TREE SHELTERS ACCELERATE SLOW-GROWING SPECIES IN NURSERIES

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Abstract. Two experiments investigated the effects of tree shelters on height, caliper, and diameter growth of liners of 14 species and cultivars. In the first year at one nursery all nine varieties had greater height growth inside shelters, averaging 325% of controls without shelters, thus adding 1.1 feet (33 cm) to 2.3 feet (70 cm) to their height. After two years at the other nursery, the varieties had increased height growth inside shelters ranging from 111% to 484% of controls, or 0.3 feet (10 cm) to 4.2 feet (128 cm). Caliper growth either was adversely affected by shelters, as much as 0.4 inch (1 cm) in two years, or did not increase in proportion to height growth. Trees in shelters were less sturdy, but other studies indicate caliper growth in subsequent years may overcome this disadvantage.

Tree shelters are translucent plastic tubes of various sizes used to protect trees while modifying a microclimate which improves survival and enhances growth rates (8,13,15).

They have been used most commonly in forest environments. Using tree shelters in nurseries to increase growth rate and change the form of slow growing varieties to meet street tree requirements is a new idea. Street trees have been grown in shelters in urban plantings (6,15); and shelters have been used in nurseries to produce containerized landscape trees (1); but tree shelters may be most beneficial when used in nurseries to modify the growth of slow growing trees to meet street tree specifications.

Tree shelters can shift a tree's natural growth responses to encourage it toward the desired street tree form, whereas severe pruning, the traditional treatment, causes wounds and decreases energy reserves. Trees grown in shelters often produce a few small lateral branches inside the shelter. This growth modification would seem to be ideal for street trees which eventually should be free of branches to a height of at least six feet. Some additional benefits which tree shelters offer are protection from browsing animals, increased survival, decreased production time, less labor involved in irrigation and pruning, and fewer graft problems (16).

The ultimate goal of this study is to determine if tree shelters can be used as an aid to nursery production of small-maturing street trees, especially slow growing species that tend to branch low. Initial objectives were to determine if significant differences occurred in the growth rates and sturdiness of sheltered versus unsheltered trees, if species or cultivars differed in their response to shelters, and if any adverse effects were associated with sheltered trees.

Materials and Methods

Two separate experiments were conducted. Experiment 1 was planted in May 1994 at Root's Nursery near Manheim, in the gently rolling hills of the piedmont region of southeastern Pennsylvania. Experiment 2 was planted in April and May 1995 at Nittany Trees Nursery near Zion, in central Pennsylvania. Nittany Trees Nursery is situated in the Nittany Valley, on a nearly level site near the base of Nittany Mountain which rises to the southeast.

Several species and cultivars were planted in Experiment 1: Merrill magnolia (*Magnolia x loebneri* 'Merrill'), paperbark maple (*Acer griseum*), eastern redbud (*Cercis canadensis*), Celestial dogwood (*Cornus kousa x florida* 'Celestial'), Summer Snow Japanese tree lilac (*Syringa reticulata* 'Summer Snow'), Adirondack crabapple (*Malus halliana* 'Adirondack') and star magnolia (*Magnolia stellata*). These species were selected with a number of factors in mind, including small mature size (<30 feet, or 9 m, tall at maturity), apparent potential as street trees, a reputation for being difficult to grow to meet street tree standards, and their availability in the required size. Star magnolia trees averaged 1.0 foot (30 cm) tall at the time of planting. The other six varieties averaged 3.2 feet (98 cm) to 4.2 feet (128 cm).

Nine species or cultivars of trees were planted in Experiment 2. Besides star magnolia and Celestial dogwood, used in both experiments, the others were Constellation dogwood (*Cornus kousa x florida* 'Constellation'), capillipes maple (*Acer capillipes*), David maple (*Acer davidii*), Japanese hornbeam (*Carpinus japonica*), American hornbeam (*Carpinus caroliniana*), Kwanzan Japanese flowering cherry (*Prunus serrulata* 'Kwanzan') and autumn flowering Higan cherry (Prunus subhirtella 'Autumnalis'). The trees averaged from 3.0 feet (91 cm) to 4.0 feet (122 cm) tall at the time of planting with the exception of star magnolia (1.8 feet, 55 cm) and American hornbeam (2.6 feet, 79 cm).

