HEIGHT, CALIPER GROWTH, AND BIOMASS RESPONSE OF TEN SHADE TREE SPECIES TO TREESHELTERS

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Abstract. Ten tree species common to the California landscape were grown from liners with or without treeshelters in the landscape for 2 years. Periodic (~ every 2 months) height and caliper measurements were taken and, at the end of the 2 years, all trees were harvested for fresh and dry weight biomass determinations. Response to the treeshelter microenvironment was species dependent. Height was greater for sheltered versus unsheltered trees during the first 30 to 250 days for all species After 2 years, only *Ginkgo biloba* and *Pinus canariensis* trees grown in shelters were taller than their unsheltered counterparts. Stem caliper was often reduced for sheltered trees. Treeshelters may be useful for tree establishment in the landscape, but should be removed once the tree has grown out of it. Staking likely will be required after removal of the treeshelter.

Treeshelters are cylindrical or square, translucent, polypropylene tubes of varying heights (60–150 cm) originally developed in Great Britain to protect newly transplanted trees from browsing animals. However, it was observed that trees growing in shelters responded with significant increases in height, sometimes exceeding 600% that of unsheltered trees (4,8). These growth enhancements have been attributed to changes in the microenvironment around sheltered trees (1,8,10). Comparisons between the interior and exterior of treeshelters show the interior to have a lower light intensity and a higher temperature, relative humidity, and CO_2 concentration, especially if the shelter is free of any ventilation holes (1,6). The low-light conditions are known to stimulate stem elongation responses by increasing internodal distances. Other responses such as above-ground biomass accumulation are not always apparent or observed, and the effects of treeshelters on below-ground growth are just beginning to be extensively studied (unpublished data).

Treeshelters have been successfully used for tree establishment (12), nursery tree production (1,13), rural releaf efforts (5), oak regeneration and rehabilitation (6), and landscape revegetation (3). They have been recommended for use in a myriad of landscape planting and revegetation situations (6,12) and found unsuitable in others (3). Most of the work with treeshelters to date has been conducted in temperate climates where treeshelters can effectively increase the length of the growing season (9). The use of treeshelters in the California landscape has been based on data and information gathered from studies conducted in other climates. Only recently has information been gathered on their use in Mediterranean climates (2,3). The objective of this 2-year study was to assess survival and determine the usefulness of treeshelters on 10 shade tree species important to the California urban landscape. In doing so, measurements were taken of the trees' height and stem diameter and assessments were made of the trees' responses (e.g., ability to stand upright after treeshelter removal) to the treeshelter microenvironment.

Materials and Methods

In April 1993, 10 replicate liners each of 10 tree species were planted in 2 blocks in a randomized complete block design with paired-tree treatments. The following seed-propagated tree species were used: *Sequoia sempervirens, Quercus lobata, Quercus agrifolia, Alnus rhombifolia, Lagerstroemia indica, Ginkgo biloba, Platanus racemosa, Fraxinus latifolia, Maytenus boaria,* and *Pinus canariensis*. The liners were planted on 1.8 m centers in rows 1.8 m apart. Each block consisted of 2 rows; all trees in 1 row were sheltered (122 cm tall, tan Tubex® shelter), while trees in the adjacent row were unsheltered (control). The paired-tree arrangement provided a clear comparison between sheltered and unsheltered tree treatments for all 10 species and reduced the potential effects due to soil type variation and varying environmental conditions. The trees were irrigated with an automatic drip system that provided plentiful amounts of water for the duration of the experiment. Trees were fertilized once, 6 weeks after planting, with Agriform 20-10-5 plus minor element tablets (Grace/Sierra, Milpitas, California). The fertilizer tablets were pressed 8 to 12 cm into the soil immediately after an irrigation.

