Photinia and Podocarpus Growth Response to a Hydrophilic Polymer-amended Medium

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Additional index words. water consumption, soil amendments, nursery production, fertilizer

Abstract. *Photinia ×fraseri* Dress and *Podocarpus macrophyllus* (Thunb.) D. Don were grown in a Metro-Mix 500 medium amended with 0.0%, 0.25%, 0.5%, 0.75%, or 1.0% (by volume) of a K-based hydrophilic polymer and were irrigated every 3, 6, 9, or 12 days with a solution that contained either 100, 200, 300, or 400 mg N/liter, respectively. *Photinia ×fraseri* plants irrigated every 6 days with 200 mg N/liter in irrigation water and grown in 0.75 % polymer-amended medium had higher root and shoot dry weights (6.3 and 28 g, respectively) after 144 days than plants grown in the unamended medium (3.4 and 17 g, respectively). Shoot dry weights of *P. macrophyllus* grown 192 days in the amended medium were similar to those of plants grown in the unamended medium. Average shoot dry weights increased from 10 to 18 g, respectively, as number of irrigations increased from every 12 days with 400 mg N/liter in irrigation water to every 3 days with 100 mg N/liter in irrigation water. *Podocarpus macrophyllus* root dry weights were 1.9 and 3.6 g for plants irrigated every 12 and 3 days, respectively, while plants grown in the unamended medium had the highest root dry weight (3.2 g). Data from this study indicated that growth response to a cross-linked, K polyacrylate/polyacrylamide, hydrophilic polymer-amended Metro-Mix 500 medium varied with species and number of irrigation and concomitant fertilizer applications.

Recent studies have indicated that amending media with hydrophilic polymers may result in beneficial or inconsequential plant responses. Gehring and Lewis (1980), Conover and Poole (1979), and Still (1976) determined that several species of herbaceous plants grown in media amended with a hydrophilic polymer were slower to wilt than plants grown in an unamended medium. Davies and Castro-Jiménez (1989) and Wang and Boogher (1987) evaluated shoot growth response of *Lagerstroemia indica* L. 'fauriei' Koehne 'Natchez' and *Chlorophytum comosum* (Thunb.) Jacques 'Vittatum' and determined that growth was greater for plants grown in polymer-amended media than in unamended media. However, Wang and Boogher (1987) did not find that a polymer-amended medium resulted in higher shoot dry weight of *Nephrolepis exaltata* (L.) Schott. 'Rooseveltii'. Ingram and Yeager (1987) observed a similar

response for *Ligustrum japonicum* Thunb., as did Keever et al. (1989) for several species of woody plants. Keever et al. (1989) determined that the needed frequency of irrigation applications was not reduced when plants were grown in a polymer-amended medium, but Wang and Boogher (1987) reported that a polymer-amended medium resulted in a decreased number of irrigation applications for Boston fern [*Nephrolepis exaltata* (L.) Schott. 'Bostoniensis']. Regardless of the polymer effect on irrigation frequency, a reduction in water-holding capacity or water absorption when fertilizer salts were applied has been cited as a limiting factor for some commonly used polymers (Bowman and Evans, 1991; Bowman et al., 1990; Wang and Gregg, 1990). The purpose of this research was to evaluate the response of *P. ×fraseri* and *P. macrophyllus* to number of irrigation and concomitant fertilizer applications when grown in Metro-Mix 500 (Grace-Sierra Horticultural Products Co., Fogelsville, Pa.) amended with a cross-linked, K polyacrylate/poly acrylamide hydrophilic polymer.

