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Shade Tree Growth and Nutritional Status as Influenced by Fabric Container and Trickle Fertigation[1]

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Abstract

Five species of landscape shade trees, when grown in fabric containers, showed small but significant reductions in caliper and height compared to field-grown control trees after each of 3 growing seasons, 1988–1990. Reductions also were observed in certain leaf nutrients: N and Ca after the second year, and P and K after the third year. There were increased levels of leaf Mn (1989), Zn (1990), and starch (1989). Trees of all species receiving 5.7 L (1.5 U.S. gal) of water per day plus 200 ppm of supplementary N applied twice weekly had consistently larger caliper after each of the 3 growing seasons and tended to have higher leaf Mn content after the second year. There was inconsistent, little, or no difference in height, or in other leaf nutrients, due to fertigation treatments or to irrigation alone.

Index words: Shade trees, mineral nutrients, carbohydrates, fabric containers, nursery culture, trickle irrigation, fertigation

Species used in this study: Littleleaf linden (*Tilia cordata* Mill. 'Olympic'); silver maple (*Acer saccharinum* L.); honey locust (*Gleditsia triacanthos* var. *inermis* Willd. 'Skyline'); green ash (*Fraxinus pennsylvanica* var. *lanceolata* (Borkh.) Sarg.); and Norway maple (*Acer platanoides* L.).

Significance to the Nursery Industry

Fabric containers are being used more by tree nurseries but there is need for information on cultural factors such as fertigation and irrigation practices. In the present study, conducted on a fertile, fine sandy loam soil with a large available moisture holding capacity, fabric containers reduced growth of all species, but the effect was limited. Final caliper reduction, although consistent across the 5 species studied and statistically significant, was small after 3 growing seasons [≤ 5 mm (0.2 in) mean over all species] and may be of marginal importance. In contrast, trickle fertigation increased growth of all species marginally; irrigation alone was of no benefit. On less fertile soil with lower moisture holding capacity, fertigation and irrigation should produce more growth and the effect of fabric containers may be more pronounced.

Introduction

In the early 1980's, nurseries began using in-ground (Field-Grow) fabric containers to grow large shade trees (11). Field-Grow containers are cylindrical with walls of a strong, non-woven, geotextile polypropylene fabric through which water and nutrients filter freely (11, 13, 14). The bottom of the container is constructed of clear, low-density polyethylene that minimizes downward root growth.

Compared with traditional-grown trees, fabric-grown trees are reported to have a greater proportion of total harvestable roots, the root system is more fibrous, smaller and easier to ship and handle (11, 12, 14), and has higher levels of carbohydrates (3, 6, 7) and (or) nutrients (3, 11). These factors are reported to reduce the seasonal constraints of planting, harvesting, and survivability of fabric-grown trees (14).

There has been limited but increasing evidence of reduced stem and root growth (2, 12) and significant redistribution

[1]Received for publication March 20, 1991; in revised form June 4, 1991. Special appreciation is extended to Braun Nurseries Ltd., Mount Hope, Ontario, for providing the trees and Field-Grow fabric containers, Shemin Nurseries Ltd., Milton, Ontario, for providing the trickle fertigation system, and Plant Products Co. Ltd. for providing the fertilizers. This project was funded in part by the Landscape Ontario Horticultural Trades Foundation, Mississauga, Ontario, and the Horticultural Research Institute, Washington, D.C. Statistical advice was provided by O.B. Allen and technical assistance by Bob Hamersma, Debbie Norton, and Mark Zolis.

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of carbohydrates and nutrients in fabric-grown trees (2, 3). Work by Chong et al. (3) indicated that root girdling with the fabric container restricted carbohydrate flow from leaves to roots outside the container, and nutrients from roots to leaves. Chong et al. (2) hypothesized from the pattern of nutrient uptake that fabric-grown trees may respond better to a higher level of fertility. Although species and location influence the effects of fabric containers (2,6,7,12), there is no information on the effects of other cultural factors. Researchers (8,10,15) have reported positive effects of trickle irrigation and (or) nitrogen fertilization on shade tree growth.

This study investigated growth and nutritional status of 5 shade tree species as influenced by fabric containers and various fertigation regimes.