The tree shelters used in Experiment 1 were five foot (1.5 m) tall Treessentials Supertubes®, commonly referred to as TUBEX®. The tubes are made of a translucent light brown plastic polymer molded into a seamless twin-walled tube in four slightly different diameters, 3.1 to 4.5 inches (8 to 11 cm). These tubes feature a flared upper rim to decrease scraping damage and ultra-violet light stabilization for a five to seven year life. The shelters were fastened to oak stakes with nylon ratchet-locking ties.

The shelters used in Experiment 2 were five foot (1.5 m) tall Tree Pro Sr.® tree protectors. One or two corrugated light brown plastic sheets made from recycled plastic materials were used to create tubes which were 3.5 and 7.0 inches (9 to 18 cm) in diameter, respectively. These tubes feature a soft plastic tape at the upper rim to decrease scraping damage and ultra-violet stabilization for a five to seven year life. The shelters were fastened to oak stakes with ratchet-locking ties. The same ties were used to fasten together two sheets for the larger shelters. (Figure 1)

Experiment 1 contained 126 trees of seven varieties separated equally into three blocks, and planted in six-tree plots. Three trees of each plot received the shelter treatment while the other three were left unsheltered as controls. Experiment 2 consisted of 240 trees of nine varieties, again divided into three complete blocks. The three treatments, 3.5 inch (9 cm) shelter, 7.0 inch (18 cm) shelter, and unsheltered control were randomly assigned to three-tree sub-plots within each varietal plot. The trees at both experiments were planted approximately five feet apart in columns, and ten feet apart in rows. Many of the maples in Experiment 2 required support to stand upright. All the unsheltered maples were planted along with their bamboo stakes, to which they were loosely attached for support.

Figure 1: First year growth of *Prunus subhirtella* "Autumnalis" at Nittany Trees Nursery. Control tree is flanked by tree shelters 7 inches and 3 ° inches in diameter.

Shelters were placed around the experimental trees shortly after the trees were planted, following the experimental design. The shelter base was sealed into the soil by pressing it into the ground, or mounding soil around the shelter base. It became necessary to remove lateral branches from a few trees to fit them into the shelters.

Care of the trees was left to nursery employees using standard nursery practices. Weed control was achieved with chemicals and mechanical cultivation. The trees were irrigated when they were planted and at times during the summer when conditions were dry. Insect and disease control was not necessary, except that the trees of Experiment 2 were sprayed several times to control Japanese beetles (*Popilla japonica*).

In both experiments tree height, caliper at 6 inches (15 cm) above ground, and diameter at 4.5 feet (137 cm) were measured after summer growth was complete each year. During the period from August 20, 1995, to February 1, 1996, maximum and minimum temperatures were recorded at six trees in Experiment 2. A tall tree (>5 feet, 152 cm) and a short tree (<2.5 feet, 76 cm) for each of the three shelter treatments were selected randomly to host a thermometer which was attached at 2.5 feet (76 cm) above the ground.

Data were analyzed using the Statistical Analysis Systems (SAS) program. Under the General Linear Model (GLM) procedure, SAS prepared analysis of variance (ANOVA) tables, means separated by Duncan's New Multiple-Range Test, and tables of data means separated by the classification variables. The ANOVA tables included the factors block, variety of tree, shelter treatment, and the interaction of treatment and variety. Time (year) was also included as a factor at Experiment 1 for the height growth data (repeated measure method analysis), as were all possible interactions with treatment and variety. A significance level of 0.05 was chosen for all statistical evaluations.

The ratio of height to caliper was calculated for each variety and treatment combination after each growing season by dividing the height of the tree in feet by the caliper of the tree in inches.

Results

The experimental trees experienced a wide variety of environmental conditions during the

Table 1. Annual height growth (feet) and mean caliper (inches) presented by varieties, shelter treatments, and years for Experiment 1.

	Height Growth				Caliper Growth	
	No Shelter		Shelter		No Shelter	Shelter
Variety	Year 1	Year 2	Year 1	Year 2	Year 2	Year 2
*Acer griseum**	0.50a	0.31a√	0.65a	1.20a	0.67a	0.40b
Cercis canadensis	-0.15b	2.74a	0.07a†	2.33a	1.02a	0.73b
Cornus 'Celestial'*	0.79b√	2.12a	2.33a	2.40a	0.87a	0.67b
Magnolia 'Merrill'*	0.32a	0.78a√	0.12b√	2.17a	0.68a	0.66a
*Magnolia stellata**	0.35a√	0.72a√	1.83b	2.93a	0.52a	0.52a
Malus 'Adirondack'	0.56b	1.31a	0.60b	1.41a	0.79a	0.52b
Syringa reticulata 'Summer Snow'*	0.10a	0.27a√	0.30a	1.25a	1.04a	0.63b
Combined*	0.38b	1.19a	0.69b	1.96a	0.80a	0.59b

For each variety, year 1 and year 2 means within treatments were compared.
Varietal means with the same letter do not differ significantly from one another in height between years, or in caliper between treatments.