Materials and Methods

Single-stem rooted cuttings of *P. ×fraseri* (13 cm high) and *P. macrophyllus* (14 cm high) were planted in 3-liter containers on 10 Jan. 1991, using Metro-Mix 500, a Canadian sphagnum peat, vermiculite, patented bark ash, and coarse pine bark medium [≈ 1.5%, 30%, 15%, and 40%, respectively (by volume)], amended with 0.0%, 0.25%, 0.5%, 0.75%, or 1.0% (by volume) Stockosorb cross-linked, K polyacrylate/poly acrylamide hydro-

philic polymer (HP) (Stockhausen, Greensboro, N. C.) with a particle size of 200 to 1000 µm. Ten plants of each taxon for each amendment rate were irrigated every 3, 6, 9, or 12 days with 450 ml of a solution that contained 100, 200, 300, or 400 mg N/liter, respectively, from a20N-8.7P-16.7K water-soluble fertilizer (Grace-Sierra). Irrigations every 3, 6, 9, or 12 days resulted in a total of 48, 24, 16, or 12 irrigations, respectively, for *P. ×fraseri* and 64, 32, 21, or 16 irrigations, respectively, for *P. macrophyllus*, because *P. ×fraseri* were grown for 144 days and *P. macrophyllus* for 192 days. The plants were completely randomized in a 5 × 4 factorial design in a fiberglass greenhouse (21 ± 10C/1 ± 3C). All containers were drenched with tap water every 48 days to avoid salt accumulation. Electrical conductivity (EC) of the unamended medium for three replicate plants of *P. macrophyllus* was determined 116 and 165 days after potting and before drenching, using the leachate collection procedure described by Yeager et al. (1983).

One hundred forty-four days and 192 days after potting *P. ×fraseri* and *P. macrophyllus*, respectively, plant stems were severed above the uppermost roots, and root and shoot dry weights were determined after drying to constant weight in a forced-air oven (70C). Shoot tissue was ground using a Cyclone mill, and tissue from four replicate plants for each amendment rate and irrigation combination was used for P, K, Ca, and Mg percentage determinations. Tissue total N was determined for three of the replicate plants. Shoot tissue macronutrient analyses were conducted by the Univ. of Georgia Soil and Tissue Analysis Laboratory (Athens). Total milligrams of N, P, K, Ca, and Mg in shoots was determined for each amendment and irrigation combination by multiplying shoot dry weight by the respective elemental percentage. Gravimetric moisture content at saturation and at 10 kPa, a tension above which plant water use is limited (Ingram and Henley, 1991), was determined for unamended medium and medium amended with 1 % polymer before potting and from the *P. ×fraseri* medium after 48 irrigation applications. Substrate moisture release determinations were made according to procedures of the U.S. Dept. of Agriculture Soil Conservation Service (1992). Data were subjected to an analysis of variance, and data exhibiting interactions could not be expressed as second-order polynomials or as a nonlinear relationship due to lack of fit. Tukey's honestly significant difference (Steel and Torrie, 1960) was calculated using the interaction mean square error.

Results and Discussion

Photinia. The interaction of amendment rate and number of irrigation applications was significant for *P. ×fraseri* root and shoot dry weights (Fig. 1). Root and shoot dry weights 144 days after potting for plants receiving 24 irrigation applications (irrigated every 6 days) were higher for plants grown with 0.75% HP than plants grown in the 0% HP. However,

Received for publication 17 May 1993. Accepted for publication 6 Nov. 1993. Florida Agricultural Experiment Station journal series R-03 142. Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product, nor does it imply approval or disapproval to the exclusion of other products or vendors that may also be suitable. We thank Steve Linda for statistical assistance; Mary Collins for water-release curve determinations; and Stockhausen, Greensboro, N.C., for financial assistance. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

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Fig. 1. *Photinia xfraseri* (A) root and (B) shoot dry weights when grown for 144 days in Metro-Mix 500 amended with 0%, 0.25%, 0.5%, 0.75%, or 1.0% (v/v) K-based hydrophilic polymer and receiving 12 (■), 16 (*), 24 (◇), or 48 (●) irrigation applications.

	df	Analysis of variance	
		Root	Shoot
Mean square			
Irrigation (Irr)	3	88.7	1782
Amendment (Amend)	4	22.1	398
Irr × Amend	12	12.1	206
Error	180	2.9	26
Significance			
Irr		***	***
Amend		***	***
Irr × Amend		***	***
H S D ²		2.8	8