At intervals of between 60 and 90 days, the trees' height and stem diameter were measured, and observations of the trees' overall appearance and quality were made. As trees grew and eventually emerged from the treeshelter, the shelter was removed; stakes (2 per tree) were used for trees unable to support themselves. Unsheltered trees were staked as needed, and not any of the *trees in either treatment were pruned.* After 1 year, half of the trees were measured (height, caliper at ground level, and caliper at 1 m above the ground). The 2 caliper measurements were used to calculate taper (caliper at 1 m minus caliper at ground level divided by 1 m to obtain a taper estimation in cm/m). Taper was not calculated for *L. indica* trees because both sheltered and unsheltered trees developed a multistem growth habit, making accurate caliper measurements impractical and the data questionable. At the end of the second year, trees were harvested by cutting the trees at ground level. Leaves and stems were cut into pieces, weighed (fresh weight), placed in paper bags, and dried for at least 1 week at 70°C to obtain dry weights. Collected biomass data included top (leaves, stems) fresh (TFW) and top dry weight (TDW). All data were analyzed using the General Linear Model (GLM) Procedure of the SAS statistical system (11).

Results

Survival. Unsheltered tree liners (in particular, *P. canariensis, L. indica,* and *M. boaria*) were subject to damage or destruction from birds immediately after planting. In these cases, treeshelters were necessary for survival.

Height Increase. The influence of treeshelters on height and caliper development is species dependent (Figures 1–5). All species had height

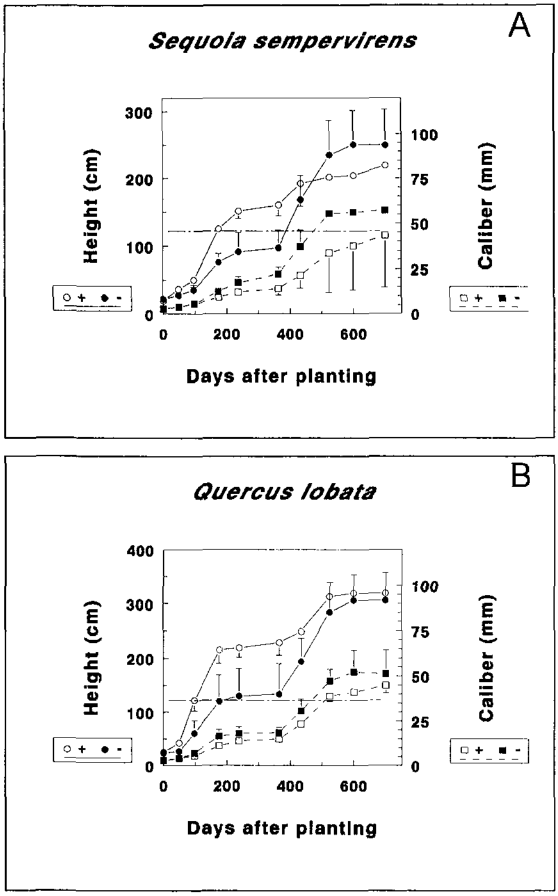

Figure 1. Height (cm) and caliper of trees grown with (○—○ or □—□) and without (●—● or ■—■) shelters for 700 days. The horizontal dashed line represents the height of the treeshelter (122 cm). Each value is the mean of 8–10 replicate trees ± 1 standard deviation.

enhancements when grown in shelters. Four species [*Q. lobata* (Figure 1B), *G. biloba* (Figure 3B), *F. latifolia* (Figure 4B), and *M. boaria* (Figure 5A)] had nearly immediate (within the first 30 days) enhancements in height. However, the enhanced height of *M. boaria* trees growing in shelters ceased after 100 days. From then until the end of the experiment, sheltered and unsheltered *M. boaria* trees grew at essentially the same rate. In all other species, the height enhancements due to the treeshelter occurred between 100 and 250 days. When trees grew taller than the shelter and the shelter was removed, the height in-