* indicates a variety with a significant difference in two-year height growth between shelter treatments.

√ indicates that the associated value is significantly lower than the value for the other shelter treatment in the same year and variety.

† identifies a mean which is not significantly different from other means despite large apparent differences, because it is based on only three highly variable measurements.

Table 2. Mean height growth (feet) and mean caliper growth (inches) presented by varieties and shelter treatments for Experiment 2 after one year.

	Height Growth			Caliper Growth		
Variety	None	Small	Large	None	Small	Large
Acer capillipes	0.37b	2.37a	2.27a	0.10a	0.14a	0.17a
Acer davidii	0.48c	1.79b	2.38a	0.12a	0.04b	0.10ab
Carpinus caroliniana	-0.16b	1.58a	1.43a	0.19a	0.18a	0.16a
Carpinus japonica	0.43b	1.85a	1.74a	0.04b	0.14a	0.16a
Cornus 'Celestial'	0.36b	1.66a	1.37a	0.14a	0.13a	0.14a
Cornus 'Constellation'	0.44b	1.91a	1.39a	0.18a	0.12a	0.12a
Magnolia stellata	0.19b	1.36a	0.67b	0.02a	0.04a	0.04a
Prunus 'Kwanzan'	1.68b	3.96a	4.04a	0.24a	0.10b	0.14b
Prunus subhirtella 'Autumnalis'	2.08b	3.17a	3.09a	0.34a	0.19b	0.16b
Combined	0.65b	2.18a	2.04a	0.15a	0.12b	0.13ab

For each variety and combined values, treatment means with the same letter do not differ significantly from one another.

study, including summer droughts and record snowfall. Extreme temperatures recorded within shelters at Experiment 2 were 52° C in August 1995 and -23° C in January 1996. During the summer months, sheltered thermometers commonly registered 5 to 10° C higher maximum temperatures than the unsheltered thermometers. Minimum summer temperatures seemed to depend on shelter size and presence, large shelters having the lowest minimum temperatures, unsheltered thermometers were intermediate, while small shelters remained warmest. There was little difference in recorded maximum or minimum temperatures during the winter, however, sheltered thermometers often recorded slightly (1 to 3°C) increased maximum temperatures.

Despite the extreme climatic conditions in shelters, only the striped bark maples (*Acer* series *Macrantha*) appeared to suffer severely. Toward the end of summer 1995 some maples in Experiment 2 were showing signs of dieback. By May 1996, it was apparent that none of the *Acer davidii* trees survived the winter. *Acer capillipes* fared slightly better, being essentially healthy outside the shelters (nine of ten trees surviving), but only one tree survived within shelters.

For all the following statistical tests, there were significant differences among the varieties tested (18). Shelter treatment differences were also significant overall, although many varieties responded differently from the average response.

Experiment 1 showed that shelters significantly increased average height growth to 0.69 foot (21 cm) in the first year, compared to the 0.38 foot (12 cm) growth of unsheltered trees; and from 1.19 feet (36 cm) to 1.96 feet (61 cm) in the second year (Table 1). In addition to the shelter treatment effects, there were also real differences among varieties (species and cultivars) and between years. The significant variety by treatment interaction indicated that shelter effects on varieties must be examined individually. Other significant interactions were variety by year and variety by treatment by year.

Although the two year height growth of most varieties in Experiment 1 (Table 1) was greater within shelters, *Cercis canadensis* and *Malus* 'Adirondack' did not have significantly greater height growth in shelters in either year. The superior growth of other varieties in shelters was

Figure 2: *Magnolia stellata* in the second year at Root's Nursery, control tree and emerging from tree shelter.

due to greater growth in the first year (Cornus 'Celestial'), or in the second year (*Acer griseum*, *Magnolia* 'Merrill', and *Syringa reticulata* 'Summer Snow') or in both years (*Magnolia stellata*). *Magnolia* 'Merrill' grew taller outside shelters in the first year, but in the second year had much greater height growth inside resulting in greater two year growth in shelters. Two-year height advantages of trees in shelters ranged from 0.32 foot (10 cm) for *Malus* 'Adirondack' to 4.22 feet (128 cm) for *Magnolia stellata*. The percentage increase in two-year height attributable to shelters ranged from 111% (*Cercis canadensis*) to 484% (*Magnolia stellata*).

