Response of Shade Trees Grown in In-ground Containers to Three Container Substrates[1]

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Abstract

Two-year-old branched seedling whips of green ash, *Fraxinus pennsylvanica* Marsh. and European birch, *Betula pendula* Roth. were grown for two seasons (1991 and 1992) in 38-liter (#10) rigid, plastic, in-ground containers in three different substrate treatments: 10%, 50% and 100% soil, containing 10:30:60, 50:30:20, or 100:0:0 of field soil:sphagnum peat:ground pine bark, respectively. Trees were also planted directly into the soil (field-grown) to serve as a baseline control treatment. Top dry mass, trunk diameter and root dry mass in 1991 and 1992 and two size categories of root dry mass (<3 and 3<6 mm) in 1991 were consistently greatest for container-grown trees in the 10% soil treatment and least in the 100% soil treatments. Corresponding results for the 50% soil treatment were intermediate between the other treatments or similar to the 10% soil treatment. In 1991, the top dry mass and trunk diameter of both species grown in containers with 10% soil and in 1992, the top dry mass of ash, in the same treatment, were greater than those of field-grown trees.

Index words: container production, media, trickle irrigation, foliar nutrients, ash, birch.

Species used in this study: green ash (*Fraxinus pennsylvanica* Marsh.); European birch, (*Betula pendula* Roth.).

Significance to the Nursery Industry

Production of large trees in in-ground containers is a technique that combines the benefits of field and container growing of trees. Several shade tree species were shown to grow faster in the in-ground container growing system because of the high degree of irrigation and fertilizer management (14). In the present study with ash and birch, both top and root growth increased as the amount of soil in the substrate decreased, indicating that a substrate with better drainage and lower bulk density was more effective for growing shade trees in large in-ground containers. In this growing system, a substrate that has good physical properties and drains well is very important to maximize tree top and root growth, factors that affect tree quality and survivability once transplanted into the landscape.

Introduction

In-ground container production in rigid plastic containers is an innovative technique for growing large-caliper shade trees. Chong and Mathers (3) described an in-ground container system for growing trees in Oklahoma. In the system, a potted tree is placed in a second container of similar size that has been permanently sunken in the ground. The intensive management of fertilizer, substrate and trickle irrigation in the in-ground system combines many of the benefits of field and container growing. In-ground container-grown trees have roots insulated during summer heat and winter cold, have root systems accessible for observation, can be harvested at any time during the season and are prevented from toppling in the wind. Murray et al. (14) reported greater growth of trees in the highly managed in-ground containers compared with field-grown trees.

The container substrate supports the roots physically and as a reservoir for the nutrients and water required for growth. In above-ground containers, plant growth was maximized in porous substrates with adequate water holding capacity (4, 9, 10, 12). Often these substrates did not contain soil. Some growers advocate including soil in the substrate to provide micronutrients and microorganisms and to increase the substrate water holding capacity. Because there was little information on soil content in substrates for growing trees in large in-ground containers, the objective of this study was to measure the effect of three container substrates, with different amounts of soil in the mix on the growth of two tree species.

Materials and Methods

Plant material and substrate treatments. On March 19, 1991, forty-eight two-year-old branched seedling whips of green ash, *Fraxinus pennsylvanica* [diameter 20 mm (0.8 in), height 2.0 m (6.6 ft)] and European birch, *Betula pendula* [diameter 20 mm (0.8 in), height 2.2 m (7.2 ft)] were dug from the nursery at the Horticultural Research Institute of Ontario, Vineland Station, and placed in cold storage at 2C (36F). Within one week, trees were transplanted into 38-liter (#10) [height 38 cm (15 in) and width 40 cm (15.75 in)] rigid-walled plastic containers using three different substrates: 1) 100% soil (Vineland fine sandy loam), 2) 50% soil:30% sphagnum peat:20% ground pine bark and 3) 10% soil:30% sphagnum peat:60% ground pine bark. Nutricote controlled release fertilizer, 20–7–10 (20N–3.1P–8.3K) Type 70 (70 day release period) at 1.2 kg m^{-3} (2 lb yd^{-3}) and Type 270 at 10.7 kg m^{-3} (18 lb yd^{-3}) (Chisso-Asahi Fertilizer Co. Ltd., Tokyo, Japan) and Granusol controlled release micronutrient supplement at 0.5 kg m^{-3} (0.84 lb yd^{-3}) (Mg 5%, Mn 3.5%, Cu