Materials and Methods

Plant material and treatments. In mid-April 1988, 150 bare-rooted whips of each of 5 tree species, littleleaf linden, silver maple, honey locust, green ash, and Norway maple, were planted directly in Vineland fine sandy loam soil or in in-ground Field-Grow fabric containers [50 cm (20 in) wide × 30 cm (12 in) deep] backfilled with the native soil. Rows were spaced 4.9 m (16 ft) apart and trees 1.8 m (6 ft) within rows.

After planting, whips were pruned to uniform size and height: 180–190 cm (6.0–6.5 ft) for linden and silver maple; 210–220 cm (7.0–7.5 ft) for the other species. A grass mixture, consisting of 90% meadow fescue and 10% annual rye, was seeded between rows at a rate of 45 kg/ha (40 lb/acre). The established sod was mowed monthly during the 1988–1990 growing seasons.

Weeds along a 0.6 m (2 ft) band on either side of the trees were controlled by spraying as follows: 1988, a mixture of Devrinol 50WP [napropamide, 4.5 kg a.i./ha (4 lb/acre)] and Gramoxone [paraquat, 1.1 kg a.i./ha (1 lb/acre)] on June 1, and Gramoxone only in late June and early August; 1989 and 1990, Devrinol only on April 21 and Gramoxone in June and August. Monthly accumulated rainfall during each of the 3 growing seasons was recorded (Table 1).

Five trickle irrigation (fertigation) treatments were evaluated: a non-irrigated control; 5.7 and 11.4 L (1.5 and 3.0 gal) of water per day with or without 200 ppm of supplementary N applied through Dosmaticplus fertilizer injectors (J.F. Equipment Co., Lewisville, TX) 2 days per week between June 1 and August 21 each year. Irrigation was supplied to trees individually through a 1.9 L/hr (0.5 gal/hr) button-type pressure-compensating emitter (Netafim Irrigation, Valley Stream, NY) placed within 15 cm (6 in) from the base of each tree. N was supplied by water-soluble 20-20-20 in 1988 and from 34-0-0 in 1989 and 1990. In April of each year, 34-0-0 was also broadcast over all plots, including the control, at rates of 120 kg N/ha (107 lb N/acre) in 1988 and 100 kg/ha (89 lb N/acre) in 1989 and 1990.

The experiment consisted of 750 trees in a split block design with 5 replications of each treatment. Within each replication, subplot treatments (5 species) were arranged in strips across mainplot (5 fertigation) treatments. Each of these 25 subplots were subdivided into 2 sub-subplots, each with half the number of trees (3) in fabric containers and half without.

Table 1. Monthly accumulated rainfall at Vineland Station during the growing seasons 1988 to 1990.

	Rainfall (mm)			
Month	1988	1989	1990	Long term average
April	48	34	65	64
May	31	111	117	70
June	8	89	59	76
July	124	73	63	64
August	72	24	79	74
September	43	85	62	73
Total	316	416	445	421

Growth and analytical measurements. During late winter and midsummer of 1989 and 1990, trees were pruned lightly to maintain a central leader growth habit. Recently matured leaf samples, combined from the 3 trees within a sub-sub plot, and corresponding soil samples from 7–12 cm (2.8–4.7 in) depth adjacent to the base of each tree were taken in mid-July of each year.

Leaf samples were dried at 70°C (158°F), ground to pass through a 40-mesh screen, and analyzed for total N by the Kjeldahl method; P by colorimetry; K, Ca, Mg, Fe, Mn, and Zn by flame emission or atomic absorption spectrophotometry (1); and soluble sugars and starch by colorimetry (3). Levels of soil nitrate-nitrogen (NO_3-N) were determined with a nitrate electrode, and P, K, and Mg as described for leaf samples. Caliper [5 cm (2 in.) above the graft union] and tree height were measured at the start of the experiment, in mid-July of 1988, and at the end of each growing season.

Results and Discussion

Despite occurrence of the most severe drought in 35 years, from May 21 to July 15, 1988 (Table 1) during which there were only 11 mm (0.43 in) of rainfall, all species established and grew relatively rapidly after planting (Table 2).

Container effects. Fabric-grown trees of all species showed consistently small but significant reductions in growth after the first, second, and third year (Table 2). Growth reductions in each of the 3 years, 1988, 1989, and 1990, were 9.7%, 6.1%, and 7.8% for caliper and 5.9%, 4.3%, and 3.5% for height, respectively. Comparative growth data (not shown) collected in mid-July of the first season showed a similar (statistically significant) trend indicating that the effects of fabric containers were manifested quite early in the first year. These results may be due to root growth restrictions and initial hydrophobic characteristics of new fabric, an occurrence that we have noted. Analysis of variance indicated no difference in caliper or height of trees at the start of the experiment.