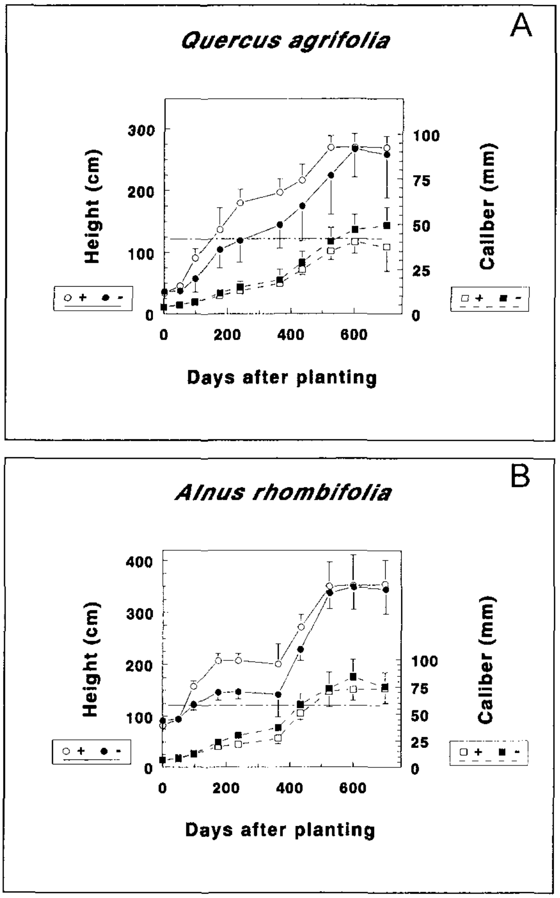

Figure 2. Height (cm) and caliper of trees grown with (○—○ or □—□) and without (●—● or ■—■) shelters for 700 days. The horizontal dashed line represents the height of the treeshelter (122 cm). Each value is the mean of 8–10 replicate trees ± 1 standard deviation.

crease rate declined [see *S. sempervirens* (Figure 1A), *Q. lobata* (Figure 1B), and *Q. agrifolia* (Figure 2A); *L. indica* (Figure 3A) and *F. latifolia* (Figure 4B)]. At the end of the experiment (700 days), tree heights were the same for sheltered and unsheltered trees except for *G. biloba* (Figure 3B) and *P. canariensis* (Figure 5B), where sheltered trees were taller than unsheltered ones.

Trunk malformations occurred in several *A. rhombifolia* trees once they emerged from the top of the shelter (Figure 6). This problem was present, but less significant, for other tree species. This may be a problem especially

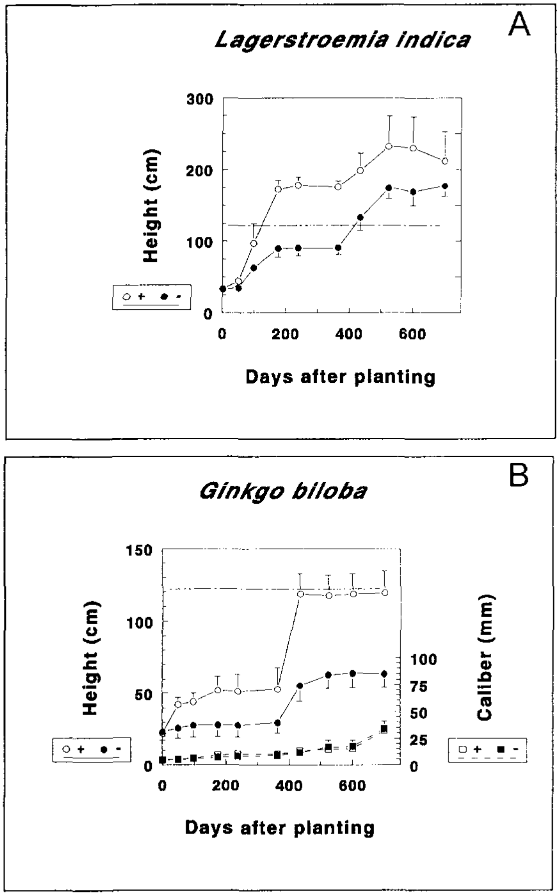

Figure 3. Height (cm) and caliper of trees grown with (○—○ or □—□) and without (●—● or ■—■) shelters for 700 days. The horizontal dashed line represents the height of the treeshelter (122 cm). Each value is the mean of 8–10 replicate trees ± 1 standard deviation.

when treeshelters are used in areas having winds that come most often from the same direction.