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0.5%, Zn 2%, Fe 7% S 10.9%, Ca 12%, B 0.03%, Mo 0.03%), (American Minerals, King of Prussia, PA) were incorporated into each substrate at mixing.

As previously described by Murray et al. (14), trees were potted in late March 1991, held in outdoor storage, and watered one to two times per week until they were moved to the field on May 6.

Field layout and experimental design. At the growing site, the potted trees were placed in another container of equal size sunken in the ground (14). The outer 38-liter container had been inserted into a predrilled 45 cm (18 in) diameter hole. Spacing was 1.2 m (4 ft) within the row and 2.4 m (8 ft) between rows. The top edges of the containers were initially placed 8–10 cm (3–4 in) above ground level to allow for settling. Containers were straightened and stabilized with back-filled soil. A block of wood [10 cm (4 in) × 10 cm (4 in) × 5 cm (2 in) thick] was placed at the bottom of each outer container to support the bottom of the container holding the tree.

Treatments were arranged in a split plot design with substrates as the main plot and species as the subplot. There were four main plot replications. Each field row contained four randomly distributed trees per species, planted in the same substrate. In each field row each experimental unit contained two trees per species per substrate.

To provide a baseline comparison for the substrate treatments, four trees per replication of each of the two species were removed from cold storage on April 11, 1991, and planted directly into the soil (field-grown trees). The field-grown tree rows were randomized spatially among the container-grown treatment rows and at the same spacing as the container-grown trees. Prior to planting trees on the experimental site, it was cultivated and 300 kg NH_4NO_3 ha^{-1} (267 lb NH_4NO_3 $acre^{-1}$) fertilizer was broadcast applied. The soil was a Toledo silty clay loam which contained adequate levels of P and K.

Cultural practices. Container-grown trees were trickle irrigated daily from May 15 until October 2, 1991, and from May 22 until August 24, 1992 (final harvest), using one pressure-compensating emitter (Netafim Irrigation Inc., Fresno, CA) per container. In 1991, separate trickle lines supplied 0.5 liter (0.13 gal) per day to the trees grown in the 100% soil treatment and 3 liters (0.79 gal) per day to the trees grown in the 50% and 10% soil treatments. In 1992 rates were increased to 1 liter (0.26 gal) and 4 liters (1.1 gal) per day, respectively. These irrigation rates were confirmed by xylem water potential data, measured by in-situ stem psychrometers (6) installed on the trunks of ash trees, 1 m from the top of the soil and below the branches. The psychrometer measurements corroborated visual observations that the 10% and 50% soil substrates lost moisture at a similar rate (13).

The field-grown trees were not irrigated since this is not a common nursery practice. It is noteworthy, however, that in a companion study conducted in adjacent plots at the same time, we observed no difference in the growth of four species (including the two species in this study) between trickle-irrigated and non-irrigated trees (14).

On April 25, 1991, the trees were minimally pruned to remove structurally inferior branches. Further pruning to provide a branch-free trunk up to 1.5 m (5 ft) was done July 17, 1991 and June 4, 1992.

