TREESHELTER EFFECT ON ROOT DEVELOPMENT OF REDWOOD TREES

by Pavel Svihra, David Burger[1], and Richard Harris[2]

Abstract. Treeshelters (Tubex® polypropylene tubes, 4 inch diameter, 4 ft tall) inhibited development of redwood tree *(Sequoia sempervirens)* roots. Unprotected redwood trees without treeshelters gained more root fresh and dry weight. Trees grown in treeshelters produced roots with smaller diameter. These data suggest that the treeshelter environment might temporarily prevent redwood trees from attaining optimal root development and anchorage. Redwood seedlings are not suitable candidates for establishment in treeshelters.

Seedling environment is seldom optimum for uninterrupted growth of young trees. Roots and shoots are forced to make metabolic and structural adjustments to stresses caused by mechanical impedance, deficient or excess water, excess salinity, lack of nutrients, insufficient O_2, and high CO_2 (9). Treeshelters (polypropylene tubes 3–4 inches in diameter and of varying heights) placed over just-replanted seedlings or naturally sprouted ones of several species have improved the growth and survival rate of seedlings (4,8,12,13,15). However, some nursery trees grown in containers and protected with treeshelters had lower root fresh weights (3). In an experiment with *Cedrus deodara, Quercus ilex*, and *Magnolia grandiflora*, treeshelters promoted shoot growth but inhibited root growth.

We wondered if root elongation and branching leading to the development of fibrous root systems of these 3 species were inhibited by the confinement of containers as well as treeshelters. Root systems are known to have a high degree of plasticity in their development as they respond to local heterogeneity of the soil, and if the plant canopy is impeded by unfavorable biotic or abiotic conditions, it reduces photosynthesis and assimilates translocation (9). Therefore, a field experiment was needed to eliminate the "container effect" and determine whether treeshelters affected root fresh/dry weight and root architecture.

In a previous paper (16) we reported that treeshelters significantly accelerated shoot growth of redwood seedlings *(Sequoia sempervirens)*. Two years after replanting, redwood seedlings protected by treeshelters quadrupled their height, while unprotected control seedlings grew only half as high. Although height growth for planted seedlings was significantly greater with treeshelters than without them, little is known about the root development. Such data are important because a well-developed root system is necessary for the landscape tree's stability and for water and nutrient uptake.

Increased shoot growth of redwood seedlings in treeshelters could be at the expense of root growth. To collect evidence about the root performance of these trees, we let the crown portion of each redwood tree grow 4 whorls of branches above the tops of treeshelters (Figure 1). Such a canopy size mirrored the silhouette of natural (unprotected) redwood trees but, more important, branches outside of treeshelters became exposed to the wind load and deflection that subsequently challenged roots to improve their anchorage.

The objective of this study was to investigate whether there is a treeshelter effect on root fresh/dry weight and root architecture of redwood seedlings.

Methods

Fifteen seedlings of coast redwood *(S. sempervirens)*, seeded on May 5, 1989, were selected at random on May 10, 1990, from flats in the forest nursery at the California Department of Forestry and Fire Protection, Davis. These redwoods began as seedlings from seeds collected from the same tree and received uniform treatment in the nursery. They were taken on the same day to Falkirk Park in San Rafael, California. The park is situated on lowland with an average annual rainfall of 26 inches (66 cm) and an annual mean temperature of 57.5°F (14.1°C). There is a

1. Associate Professor, Department of Environmental Horticulture, University of California, Davis.
2. Professor Emeritus, Department of Environmental Horticulture, University of California, Davis.

Figure 1. Redwood tree in treeshelter, 4 growing seasons after replanting.

distinct dry season from mid-April to mid-October with very little or no rain. The soil of the experimental field is heavy clay (about 2 ft [60 cm] deep) that was spaded and weeded by hand the day before planting. Exposed to full sun from 9:00 A.M. to 6:00 P.M., the experimental field has been fenced for protection from browsing deer and vandalism.