Although comparative growth measurements of roots were not made, examination of several fabric-grown plants after the first year showed that roots had penetrated the fabric and were establishing "nurse" roots (2) in the surrounding soil. At harvest (after the third growing season), roots of fabric-grown plants were typically smaller and more fibrous than their field-grown counterparts (11, 14). However, roots of all species had started circling the base of the container, as previously described for poplar (3). There was a tendency for some larger roots to penetrate the container, especially

Table 2. Influence of fertigation and Field-Grow fabric container on caliper and height of 5 shade tree species at the end of the growing seasons, 1988–1990.

	Caliper (mm)			Height (cm)		
Treatments	**1988**	**1989**	**1900**	**1988**	**1989**	**1990**
Species (S)						
Linden	23	39	53	213	261	302
Norway maple	29	45	56	266	327	387
Green ash	33	53	69	289	395	451
Silver maple	34	57	74	289	401	480
Honey locust	30	44	53	332	409	459
LSD 5%	2	3	4	6	21	20
Fertigation (F)						
Control	28	44	59	274	352	412
5.7 L	29	46	59	278	363	418
11.4 L	29	47	61	277	360	418
5.7 L + 200 ppm N	31	51	64	287	367	427
11.4 L + 200 ppm N	31	48	62	277	356	413
LSD 5%	1	4	3	6	NS	NS
Container (C)						
Without	31	49	64	287	368	425
With	28	46	59	270	352	410
LSD 5%	1	2	2	4	9	8
Interactions						
F × S	NS[z]	NS	*	**	NS	NS
F × C	**	NS	*	**	NS	NS
C × S	**	NS	NS	**	*	NS
F × C × S	NS	NS	NS	NS	NS	NS

[z]Nonsignificant (NS) or significant 5% (*) or 1% (**).

through the seams at the junction of the container sidewalls and the polyethylene base as described by Remphrey et al. (12). Top growth reduction was likely due to this root restriction.

While no differences occurred in leaf nutrient or carbohydrate levels due to the fabric container in the first year, all fabric-grown trees showed small but significant reductions in leaf N and Ca after the second year, and in leaf P and K after the third year (Table 3). Increases were observed in leaf Mn (1989), Zn (1990) (Table 3), and starch (1989) (data not shown). This reverse trend of increased micronutrients with containers was interesting but needs further

Table 3. Influence of fertigation and Field-Grow fabric container on contents of leaf macro- and micro-nutrients in 5 shade tree species (1989–1990).

	% dry wt								ppm			
	N		P		K		Ca		Mn		Zn	
Treatments	**1989**	**1990**	**1989**	**1990**	**1989**	**1990**	**1989**	**1990**	**1989**	**1990**	**1989**	**1990**
Species (S)												
Linden	2.83	3.19	0.23	0.21	1.57	1.59	2.22	1.59	57	25	36	32
Norway maple	2.78	2.92	0.27	0.24	1.11	1.25	2.17	1.25	67	43	38	38
Green ash	2.64	2.70	0.32	0.27	1.36	1.38	1.54	1.38	40	25	39	47
Silver maple	2.91	3.25	0.29	0.30	1.06	1.27	1.20	1.27	65	44	42	38
Honey locust	3.09	2.82	0.31	0.24	1.47	1.46	2.90	1.46	40	22	37	22
LSD 5%	0.12	0.10	NS	0.02	0.12	0.10	0.26	0.10	13	12	NS	NS
Fertigation (F)												
Control	2.90	2.92	0.26	0.26	1.29	1.40	1.96	1.40	43	27	36	32
5.7 L	2.81	2.93	0.30	0.28	1.26	1.38	2.04	1.38	47	27	35	36
11.4 L	2.71	2.91	0.31	0.25	1.32	1.37	2.00	1.37	48	28	39	34
5.7 L + 200 ppm N	2.97	3.10	0.27	0.24	1.33	1.35	2.19	1.35	57	32	42	32
11.4 L + 200 ppm N	2.86	3.02	0.27	0.24	1.38	1.43	1.85	1.43	76	45	40	43
LSD 5%	0.12	NS	0.02	0.02	0.06	NS	0.16	NS	12	7	NS	NS
Container (C)												
Without	2.90	3.02	0.28	0.26	1.32	1.42	2.09	1.42	52	31	38	29
With	2.80	2.92	0.28	0.24	1.31	1.35	1.93	1.35	57	33	39	42
LSD 5%	0.06	0.05	NS	0.01	NS	0.04	0.08	0.04	4	NS	NS	12
Interactions												
F × S	NS[z]	NS	**	**	**	NS	**	NS	*	**	NS	NS
F × C	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS
C × S	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	*	NS
F × C × S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Nonsignificant (NS) or significant 5% (*) or 1% (**).