Caliper Development. Trees growing in shelters tended to have reduced caliper development, but they were rarely significantly lower (Figures 1–5). *S. sempervirens* (Figure 1A) and *Q. lobata* (Figure 1B) showed some caliper reduction in sheltered trees during the early stages of growth (days 200 through 400), and *F. latifolia* (Figure 4B) was the only tree species to show significantly reduced stem caliper at the end of the experiment. None of the

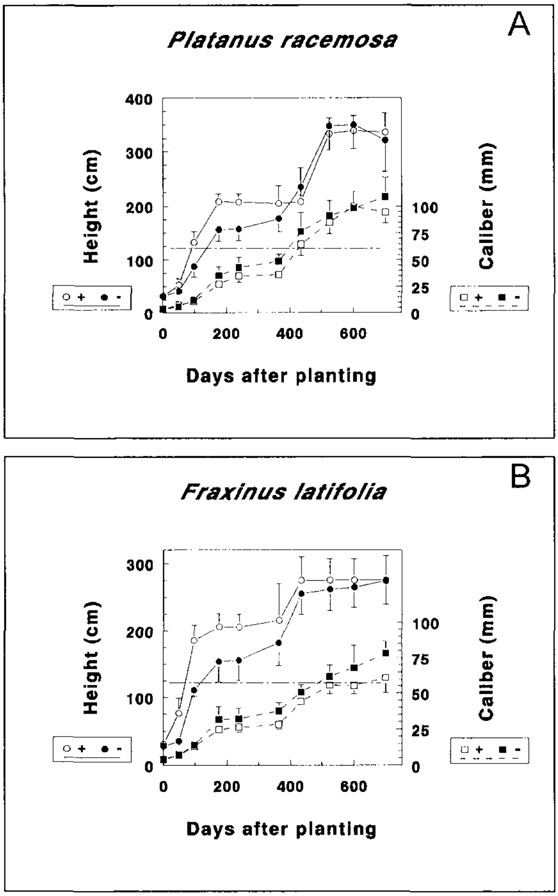

Figure 4. Height (cm) and caliper of trees grown with (○—○ or □—□) and without (●—● or ■—■) shelters for 700 days. The horizontal dashed line represents the height of the treeshelter (122 cm). Each value is the mean of 8–10 replicate trees ± 1 standard deviation.

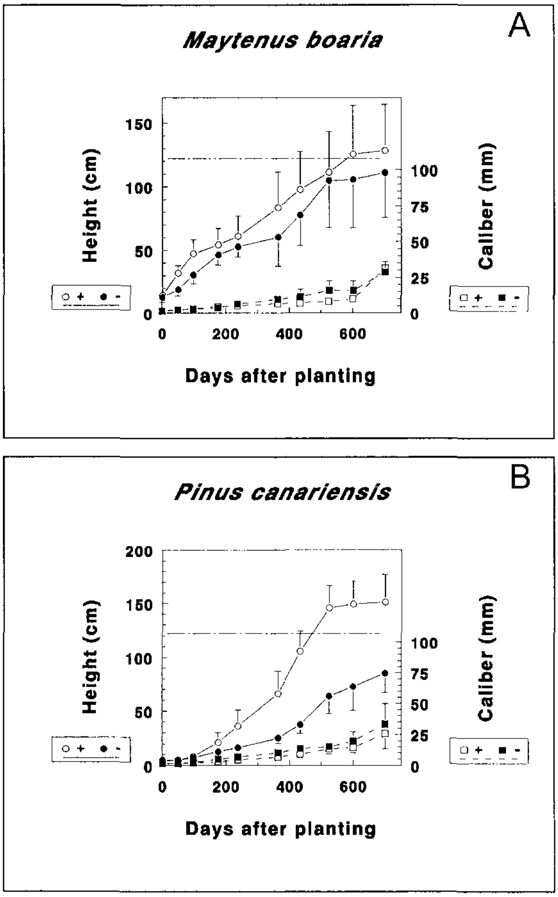

Figure 5. Height (cm) and caliper of trees grown with (○—○ or □—□) and without (●—● or ■—■) shelters for 700 days. The horizontal dashed line represents the height of the treeshelter (122 cm). Each value is the mean of 8–10 replicate trees ± 1 standard deviation.

tree species growing in shelters could stand alone once the treeshelter was removed. All had to be staked.

