higher in peat and 1 to 2 cm (3/8–3/4 in) higher in bark. A flooding depth greater than 3 cm (1 3/16 in) may have increased wetting front height, an advantage for bark.

Visually inspected root distribution in the two substrates generally reflected the differences in wetting, since in bark roots were less plentiful in the upper part of the container. There were no roots in the top 1 to 2 cm (3/8 to 3/4 in) of either substrate, probably as a result of limited moisture and high EC levels.

Flood vs. overhead irrigation.

Growth, substrate EC, pH and N (lower two-thirds of container), and foliar N. October data only for EC and N are shown since those from August were generally similar. Flood irrigated plants in the bark substrate grew as much as (*Euonymus*) or more than (*Thuja*) those with overhead irrigation, but in peat both species grew less with flood (Table 3). This result was probably because flood irrigated plants grew less in peat than bark (significant for *Thuja*, trend for *Euonymus*; Table 1), likely a response to high nutrient levels in peat. Plants with overhead irrigation grew similarly in either substrate (trend evident in Table 3). Other researchers have reported more growth with sand beds (8, 16) and flood (4, 8) compared to overhead irrigation.

Substrate EC levels for both species in bark were lower with flood than overhead irrigation; however, in peat, levels were higher with flood although the difference was not significant for *Euonymus* (Table 3). This opposite response in the two substrates was likely due to a combination of factors: less water absorption/wetting in bark with flood and thus less effective release of nutrients in the dryer substrate (14, 17); and a higher cation exchange capacity of peat (7) with little if any leaching with flood irrigation (16). The different response for the two species may have been due to

Table 3. Top dry weight, substrate EC and NO_3-N (lower 2/3 of container), and foliar N for *Euonymus fortunei* 'Emerald Gaiety' and *Thuja occidentalis* 'Little Giant' grown in two substrates with either flood or overhead irrigation.[z]

	Euonymus		Thuja	
	Bark[y]	Peat[y]	Bark	Peat
Top dry wt. (g)				
Flood	11.0a[x]	8.2b	33.9a	24.2b
Overhead	11.8a	10.4a	29.4b	32.0a
EC(dS/m)				
Flood	1.5b	3.7a	0.8b	2.8a
Overhead	2.2a	2.6a	1.1a	2.1b
NO_3-N (ppm)				
Flood	196a	492a	72b	366a
Overhead	275a	323a	116a	253b
Foliar N (%)				
Flood	2.8a	4.1a	1.9a	2.6a
Overhead	3.0a	3.7b	1.8a	2.3b

[z]Values from high fertilizer rate treatment [Sierra 17–6–12, 6.0 kg/m³ (10 lbs/yd³)] in October.

[y]Bark = 2/3 ground pine bark, 1/3 sphagnum peat; Peat = 1/3 ground pine bark, 2/3 sphagnum peat.

[x]Mean separation in columns within factor by t-test ($P \leq 0.05$); n = 6.

less seasonal growth of *Euonymus* and the fact that they were smaller and younger plants at planting than *Thuja*.

Substrate N levels followed the same trend as EC; however, the difference between flood and overhead irrigation was not significant for *Euonymus* in the bark substrate (Table 3). Higher substrate N levels with the flood than overhead irrigated peat (significant for *Thuja*, trend for *Euonymus*) were probably the result of the high EC in peat. Substrate pH was higher with flood, except for *Euonymus* in peat, perhaps the result of less leaching of the high pH (+/– 7.5) irrigation water (data not shown). Foliar N levels of flood compared to overhead irrigated plants followed a somewhat similar trend to substrate EC and N (Table 3).

Water retention and root distribution. Our measurements of water retention were confounded by the fact that overhead irrigated plants, under the control of the nursery computer system, were watered more frequently than the flood plants, probably resulting in a greater water content prior to the next irrigation. Thus we have not reported these results. The total amount of roots and root distribution of flood and overhead irrigated plants appeared to be similar. With overhead, there was a more even vertical distribution of roots in bark than peat. These results are not consistent with those of Morvant et al. (22) who found more roots on subirrigated geranium.

Our results indicate that flood is a possible alternative to overhead irrigation. Further studies with flood irrigation are needed to determine if fertilizer rates can be reduced more than one-third and how additional species in larger container sizes grow.

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