Before treeshelters were erected, the height and trunk caliper of each experimental seedling were measured. Ten Tubex® treeshelters (4 ft tall) were placed over randomly selected seedlings; 5 shelters were marked with a dot and the letter 'S', and 5 with an asterisk and the letters 'SR'. The tubes were pushed down into the soil around the seedlings and fastened to wooden stakes. The remaining 5 seedlings were left unprotected as controls (marked 'C') and grew freely without stake support. Seedlings were planted in 3 north-south rows with 150 cm (60 inches) between plants. The entire experimental plot was mulched with a 6-inch-deep shredded, redwood bark layer to alleviate direct soil irradiance and reduce water evaporation. The mulch layer and hand-weeding kept the site weed-free year-round.

For 13 days, seedlings were irrigated daily with 1 L (about 1 qt) of water per plant. Beginning 14 days after planting, the seedlings were irrigated as follows:

a. Each seedling in a treeshelter with an asterisk (SR) received 1 L of water every 7 days.
b. Each seedling in a treeshelter with a dot (S) received 1 L of water every 14 days (according to the manufacturer, treeshelters "block winds that scorch leaves, and water vapor that transpires from the leaves is collected on a treeshelter wall where it condenses, and trickles back into the ground—where the tree can use it again") (1).
c. Control seedlings (C) received 1 L of water every 7 days. These irrigation schedules ended on October 29, 1990 (6 months after planting), when the first rain occurred in the area. After that, the plants were left to adjust their growth and survival to the water supply from natural precipitation.

Seedlings were checked weekly during the growing season and biweekly in the fall and winter or immediately after any unusual storm, freeze, or very high temperature. Height and trunk caliper were remeasured on April 10, 1991, and on May 27, 1992. The results of these measurements have been presented previously (16).

Four growing seasons after replanting were required until all redwoods in treeshelters grew 4 whorls above the treeshelter rims (Figure 1). At the end of the fourth growing season, on November 8, 1993, experimental plants were harvested destructively to determine total tree growth and root distribution in the soil. Height and trunk caliper (slightly above the root flare) were measured for each experimental plant. Then each tree was cut close to the root flare, labeled, and stored separately for transport in a plastic bag tied with a wire.

The soil around each experimental tree's root system was carefully washed off, and the muddy water vacuumed away with the Vactor truck for slurry removal. We had to alter only slightly this previously described technique (5). It took about 15 minutes to wash and excavate a single redwood root system. If some root was still attached to the soil, we dug it out with a specially designed handpick. The whole architecture of the roots was fully exposed for measuring the diameters of lateral roots and photographing their distribution.

We measured the diameter of each root at a distance of 5 cm (2 inches) from the root crown area. A square frame covering 0.5 m^2 divided with wire into 4 equal quadrants was superimposed over the root zone to categorize cardinal directions of roots. Then the root system was lifted, labeled, and hung on the wire to be photographed again for studying its side view architecture and profile. Then each root system was placed into a plastic bag similar to the corresponding tree top for transportation to the Department of Horticulture, University of California, Davis, to determine shoot fresh/dry weight and root fresh/dry weight. These weights were used to compare biomass accumulation for 4 years by redwood trees grown with and without protection of treeshelters.

Results and Discussion

No seedling death or foliage scorching was observed in the first year of the watering schedule during establishment of the redwood seedlings. In January 1991, 1 unprotected (control) seedling and 1 seedling in a treeshelter (irrigated with SR-schedule) suddenly died. It is not clear whether the cause was the unusual freeze of the last half of December 1990 or winter desiccation. There was no visible injury on the remaining trees after this extreme freeze during which temperatures dropped as low as –8.3 to –9.4°C (15 to 17°F). Survival after the first growing season was not affected by site quality or treatment, including treeshelter treatments.

According to Hellmers (6), roots of redwood seedlings grow best in soil at 18°C (64°F) under both high and low air temperature conditions. Such conditions could not be achieved in the experimental field, yet the seedlings displayed no visible symptoms of stress. However, twice in July 1991 and again in September 1991, when the air temperature exceeded 38°C (100°F), we observed severe scorching and leader dieback on all except one of the seedlings protected by treeshelters. Young redwoods with treeshelter protection quickly reversed these short-lasting heat injuries by rapid regrowth with apparently healthy green foliage. Unprotected control seedlings displayed no scorching.