Top Fresh and Dry Weight and Taper (Year 1). After 1 year, top fresh and dry weights of *S. sempervirens* and *P. racemosa* were significantly reduced in sheltered trees (Table 1). Statistically significant reductions in top fresh and dry weight could not be shown for either of the *Quercus* species. Taper was significantly reduced (63–87%) in all sheltered trees that had grown out of the treeshelter during the first year (Table 1). Several *A. rhombifolia* trees in shelters died or were damaged during the first summer (undetermined reasons), preventing accurate measurements the first year.

Top Fresh and Dry Weight (Year 2). After 2 years, the top fresh and dry weights of unsheltered trees were greater than those of sheltered trees for all species except *G. biloba* (Table 2). The increases for TFW ranged from 25% to 72%, while those for TDW ranged from 23% to 72%.

Discussion

The combination of increased height, decreased TFW and TDW, and decreased caliper of sheltered

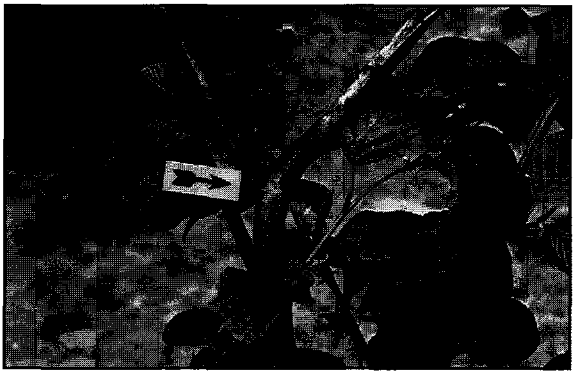

Figure 6. Trunk malformation (bending) of *Alnus rhombifolia* due to the predominant wind (from the left). The arrow designates where the top of the treeshelter was.

trees resulted in trees incapable of standing alone after shelter removal. Trees growing in shelters had limited opportunity for movement that occurs in unsheltered or unstaked trees. It has been shown that trees kept from moving (e.g., rigidly staked) grow taller and have reduced stem caliper development and taper (7). Caliper and taper development were further diminished by the reduced light intensity found inside treeshelters.

When the shelter was not removed soon after the trees grew out of them, the trunk was subject to deformities due to predominant winds creating a bend at the location on the trunk corresponding to the height of the shelter. This tendency to bend at the top of the treeshelter could be accentuated if trunk taper and reaction/compression wood formation are diminished.

The reduced top biomass of sheltered trees after 1 year is not surprising since the light intensities inside shelters are roughly half that of full sun (1). Though the carbon dioxide concentration can be up to 30% higher inside the shelter (1), the overall photosynthetic rates of sheltered trees are most assuredly lower than those of unsheltered ones since light was a limiting factor. Reduced photosynthetic rates may then lead to a reduction in root biomass if a change in the photosynthetic partitioning ratio does not occur.

The effect on top growth for most of the species tested was sustained for the duration of the experiment (2 years). In contrast, height differences between the sheltered and unsheltered trees of most species were evident only during the first growing season. Similar to what Dunn et al. (3) found, unsheltered trees had slower rates of height increase during the early stages of the experiment, but caught up by the end. This suggests that sheltered trees benefit from the favorable microenvironment early in their development, but as the trees grow out of the shelters, its effect diminishes.