Sampling and analysis. Trunk diameter was measured 15 cm (6 in) above the soil or container substrate at planting, prior to harvesting half the number of trees on September 20, 1991, and also prior to harvesting the remaining trees on August 24, 1992. At each harvest, the top portion of each tree was separated into branches and trunk and each portion was weighed immediately. Representative samples of branches (one each from the lower, middle and upper regions of the canopy), and trunk [three 15 cm (6 in) long pieces from the lower, middle, upper trunk] were collected, weighed, dried at 80C (176F) and reweighed. Total branch and trunk dry mass were calculated by multiplying the percentage of dry mass of the branch or trunk sample by the corresponding total branch or trunk fresh mass. At each harvest, roots from one tree per treatment combination were removed from the container, thoroughly washed with a high pressure hose, and dried at 80C (176F). In 1991, all roots <3 mm and 3<6 mm in diameter were removed from the washed and dried rootball and were weighed separately.

Foliar samples were collected August 7, 1991, and July 29, 1992, dried at 80C (176F) and ground to pass through a 40-mesh screen. Total N was determined by the Kjeldahl method and K, Ca, Mg, Mn, Fe, and Zn by atomic absorption spectrophotometry after dry ashing at 550C (1022F). Phosphorous was analyzed by colorimetry.

The bulk density of each substrate was measured by collecting four cylindrical samples of substrate [volume 90.5 cm^3 (5.5 in^3)], then weighing them after oven drying. For percent moisture content at container capacity, each substrate was saturated then allowed to drain without evaporation for 24 hours, after which four samples per substrate were weighed then reweighed after they had been oven dried.

Data were analyzed with SAS statistical software using general linear models analysis (18). Root data are presented as individual main effects, while top dry mass and trunk diameter are separated by species as the substrate by species interaction was significant. Means were separated by the Least Significant Difference (LSD) test. Data for field-grown trees were compared to individual substrate treatments using *t* tests.

Results and Discussion

Top and root growth of container-grown trees. Among the three substrate treatments, top dry mass and trunk diameter (Fig. 1) and root dry mass (Fig. 2) in each of the two years, and the two size categories of root dry mass (<3 and 3<6 mm) in 1991 only (Fig. 2), were consistently greatest for container-grown trees in the 10% soil treatment and least in the 100% soil treatment. The corresponding results in 50% soil were intermediate between the other two treatments or similar to those in the 10% soil treatment. Despite the significant species × substrate interaction for top dry mass and trunk diameter in 1991, in both cases, the trend for each species was similar, but the magnitude of the differences among the treatments for the ash was smaller than for the birch (Fig. 1).

Container-grown versus field-grown trees. For both species in 1991, top dry mass and trunk diameter were greater for container-grown trees in the 10% soil substrate than for the field-grown trees (Table 1). In 1992, top dry mass was greater for ash in the 10% soil substrate than for the field-grown trees. No meaningful comparisons could be made between the roots of container-grown and field-grown trees