Four growing seasons after replanting, treesheltered redwoods continued to be 6 to 9 inches taller than controls, but these differences were no longer significant (Table 1) as we observed and measured their growth in previous years (16). Correspondingly, differences between sheltered and unprotected trees in shoot fresh weight (SFW) and shoot dry weight (SDW) were not significant (Table 2), but the data show a trend: 6–9-inch shorter unprotected redwoods accumulated 53–58% more SFW and 57–63% more SDW than did the protected ones. Unprotected control redwood trees produced a larger and heavier root system: the root fresh weight (RFW) and root dry weight (RDW) were significantly different (Table 2).

Root fresh and dry weight accumulations may be directly related to the redwood tree root pattern, size, and architecture differences between the 2 treatments. The inhibitory effect of treeshelters on root development is clearly visible in photographs of the unprotected (control) redwood tree and the redwood grown in a treeshelter subjected to SR irrigation schedule (Figures 2 and 3). A statistically significant difference in the diameter of lateral roots (Figure 4) is an additional variable indicating that treeshelters had an inhibitory effect

Table 1. Height and diameter of replanted redwood trees after 4 growing seasons in a landscape setting.

Treatment	Height (in)	Diameter (in)
Control	57.2a*	0.98a
Shelter (S-schedule)	75.0a	0.81a
Shelter (SR-schedule)	63.2a	0.67a

*Values followed by the same letter are not significantly different based on Scheffé's Multiple Range Test, p = 0.05.

Table 2. Shoot fresh weight (SFW), shoot dry weight (SDW), root fresh weight (RFW), and root dry weight (RDW) of redwood trees grown with treeshelters (S, SR) and without, from May 1990 to November 1993.

Treatment	SFW (g)	SDW (g)	RFW (g)	RDW (g)
Control	966.2a	384.5a	558.7a	234.0a
Shelter (S-schedule)	559.0a	241.4a	223.8b	101.0b
Shelter (SR-schedule)	510.7a	221.0a	159.7b	76.2b

*Values followed by the same letter are not significantly different based on Scheffé's Multiple Range Test, p = 0.05.

on root development of redwood seedlings grown for 4 years after replanting. The root silhouette, number, growth, and branching (Figure 2) developed by naturally grown redwoods are larger, and roots are longer and thicker. We hypothesize that redwoods in treeshelters partitioned less assimilates for the support of root development.

The Vactor system (Figures 2 and 3) is an effective technique that helps to uncover quickly and with little labor very fine roots for detailed study. Although numerous detailed studies of plant root systems exist, very few can analyze the entire root architecture and distribution as swiftly and

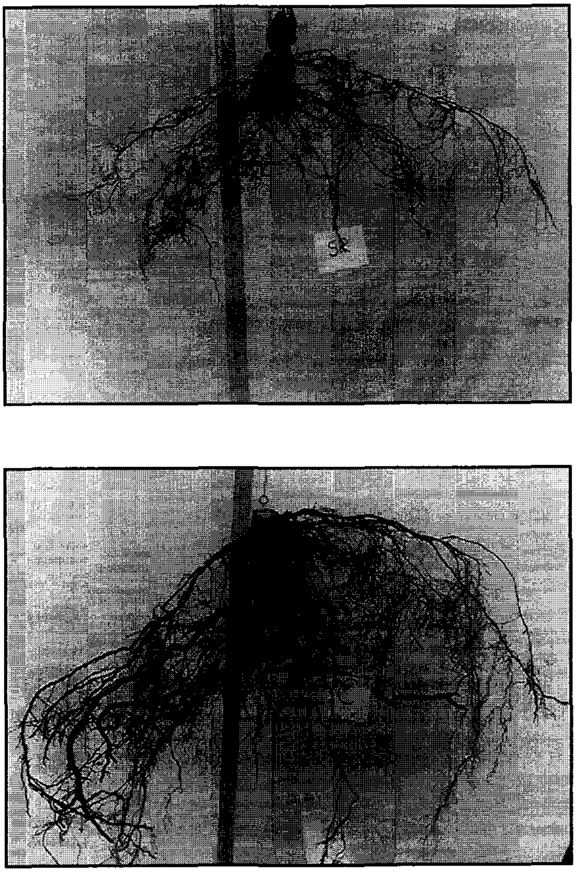

Figure 2. Side view of sheltered (top) and unsheltered (bottom) redwood root systems 4 years after replanting. Note the differences in root diameter and volume between 2 treatments. A displayed detail of fine roots demonstrates reliability of the Vactor vacuum soil extraction technique for collecting data on tree roots.