Similar results were obtained from Experiment 2 (Table 2). Height growth was significantly increased in at least one size shelter for every variety as compared to the unsheltered trees. Average unsheltered trees had height growth of 0.65 foot (20 cm) while average sheltered trees grew more than 2 feet (61 cm), or 325% of controls. There were differences in the magnitude of increase, which depended on variety, and in their response to shelter size, producing a significant variety by treatment interaction. The magnitude of increase over controls ranged from 1.09 feet (33 cm) for *Prunus subhirtella* 'Autumnalis' to 2.28 feet (70 cm) for *Prunus 'Kwanzan'*.

The two shelter sizes used in Experiment 2 did

Table 3. Diameter means (inches) presented by varieties and shelter treatments for Experiment 1 after two years.

Variety	No Shelter	Shelter
Acer griseum	0.15 a	0.17 a
Cercis canadensis	0.23 b	0.49 a
Cornus 'Celestial'	0.21 b	0.37 a
Malus 'Adirondack'	0.19 a	0.28 a
Magnolia 'Merrill'	0.13 b	0.41 a
Magnolia stellata	--	0.27
Syringa reticulata 'Summer Snow'	--	0.20
Combined	0.20b	0.32 a

For each variety and combined values, treatment means with the same letter do not differ significantly from one another.

not always produce the same results, for all varieties. It was common for both shelter treatments to have no significant difference between them, while each had greater height growth than the control trees. *Acer davidii* produced the greatest height growth in the larger shelter diameter, followed by the small shelter and then the control treatment. *Magnolia stellata* produced significantly greater growth in only the small shelter. (Figure 2)

Caliper is another growth attribute important to a high quality street tree. In Experiment 1 caliper measured after two years was found to be significantly different for shelter treatments and varieties. Caliper development averaged 0.80 inches (2.0 cm) for unsheltered trees and 0.59 inches (1.5 cm) for sheltered trees (Table 1). For *Magnolia* 'Merrill' and *Magnolia stellata*, differences in caliper were not significant between treatments, resulting in a significant interaction between variety and treatment.

The results of Experiment 2 were similar, one year caliper growth differences being significant for varieties, treatments, and the interaction between them. Average caliper growth was reduced in the shelters as compared to control trees, but the significant interaction indicates that

Table 4. Diameter means (inches) presented by varieties and shelter treatments for Experiment 2 after one year.

Variety	No Shelter	Small Shelter	Large Shelter
Acer capillipes	0.12	0.24	0.22
Acer davidii	0.10	0.21	0.27
Carpinus caroliniana	--	0.13	0.13
Carpinus japonica	--	0.14	0.13
Cornus 'Celestial'	0.10	0.12	0.10
Cornus 'Constellation'	0.10	0.14	0.15
Magnolia stellata	--	0.10	--
Prunus 'Kwanzan'	0.22	0.36	0.39
Prunus subhirtella 'Autumnalis'	0.10	0.30	0.21
Combined	0.12b	0.22a	0.21a

Treatment means with the same letter do not differ significantly from one another. Duncan's separations are not presented for each variety due to the non-significance of the interaction between variety and treatment.

Table 5. Ratio of height (feet) to caliper (inches) presented by varieties, years and shelter treatments for Experiment 1.

Variety	Year 1 No Shelter	Year 2 No Shelter	Year 2 Shelter
Acer griseum	7.7	6.1	13.5
Cercis canadensis	6.7	6.1	12.2
Cornus 'Celestial'	7.5	7.6	12.4
Malus 'Adirondack'	6.4	7.3	12.0
Magnolia 'Merrill'	7.9	6.5	10.9
Magnolia stellata	4.6	4.3	11.4
Syringa reticulata 'Summer Snow'	4.4	3.7	7.9
Combined	6.4	6.0	11.6

Caliper was not measured in Year 1 within shelters.

not all varieties responded in the same way (Table 2). One species (*Carpinus caroliniana*) had significantly less caliper growth when unsheltered. Only the two cherries had caliper growth that was significantly greater outside the shelters than both of the sheltered treatments. Of the remaining trees, only *Acer davidii* had a significant difference between any of the treatments, where the control treatment was significantly greater than the small shelter.