²Tukey's honestly significant difference

***Significant at $P \leq 6.0001$.

root and shoot dry weights for plants receiving 24 irrigation applications and grown with 0.75% HP were similar to those of plants grown with 0% HP and receiving 48 irrigation applications. Plants grown with 0.75% HP with 24 irrigation applications also contained more elemental P, K, Ca, and Mg than plants grown with 0% HP (Table 1) and receiving 24 irrigation applications. Root and shoot dry weights for *P. xfraseri* that received 12 and 16 irrigation applications were unaffected by amendment rate (Fig. 1). For plants that received 48 irrigation applications (irrigated every 3 days), 1% HP resulted in lower root and shoot dry weights than 0% HP. This response may be attributable to the large amount of moisture, 500% to 296% in medium with 1% HP between saturation and 10 kPa, compared to medium with 0% HP that contained 330% to 226% moisture, respectively. The

initial medium before potting contained 434% to 243% moisture with 1% HP between saturation and 10 kPa compared to medium with 0% HP that contained 352% to 207% moisture, respectively. At the end of the experiment, the 1% amended medium contained a larger percentage of moisture than at the experiment's initiation, which indicates that polymer water absorption was not reduced when fertilizer was added, unlike data reported by Bowman et al. (1990). As the number of irrigation applications increased from 12 to 48 for 0%, 0.25%, 0.5%, and 0.75% HP, root and shoot dry weights and shoot tissue K, Ca, and Mg increased while shoot tissue N and P increased for 0.25%, 0.5%, and 0.75% HP. This response was probably the result of constant replenishment of nutrients in the growth medium due to fertilizer applied at each irrigation, although a lower nutrient concentration

was applied with the more frequent irrigation applications.

Podocarpus. Interaction of amendment rate and number of irrigations was not significant for shoot and root dry weights. Data presented in Fig. 2 are for shoot dry weights 192 days after potting and are presented using the natural log transformation of dry weights, which induced homogeneity of variance. Data are averaged over the main effect of amendment rate, which was nonsignificant. From the non-linear function describing shoot dry weight (Fig. 2), 90% of maximum growth could be obtained with 23 irrigation applications of 278 mg N/liter. Our data for *P. macrophyllus* shoot dry weights concur with previous findings of Tripepi et al. (1991) for birch (*Betula pendula* Roth), Ingram and Yeager (1987) for *Ligustrum japonicum* Thunb., and Wang and Boogher (1987) for Boston fern, in that amending the medium with a hydrophilic polymer does not result in increased shoot weights compared to unamended media.

Shoot dry weights in our study increased as number of irrigation applications increased. This finding concurs with those of Tripepi et al. (1991), who found that birch plants irrigated every 3 days had higher shoot dry weights than plants irrigated every 5 days. However, our findings are contrary to those of Ingram and Yeager (1987), where *L. japonicum* shoot dry weight decreased as irrigation frequency increased from 8 or 12 days to 2 or 3 days, respectively. The difference in response to increasing frequency of irrigations may be that, in our study, N, P, and K were applied at each irrigation, and thus, adequate nutrition was maintained in the medium as indicated by average ECs for the unamended medium of *P. macrophyllus* that were 2.8, 2.7, 2.5, and 1.5 dS·m⁻¹ for irrigation frequencies of 16, 21, 32, and 64, respectively. Yeager et al. (1980) reported an EC of 1.5 dS·m⁻¹ when *Ilex crenata* Thunb. 'Helleri' was fertilized every 7 days with a solution containing 300 mg N/liter from a water-soluble 20N-8.7P-16.7K fertilizer. Gilliam et al. (1982) grew fern (*Nephrolepis exaltata* 'Rooseveltii') in a medium not amended with a hydrophilic polymer and determined that 150 mg N/liter in irrigation water applied twice a week resulted in larger plants after 12 weeks than 300 mg N/liter in irrigation water applied once a week.