Table 4. Influence of fertigation and Field-Grow fabric container on contents of soil NO_3-N, P, and K (1988–1990).

	NO_3-N (ppm)			P (ppm)			K (ppm)		
Treatments	1988	1989	1990	1988	1989	1990	1988	1989	1990
Fertigation (F)									
Control	34[z]	24	42	57	63	77	244	224	246
5.7 L	21	19	30	57	58	76	179	158	186
11.4 L	24	17	30	58	58	74	176	126	159
5.7 L + 200 ppm N	44	30	62	80	70	84	238	156	165
11.4 L + 200 ppm N	56	19	47	96	75	99	236	144	159
LSD 5%	20	8	13	8	10	17	32	35	27
Container (C)									
Without	35	22	45	68	64	81	213	174	206
With	37	21	39	71	66	83	216	153	161
LSD 5%	NS[y]	NS	3	NS	NS	NS	NS	6	10
Interaction									
F × C	NS	NS	NS	NS	*	NS	NS	NS	NS

[z]Each datum represents an average across 5 species and 5 replications.
[y]Nonsignificant (NS) or significant 5% (*) or 1% (**).

clarification since the occurrence was limited. Also lower NO_3-N (1990) and K (1989 and 1990) quantities were found in soil sampled within the fabric container (Table 4).

Fertigation effects. Trees of all species receiving trickle irrigation at the lower rate [5.7 L (1.5 gal)/day] and supplementary N had larger caliper in each of the 3 years (Table 2). A similar result was observed with the higher rate [11.4 L (3.0 gal)/day] + N in the first year only. Height was not affected except for a small increase with the 5.7 L (1.5 gal) + N treatment in 1988 (Table 2). Thus, irrigation alone (both rates) had no significant effect on growth.

Analysis indicated a tendency for higher concentrations of NO_3-N and P in soil from irrigation treatments receiving fertilizer (Table 4). However, unlike P which tended to remain higher in the soil even in years when no extra P was added (1989 and 1990, Table 4), K content decreased significantly in all trickle treatments in 1989 and 1990, or in treatments [1988, 5.7 and 11.4 L (1.5 and 3.0 gal)] when no extra K was added (Table 4). Notwithstanding these changes, soil NO_3-N, P and K levels were always adequate.

Significant species differences in leaf composition were found (Table 3). Trees receiving trickle irrigation and fertigation tended to have higher leaf Mn content after the second year (Table 3). Variations in other leaf constituents due to fertigation treatments were few, small or inconsistent. N applied in the irrigation water increased leaf N in 1989 but not in 1990. P levels tended to be higher with irrigation and be lowered when N was applied in irrigation. Leaf Mg and Fe were not affected by treatments (data not shown).

Similar to previous studies (9,10,15), the trickle system delivered fixed amounts of water on a daily basis during the growing period, regardless of climatic conditions. It is noteworthy, however, that the soil was a fertile and deep Vineland fine sandy loam with a high moisture holding capacity, and was well drained since the field was tiled. This soil typically yielded excellent growth of fruit trees, although only marginal increases due to sprinkler and trickle systems have been obtained (4). This evidence seems to explain in part the limited effects on growth of trickle irrigation despite the drought conditions of the first year. The early (April) planting also may have been beneficial.