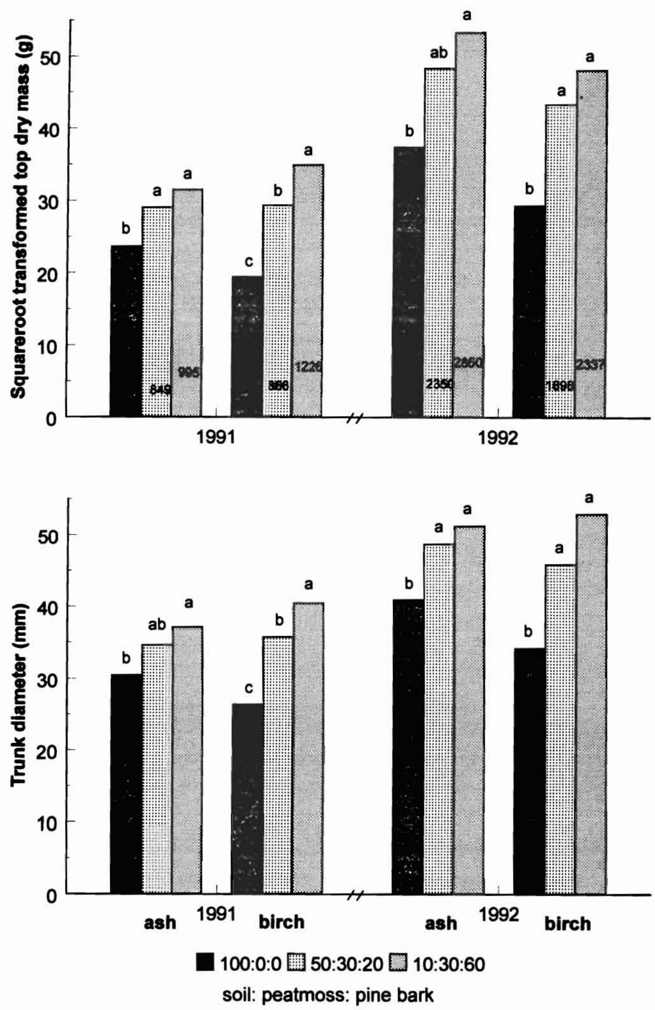

Fig. 1. **Top dry mass and trunk diameter of ash and birch trees grown in 38-liter in-ground containers. Substrate treatments with 100%, 50% and 10% soil contained the following proportions of field soil:sphagnum peat:ground pine bark: 100:0:0, 50:30:20 and 10:30:60, respectively. Data for top dry mass was squareroot transformed for analysis. The back transformed values are shown inside the bars. Substrate treatments were separated (a,b,c) within year and by species, by LSD at $P \leq 0.05$.**

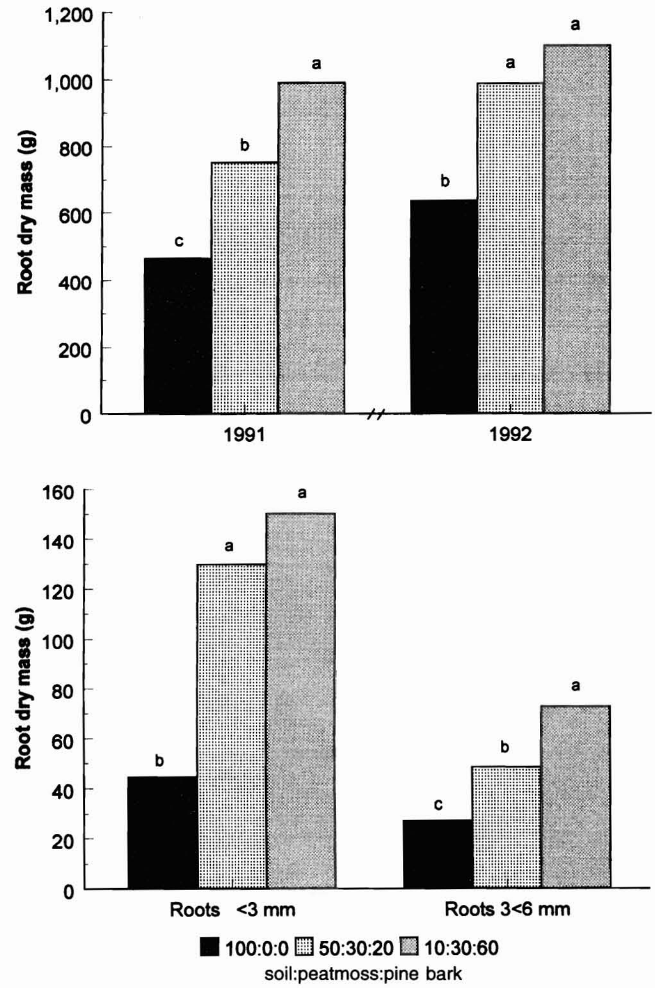

Fig. 2. **Root dry mass (1991 and 1992) and dry mass of <3 and 3<6 mm diameter roots (1991 only) averaged over the two species (ash and birch) grown in 38-liter in-ground containers. Substrate treatments with 100%, 50% and 10% soil contained the following proportions of field soil:sphagnum peat:ground pine bark: 100:0:0, 50:30:20 and 10:30:60, respectively. Treatments within size classes were separated (a,b,c) by LSD at $P \leq 0.05$.**

since harvest of the entire root system of the field-grown trees was not possible.