Treeshelters stimulate rapid height increases of trees and protect trees from browsing animals and from chemical or mechanical weed control (9). If treeshelters are to be used, they are probably most effective when they are kept to no more than 60 cm tall and removed when trees grow out of them. Alternatively, trees may (and should) be staked when they grow taller than the shelter.

Table 1. Top fresh and dry weight (TFW, TDW) and taper (cm/m) of 5 tree species that grew out of the 122 cm treeshelter after 1 year, n = 10.

	TFW,g		TDW,g		Taper, cm/m	
Species	Control	Shelter	Control	Shelter	Control	Shelter
Sequoia sempervirens	1213a[z]	316b	386a	102b	2.1a	0.4b
Quercus lobata	350a	210a	162a	96a	1.6a	0.2b
Quercus agrifolia	289a	221a	143a	113a	1.1a	0.3b
Platanus racemosa	4735a	2243b	1518a	720b	3.0a	0.7b
Fraxinus latifolia	1658a	1345a	542a	463a	1.2a	0.4b

[z]Means followed by different letters are significantly different from one another based on Scheffé's Multiple Mean Comparison procedure.

Table 2. Top fresh and dry weight (TFW, TDW) of sheltered and unsheltered trees after 2 years of growth, n = 10.

	TFW,g		TDW,g	
Species	Control	Shelter	Control	Shelter
Sequoia sempervirens	7290a[z]	3745b	2969a	1554b
Quercus lobata	2624a	1770b	1470a	986b
Quercus agrifolia	3307a	2470b	1511a	1149b
Alnus rhombifolia	8622a	4833b	3473a	2062b
Lagerstroemia indica	2262a	1689b	1215a	936b
Ginkgo biloba	61b	111a	24b	43a
Platanus racemosa	12897a	9511b	5148a	3733b
Fraxinus latifolia	4052a	2551b	2406a	1362b
Maytenus boaria	321a	88b	123a	34b
Pinus canariensis	968a	536b	348a	201b

[z]Means followed by different letters are significantly different from one another based on Scheffé's Multiple Mean Comparison procedure.

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Résumé. Dix espèces d'arbres, couramment employées dans les aménagements paysagers de Californie, ont été plantés sur un banc d'essai en plein champ, avec ou sans protecteurs d'arbres, pour une durée de deux ans. La hauteur et le diamètre ont été recueillis aux deux mois ainsi qu'à la fin des deux années. Par la suite, tous les arbres ont été arrachés pour en évaluer leurs masses humide et sèche en biomasse. La réponse au micro-environnement créé par les protecteurs d'arbres était dépendante de l'espèce. Tous les arbres comportant des protecteurs avaient une sorte d'accroissement de départ en hauteur plus élevée ainsi qu'une tendance envers un diamètre inférieur. Les protecteurs d'arbres ont été efficaces pour améliorer la croissance de départ en hauteur , mais cette amélioration diminuait avec le temps. Après deux années, seuls le *Ginkgo biloba* et le *Pinus canariensis* présentaient des arbres avec des protecteurs plus grands que ceux de leurs homologues non protégés.

Zussammenfassung. Über einen Zeitraum von zwei Jahren wurden zehn, in Kalifornien heimische Baumarten als Heister mit und ohne Baumschutzhüllen ausgepflanzt. Die Höhe und der Durchmesser wurden alle zwei Monate und am Ende der zwei Jahre gemessen. Alle Bäume wurden dann komplett entnommen, um die Biomasse im Frisch- und Trockengewicht zu messen. Die Reaktion auf die Bedingungen innerhalb der Baumschutzhüllen war artenspezifisch. Alle Bäume mit Baumschutzhüllen hatten einen frühen Höhenzuwachs und die Tendenz zu einem geringeren Umfang. Die Baumschutzhüllen zeigten sich effektiv, um frühes Höhenwachstum zu fördern, aber mit fortschreitender Zeit nahm dieser Effekt ab. Nach zwei Jahren waren nur *Gingko biloba* und *Pinus canariensis* in den Baumschutzhüllen größer als ihre frei gewachsenen Vergleichsbäume.