Number of irrigations and amendment rate main effects for *P. macrophyllus* root dry weights were significant (Table 2). The medium with 0% HP resulted in the highest root dry weight (3.2 g) when data were averaged over number of irrigations, while root dry weights averaged over amendment rates increased as number of irrigations increased. Shoot tissue N, P, and K increased for 32 irrigation applications compared with 16 irrigations for 0.25% HP (Table 3). However, the increase in tissue P and K was not exclusive to 0.25% HP. Tissue N, P, and K for 0.25% and 0.5% HP were similar to those for 0% HP for all irrigation treatments except for K in shoots of plants grown in 0.5% HP and irrigated 21 times. Taylor and Halfacre (1986) grew *L. lucidum* Ait. 'Compactum' in a 3 pine bark :1

Table 1. *Photinia × fraseri* shoot tissue N, P, K, Ca, and Mg (in milligrams) when grown for 144 days in Metro-Mix 500 amended with a K-based hydrophilic polymer and receiving 12, 16, 24, or 48 irrigation applications.

Irrigation ² (no. applications)																				
Amendment (v/v)	12					16					24					48				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
0%	321	155	246	133	54	293	191	344	147	68	378	184	325	152	70	404	209	520	286	117
0.25%	230	136	281	109	44	309	207	411	188	67	489	258	490	249	91	517	255	554	317	123
0.50%	268	143	317	111	41	348	219	415	179	64	460	243	416	238	75	551	304	564	358	127
0.75%	294	180	378	125	49	384	245	463	190	74	586	355	642	257	111	602	278	566	324	133
1.00%	226	160	401	102	31	331	241	473	160	46	444	206	394	164	58	248	110	178	100	44
<i>Analysis of variance</i>																				
		df		N		P		K		Ca		Mg								
Mean square																				
Irrigation (Irr)		3		150969		33990		89356		91707		15073								
Amendment (Amend)		4		41013		19277		63535		25066		4918								
Irr × Amend		12		14867		8224		44880		9578		926								
Error		60		5122		586		1514		568		46								
Significance																				
Irr				***		***		***		***		***								
Amend				***		***		***		***		***								
Irr × Amend				**		***		***		***		***								
HSD				221		63		102		62		18								

²Irrigation water contained either 400, 300, 200, or 100 mg N/liter from a 20N-8.7P-16.7K water-soluble fertilizer for each of the 12, 16, 24, or 48 applications respectively.

***Significant at $P \leq 0.01$ and 0.0001, respectively. Error df for N = 40.

builders' sand medium (v/v) either unamended or amended with $\approx 65\%$ of the amount of HP used for our 0.25% HP. In their study, N and K percentages in the upper leaves were higher for plants grown in the amended compared to unamended medium; however, the data were averaged over fertility rates of 2.7, 5.4, and 8.1 g of N per 7.6-liter container, and shoot growth for the HP-amended medium was greater than for the unamended medium at the low fertility rate and less than that for the unamended medium at the high fertility rate. Phosphorus percentages were similar in their study (Taylor and Halfacre, 1986), while Ca and Mg percentages were less in upper leaves of plants grown in the polymer-amended medium. Our data indicate that amendment with 0.25% and

0.75% HP resulted in decreased milligrams of Ca in shoot tissue for 16, 21, and 32 irrigation applications (Table 3), while Mg was unaffected by 0.25% HP.

In conclusion, *P. × fraseri* plants irrigated every 6 days (24 irrigation applications) with 200 mg N/liter and grown in Metro-Mix 500 amended with 0.75% K-based HP had higher root and shoot dry weights than plants grown in an unamended medium and receiving the same frequency of irrigation. However, root and shoot dry weights were similar for plants grown in 0% HP and irrigated every 3 days (48 irrigation applications) with 100 mg N/liter or irrigated every 6 days with 200 mg N/liter and grown with 0.75% K-based HP. Root and shoot dry weights for plants of the latter treat-