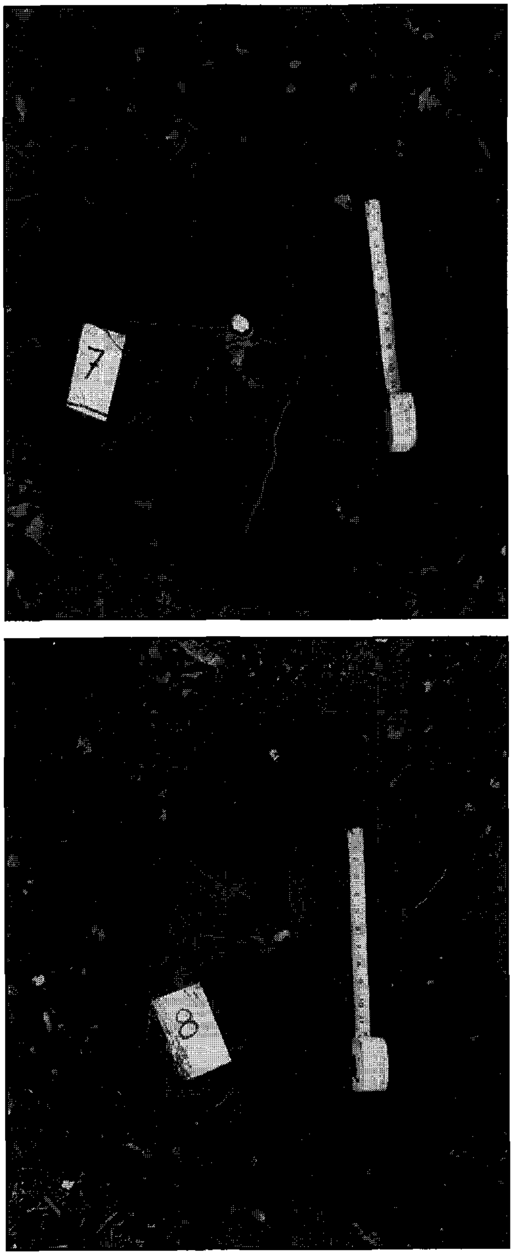

Figure 3. A bird's eye view of root architecture and distribution completed in 4 years by the unsheltered redwood (top) and the redwood grown in a treeshelter and subjected to S-schedule (bottom). The roots of the unsheltered redwood are more fibrous and longer, and radiate evenly in all directions. The roots of the treesheltered redwoods are conspicuously smaller (a 12-inch tape measure serves as a scale).

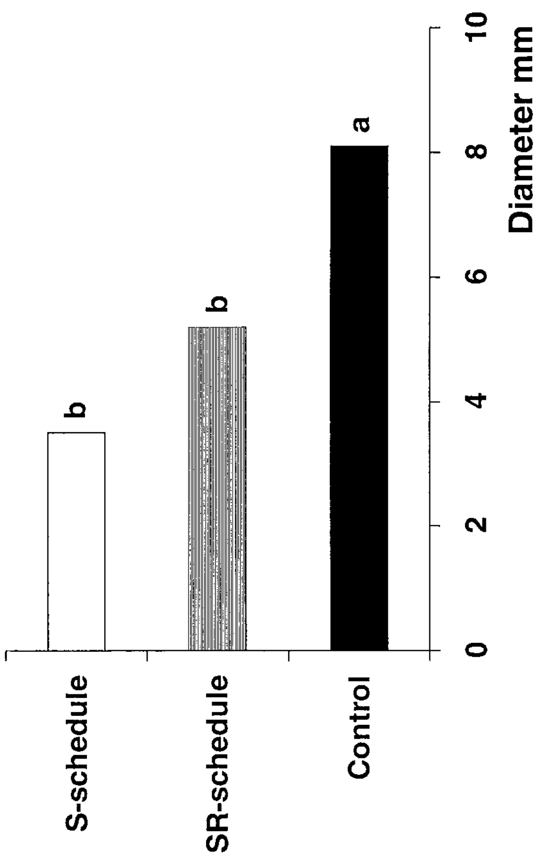

Figure 4. Effect of treeshelter environment on the diameter of lateral roots measured 5 cm (2 inches) away from the root crown. Columns followed by the same letter are not significantly different based on Scheffé's Multiple Range Test, p = 0.05.