Diameter. Stem diameter at 4.5 feet (137 cm) above ground measured after two years growth at Experiment 1 was significantly different between treatment and varieties. The treatment by variety interaction was also significant (Table 3). Only one *Syringa reticulata* 'Summer Snow' and no *Magnolia stellata* trees grew to be 4.5 feet (137 cm) tall when unsheltered, so their diameters could not be measured. Of the remaining trees only *Acer griseum* and *Malus* 'Adirondack' did not show a significant treatment effect. For all other varieties the sheltered treatment had greater diameter than the control treatment.

At Experiment 2 diameter differences after one year were significant for variety and treatment, but the interaction of these variables was not significant (Table 4). Overall, sheltered trees had a greater diameter than unsheltered trees while there was no significant difference between shelter sizes.

The ratio of height (in feet) to caliper (in inches), indicating stem taper, was calculated for each possible combination of year and treatment of Experiment 1 and Experiment 2. At Experiment 1 (Table 5), unsheltered ratios ranged from 4.4 for *Syringa reticulata* to 7.9 for Magnolia 'Merrill' after the first year; in the second year most ratios were lower, and ranged from 3.7 for *Syringa reticulata* to 7.6 for *Cornus* 'Celestial'. Sheltered ratios in the second year ranged from 7.9 for *Syringa reticulata* to 13.5 for *Acer griseum*, all of them higher than unsheltered ratios.

Similar results were found at Experiment 2 where shelters increased the ratio of height to caliper (Table 6). Shelter size was not a consistent predictor of ratio values, three varieties having their higher ratios in the large shelters while the six others were greater in the small shelters.

Table 6. Ratio of height (feet) to caliper (inches) presented by varieties and treatments for Experiment 2 after one year.

Variety	No Shelter	Small Shelter	Large Shelter
Acer capillipes	11.8	15.8	14.2
Acer davidii	6.3	9.5	9.8
Carpinus japonica	10.8	14.1	15.3
Carpinus caroliniana	11.2	13.5	12.8
Cornus 'Celestial'	7.0	9.8	8.3
Cornus 'Constellation'	6.7	10.5	9.7
Magnolia stellata	8.5	13.0	12.1
Prunus 'Kwanzan'	7.6	15.1	13.4
Prunus subhirtella 'Autumnalis'	9.6	15.8	16.4
Combined	8.8	13.0	12.4

Discussion

Merchantable size for street trees when they leave the nursery is determined by a caliper of approximately two inches (5 cm) and a total height of at least eight feet (2.4m). Ultimately street trees should be free of branches to a height of at least six feet (1.8 m).

Height growth was the primary factor used to evaluate the early growth of trees in Experiments 1 and 2, as it is generally accepted as a measure of tree vigor and value. Twelve of the fourteen varieties studied grew taller in shelters, as most broad-leaved trees do (13).

But the early caliper growth of many varieties was reduced in shelters. Accelerated height growth without increased caliper and resultant sturdiness is adverse, and is a serious concern for many of the tested varieties. Potter (13) stated that three year old trees in shelters lacked taper, and required additional support to stand erect; although after five years most sheltered trees were able to support themselves, having stem shape similar to unsheltered trees. The current experiments have not progressed far enough to determine if the varieties tested will develop a strong trunk.

Although sheltered height growth means were always greater than or equal to unsheltered height growth means, caliper growth was significantly greater, not significantly different, or less than unsheltered trees depending on variety. This variation in caliper growth is consistent with Potter's (13) statement that caliper development in shelters is dependent on variety. Trees of a common genus often had similar growth responses for caliper and height growth, responding to shelter treatment similarly. The ratios of height to caliper also differed considerably among varieties, treatments, and experiments.

The two varieties that were included in both experiments, *Magnolia stellata* and *Cornus* 'Celestial', had significantly greater height growth in tree shelters during the first year of their respective experiments. However, these varieties grew much more in Experiment 1 than in Experiment 2. This is probably a result of climatic influences rather than a difference between the experimental sites, as the first growing season at Experiment 2 was extremely hot and dry.

The large number of significant interactions demands a closer look at how each variety grew in each shelter treatment. The *Magnolias* of Experiment 1 had significantly increased height growth in shelters without significantly changed caliper. *Cercis canadensis* and *Malus* 'Adirondack' had significantly smaller caliper without increased height growth. The three remaining varieties in Experiment 1 had significantly greater height growth with significantly lower caliper. The significance of overall annual height growth at Experiment 1 resulted from differential responses in height growth, which in most cases occurred in only one year.

At Experiment 2, all varieties had significantly greater height growth in shelters during the first year. *Carpinus caroliniana* had increased height growth with increased caliper growth. Most cultivars had increased height growth without significantly changed caliper growth. *Prunus* trees showed increased height growth with significantly decreased caliper growth.