ment were also not different from plants grown in the same medium and irrigated every 3 days. Consequently, a 50% irrigation water savings would result from the 6-day compared to 3-day irrigation schedule in addition to the possibility of reduced nutrient leaching due to polymer amendment as indicated by the fact that shoots of plants irrigated every 6 days and grown with 0.75% HP contained more milligrams of P and K than plants grown in medium amended with 0%, 0.25%, 0.5%, or 1.0% HP. Shoot tissue Ca, Mg, and dry weights increased when irrigation applications increased from every 12 days (12 irrigation applications) with water containing 400 mg N/liter to every 3 days (48 irrigation applications) with water containing 100 mg N/liter if the medium was amended with 0%, 0.25%, 0.5%, or 0.75% HP. Shoot tissue Ca did not decrease for the amended compared to unamended medium for plants irrigated every 6, 9, or 12 days; however, this was not the case for *P. macrophyllus* irrigated every 6, 9, or 12 days (32, 21, or 16 irrigation applications, respectively) and grown in medium amended with 0.25% or 0.75% HP. *Podocarpus macrophyllus* shoot dry weights for plants grown in amended and unamended medium were similar. Shoot dry weights of *P. macrophyllus* increased as the number of irrigation applications increased, with 90% of maximum growth predicted for irrigation every 8 days with water containing 278 mg N/liter. These data indicate that growth response to a cross-linked, K polyacrylate/polyacrylamide, HP-amended Metro-Mix 500 varied with plant species and number of irrigations/fertilizations. This variable response could be due to fertilizer applied or micronutrient and limestone amendments as noted by Foster and Keever (1990) and Wang and Gregg (1990). Thus, to establish the effectiveness of a K-based HP for use in commercial nurseries, nursery operators should evaluate the polymer in combination with various plant species and cultural regimes used by their nursery.

Fig. 2. *Podocarpus macrophyllus* shoot dry weight response to number of irrigation applications when grown for 192 days in Metro-Mix 500 amended with a K-based hydrophilic polymer. Log shoot dry weight = $2.820[1 - e^{-0.102(\text{no. applications})}]$.

Table 2. Amendment and number of irrigation applications main effects for root dry weights of *Podocarpus macrophyllus* grown 192 days in Metro-Mix 500 amended with a K-based hydrophilic polymer.

Amendment		Irrigation ²	
% (v/v)	Root dry wt (g)	No. applications	Root dry wt (g)
0	3.2	16	1.9
0.25	2.3	21	2.6
0.50	2.8	32	3.3
0.75	3.0	64	3.6
1.00	2.9		
<i>Analysis of variance</i>			
	df	Mean square	Significance
Irrigation	3	28.1	***
Amendment	4	4.5	*
Error	192	1.5	

²Irrigation water contained either 400, 300, 200, or 100 mg N/liter from a 20N-8.7P-16.7K water-soluble fertilizer for each of the 16, 21, 32, or 64 applications, respectively.

***Significant at $P \leq 0.05$ or 0.0001, respectively.

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Table 3. *Podocarpus macrophyllus* shoot tissue N, P, K, Ca, and Mg (in milligrams) when grown for 192 days in Metro-Mix 500 amended with a K-based hydrophilic polymer and receiving 16, 21, 32, or 64 irrigation applications.

Amendment (v/v)	Irrigation ² (no. applications)														
	16					21					32				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
0%	230	44	277	134	65	287	65	329	173	81	344	83	318	318	84
0.25%	153	30	256	86	41	206	59	328	127	57	378	80	363	154	77
0.50%	176	43	289	86	41	276	79	436	181	73	285	84	361	145	88
0.75%	235	47	352	96	41	211	52	267	87	39	294	85	412	149	71
1.00%	177	52	350	104	34	176	58	285	123	38	296	124	473	231	77
<i>Analysis of variance</i>															
	df	N		P		K		Ca		Mg					
Mean square															
Irrigation (Irr)	3	42538		9591		24901		39781		7666					
Amendment (Amend)	4	8927		272		5955		12215		1517					
Irr × Amend	12	8117		749		14606		6824		717					
Error	60	2573		106		942		147		118					
Significance															
Irr		***		***		***		***		***					
Amend		*		*		**		***		***					
Irr × Amend		**		***		***		***		***					
HSD		157		27		80		32		28					

²Irrigation water contained either 400, 300, 200, or 100 mg N/liter from a 20N-8.7P-16.7K water-soluble fertilizer for each of the 16, 21, 32, or 64 applications, respectively.

***Significant at $P \leq 0.05$, 0.01, or 0.0001, respectively. Error df for N = 40.