Substrate properties. The water content at container capacity was 35%, 28% and 17% for the 100%, 50% and 10% soil substrate treatments, respectively. The corresponding bulk densities were 1.32, 0.74 and 0.30 g cm^{-3}.

In 1991, tree top dry mass, total root dry mass and root dry mass in both size classes (<3 mm and 3<6 mm) decreased as the amount of soil in the container substrate increased. The higher moisture content at container capacity and higher bulk densities as the percentage of soil in the substrate increased and the volume of peat and pine bark decreased would have resulted in progressively lower aeration porosities and thus lower oxygen levels for root respiration, which in turn would reduce shoot and root elongation (19). In this study, container substrates with greater volumes of peat and bark had lower bulk densities and greater total porosities, conditions under which shoot and root growth were greater, similar to

Table 1. **Percent increase in squareroot transformed top dry mass and trunk diameter of container- grown over field-grown trees.**

Container substrate treatment	1991 Ash	1991 Birch	1992 Ash	1992 Birch
	Squareroot transformed top dry mass			
100% soil[z]	–6.8	–20.7	–15.9	–39.0
50% soil	14.4	22.0	8.7	–9.5
10% soil	24.0*	45.2*	20.0*	–1.9
	Trunk diameter			
100% soil	2.9	–13.9	–12.8	–22.7
50% soil	17.2	16.7	3.7	3.5
10% soil	25.6*	32.2*	9.0	19.3

[z]substrate treatments with 100%, 50% and 10% soil contained the following proportions by volume of field soil:sphagnum peat:ground pine bark: 100:0:0, 50:30:20, and 10:30:60, respectively.

*significantly different from field-grown trees by *t*-test at $P \leq 0.05$.

observations made by Keever and Cobb (9). Gilman and Beeson (8) also found that holly and laurel oak grown in fabric containers backfilled with native soil or field-grown had several times less roots 2 mm or less in diameter, compared to trees grown in soilless substrate in plastic containers.

The three different substrates were irrigated independently and kept consistently moist; however, periods of precipitation resulted in excess moisture in the containers, especially early in each season. In the 100% soil substrate treatment, several of the birch trees died, presumably due to the reduced aeration conditions resulting from the higher bulk density and higher moisture content in this treatment. However, there was no mortality among the container-grown ash in the 100% soil, indicating that ash was better able than birch to tolerate the high moisture levels in the containers when precipitation levels were high.

Container substrate drainage is generally poor because downward capillary movement of water is interrupted by the pot base, creating a perched water table (17). In our experiment, this effect was increased as the increasing proportion of soil in the mix resulted in a substrate with higher bulk density. Woody plants are not generally grown in a container with 100% field soil; however, this treatment was included to provide a 'worst case' comparison for the experiment. It is noteworthy that when trees are grown using in-ground fabric containers they are typically backfilled with 100% field soil (1, 2, 16, 20).

Our previous study (14) indicated that the top and root growth of trees in the 38-liter (#10) containers was restricted in the second year due primarily to the limitations in the pot size. Other researchers (2, 7, 11, 14) have also reported reduced growth due to constriction of the root system. Therefore, for optimal growth over two seasons, trees would require larger containers.

Although there were significant differences in some foliar nutrients (data not shown) due to the substrate treatments, and between individual substrate treatments and field-grown trees, the differences were generally small, or inconsistent and were within sufficiency ranges for adequate tree growth (5) . No toxicity or deficiency symptoms were observed in either species, indicating that the differences did not play a major role in treatment effects on plant growth.

Optimal tree growth in the in-ground containers was dependent on the physical properties of the substrate. Both top and root growth increased as the substrate bulk density and water holding capacity decreased concurrently, which occurred as the amount of soil in the substrate decreased. The increased total root dry mass of the container-grown trees in the 10% and 50% soil substrates should result in increased transplant success over those grown with 100% soil.

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