Alteration of stem taper in shelters could be caused by a number of microclimate factors. Temperature, humidity, protection from wind, lowered light levels and elevated carbon dioxide concentration have been connected to tree growth in shelters (3, 4, 7, 9, 10, 11, 13).

Other factors which may have affected the experimental results include mammal browsing, insects (Japanese beetles and gypsy moth (*Lymantria dispar*), birds, herbaceous competition, abrasion, breakage and modified temperature regimes. Overall these factors caused few problems. *Prunus*, and *Carpinus* to a lesser extent, seemed to be most affected by Japanese beetles, but chemical control was used before much damage could be done. Maples seemed to suffer the most from physical conflict with shelters, being subject to breakage near the top of the shelter when wind or birds put pressure on the stem. Subsequently the shelter panels were fastened together at a higher point so that the stem could not get caught between the edges, where most breakage seemed to occur. Earwigs (*Euborellia annulipes*) were noted residing in the shelter corrugations in large numbers, but were not observed to cause any damage to the experimental trees.

The extreme high temperatures and drought during summer were likely the primary stress factors which allowed the trees of both striped bark maples to be attacked by various weak pathogenic fungi (Penn State Plant Pathology Department). Dirr (2) states that striped bark maples grow in cool mountain conditions and that *Acer capillipes* is probably the most heat tolerant of the Series, enabling this species to survive outside shelters where the temperature was not as high. Many studies have noted that temperatures are often higher inside tree shelters (1, 5, 12, 14, 17). None of the other varieties appeared to suffer from the high summer temperatures, however the extreme winter conditions did cause approximately a dozen shelters to be laid over by wind, snow, and ice causing breakage of a few trees inside.

Shelter types as they affect durability and nursery practices are important considerations. Although there are no observable differences in tree growth which were attributable to shelter type, some may be anticipated as trees grow larger.

Conclusions

Tree shelters promoted the growth of some varieties more than others. *Carpinus caroliniana* appears to be an excellent candidate for tree shelter use, having greater height and caliper growth in shelters. *Carpinus japonica*, *Cornus* 'Constellation', *Magnolia stellata* and *Magnolia* 'Merrill' have a good chance of becoming excellent street trees. Their increased height growth and form changes are encouraging, while non-significant caliper differences may not be important if the trees are able to support their own weight in the next few years. *Acer griseum*, *Cornus* 'Celestial', *Syringa reticulata* 'Summer Snow', *Prunus* 'Kwanzan' and *Prunus subhirtella* 'Autumnalis' may still recover from their reduced caliper. Their increased height growth may help them to gain additional caliper while the shelters act to protect the trees from breakage and provide support to encourage upright growth.

Cercis canadensis and *Malus* 'Adirondack' do not appear to benefit from tree shelter use, having significantly decreased caliper without increased height growth. It is unlikely that either of these trees will show any improvement as they are already considerably taller than the shelters. Although neither of the striped bark maple species can be recommended for use in tree shelters due to their intolerance of the high shelter temperatures, their growth figures may represent their potential to grow well in shelters in a cooler climate.

The results presented in this paper are just the beginning of a better understanding of the way tree shelters affect tree growth in nurseries. More data will be gained from these experiments in the future. Measures of height growth, caliper growth and diameter will determine how quickly a tree becomes ready for sale and use as a street tree. What we do not yet know is the quality of the trees that will be produced. How many low branches will remain? What will be the size of these branches or the resulting pruning wounds? How sturdy will the trees be?

Although much remains to be learned, it appears that tree shelters offer a promising technique for the production of trees which would otherwise be too slow growing or bushy to be grown as street trees.

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Résumé. Deux projets de recherche ont vérifiés les effets des ombrières sur la croissance en hauteur et en diamètre de rangées de culture de 14 espèces et cultivars différents. Dans une pépinière la première année, neuf variétés avaient une croissance supérieure en hauteur sous les ombrières, dépassant de 325% en moyenne la hauteur des arbres témoin sans ombrière. Dans une autre pépinière après deux ans, les variétés poussant sous les ombrières avaient une croissance en hauteur supérieure de 111 à 484% à celle des arbres témoin. La croissance en diamètre était, soit affectée négativement par l'ombrière, ou encore n'augmentait pas dans les mêmes proportions que celle en hauteur. Les arbres sous les ombrières étaient moins robustes; mais d'autres études mentionnent que la croissance en diamètre des années subséquentes peut arriver à compenser ce désavantage.