In a study with 4 shade tree species, Ponder and Kenworthy (9) observed that continuous trickle irrigation [total applications up to 5.7 L (1.5 gal)/day] did not promote any consistently significant changes in nutrient composition of leaves, although growth increases due to irrigation varied (0-2x) depending on application frequency per day, species, and year. Similarly, under conditions with trickle irrigation based on soil moisture conditions, Eakes et al. (5) observed marginal effects of irrigation rates on foliar nutrient levels; 4 of 5 species tested showed only limited growth response. Under the conditions of the present study, the lower irrigation rate [5.7 L (1.5 gal)/day] with supplementary N was adequate for shade tree production, but further research is required to determine optimum application rates. There were significant fertigation × species and fertigation × fabric container interactions for both caliper and height in certain years (Table 2).

Remphrey et al. (12) reported significant and progressively greater top growth decline after the first, second, and fourth year of growth of silver maple, ash, and linden, respectively, in 2 commercial size (46 and 56 cm; 18 and 22 in) Field-Grow fabric containers. With poplar grown in small experimental-size [0.6-14.0 L (0.2-3.7 gal)] fabric containers, Chong et al. (3) detected a buildup of carbohydrates in leaves and roots after the first year, followed later (after the second year) by progressive and increasing reductions in foliar nutrients and top growth (2). There was little or no effect of container size on foliar carbohydrate and nutrient levels (2,3). Ingram et al. (6,7) observed no influence of 36 cm (14 in) Field-Grow fabric containers on top growth of 7 tree species after one year, although increased carbohydrates were found in roots of 2 of 5 species analyzed.

The results of this study confirm some growth reduction and lower foliar nutrient concentrations of some elements in all 5 tree species grown in commercial-size fabric containers. However, there was little effect on foliar carbohydrate contents.

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Growth Regulators and Pruning Alter Growth and Axillary Shoot Development of *Dianthus*[1]

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Abstract

Annual carnation, *Dianthus caryophyllus* L., and garden pink, *Dianthus chinensis* L., were treated with foliar sprays of Bonzi (paclobutrazol), Cycocel (chlormequat chloride), or Pro-Shear (BA), and/or pruned to suppress shoot elongation or promote axillary shoot development. Bonzi (paclobutrazol) at 100 or 200 ppm was effective in suppressing shoot elongation of annual carnation over a 14-week period and garden pink over an 8-week period without increasing days to flower of either species. The combination of pruning and Bonzi (paclobutrazol) inhibited shoot elongation of both species compared to pruning alone. Flowering of both species was delayed 11 to 14 days compared to the control when pruning was combined with Bonzi (paclobutrazol). Cycocel (chlormequat chloride) suppressed shoot elongation of annual carnation but was not as effective as Bonzi (paclobutrazol); shoot elongation of garden pink was only suppressed for 2 weeks after Cycocel (chlormequat chloride) application. Application of Pro-Shear (BA) at 100 or 200 ppm did not promote axillary shoot development of either species nor did Pro-Shear (BA) combined with pruning. Pruning of annual carnation and garden pink suppressed shoot elongation through week 7 and week 4, respectively, compared to the control. Pruning of annual carnation increased axillary shoot development compared to all other treatments, while pruning of garden pink decreased flower and primary axillary shoot numbers. Pruning delayed flowering in both species about 12 days compared to the control.

Index words: paclobutrazol, chlormequat chloride, BA, Bonzi, Cycocel, Pro-Shear, growth retardant, pruning

Growth regulators used in this study: Bonzi (paclobutrazol), β-[(4-chlorophenyl)methyl]-α-(1,1-dimethylethyl) -1*H*-1,2,4,-triazole-1-ethanol; Cycocel (chlormequat chloride), 2-chloro-*N*,*N*,*N*-trimethylethanaminium chloride; Pro-Shear (BA), *N*-(phenylmethyl)-1*H*-purin-6-amine.

Species used in this study: annual carnation (*Dianthus caryophyllus* L. 'Knight Hybrid Scarlet'); garden pink (*Dianthus chinensis* L. 'Queen of Hearts').

Significance to the Nursery Industry

In a competitive industry where increased efficiency is essential to survival, a reduction in labor requirements reduces production costs and adds to profits. Bonzi (paclobutrazol), a growth retardant, is effective on a wide range of plants including *Dianthus*. Stem elongation of treated plants may be inhibited over the entire production cycle as a result of a single application of Bonzi (paclobutrazol). Cycocel (chlormequat chloride), a commonly used growth retardant on *Dianthus* species, usually requires 2-3 applications to suppress stem elongation, depending on the cul-

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