effectively as the Vactor (destructive root harvest) system allows. The root systems of 13 redwoods were rinsed off within less than 2 hours with the Vactor technique. Selection of root study methods is critical in evaluating associations or relationships among root and shoot components. Root study methods have been developed for destructive and nondestructive sampling (2,14). A rhizotron observation of root growth over extended time might be required to determine whether a treeshelter environment inhibits the root development of other woody plants (11).

Numerous studies have been done on the influence of spacing and planting design of seedlings, stem taper, branch density, and thickness and size of crown, but none evaluates root quantity or quality under landscape conditions. We found 150 cm (60 in) spacing between experimental plants to be sufficient for this 4-year-long study. The thorough method of washing off soil and vacuuming slurry away from the root zone revealed minimal or no interference among roots of neighboring plants (Figure 3).

All seedlings had grown in a relatively similar deep soil; nevertheless, there was a high variability in root systems among unprotected redwood trees and among treatments. Root dry-weight accumulation, number, diameter, length, surface area, and distribution in a soil profile can differ within species (10). The size, morphology, or architecture of a root system may control relative size and growth rate of the shoot (10). It appears that this rule does not apply to redwoods grown in treeshelters. Water limitations imposed on the experimental trees could result in retarded growth of shoots and roots. Specifically, trees in treeshelters received daily a condensed water trickling down the treeshelter wall and drained down around the root crown. This partially explains why the roots are thinner and more concentrated around the root crown area (Figure 3).

Data collected in this experiment provide the first information on root development of landscape-grown redwoods in treeshelters. According to Hicks et al. (8) treeshelters were the only factor that significantly increased the number of leaves on planted oak seedlings in experiments conducted in West Virginia. Our analysis of SFW and SDW of naturally grown redwoods and those in treeshelters has not shown a similar trend. We are not aware of other studies with which our results can be compared.

Acknowledgments. This study was partially supported by a California Association of Nurserymen grant. We are very thankful to the San Rafael Parks Department for preparing the site and providing the Vactor vacuum to rinse the root systems of redwood trees.

Literature Cited

1. Anonymous. 1994. Introducing Supertube. Treessential Company Solutions. St. Paul, MN.
2. Bohm, W. 1979. Methods of Studying Root Systems. Springer-Verlag, Berlin.
3. Burger, D.W., Svihra, P., and Harris, R.W. 1992. *Treeshelter use in producing container-grown trees.* HortScience 27(1): 30–32.
4. Costello, L.R., Peters, A., and Giusti, G.A. 1996. *An evaluation of treeshelter effects on plant survival and growth in a Mediterranean climate.* J. Arboric. 22(1): 1–9.
5. Gross, R. 1993. *Hydraulic vacuum excavation: Getting down to the roots.* Arbor Age, July 1993: 10–12.
6. Hellmers, H. 1963. *Effect of soil and air temperatures on growth of redwood seedlings.* Bot. Gaz. 124: 172–177.
7. Hicks, D.M., McNeel, C.A., and Townsend, E.C. 1994. *Treatments for enhancing early survival and growth of northern red oak seedlings.* Tree Planter's Notes 45,4: 137-141.
8. Kittredge, D.B., Kelty, M.J., and Ashton, P.M. 1992. *The use of tree shelters with northern red oak natural regeneration in southern New England.* Northern J. Appl. For. 9: 141–145.
9. Leskovar, I.D. 1995. *Seedling morphological and physiological adaptation to abiotic stress: Introduction to the Colloquium.* HortScience 30(6): 1152.
10. Leskovar, I.D., and Stoffella, P.J. 1995. *Vegetable seedling root systems: Morphology, development, and importance.* HortScience 30(6): 1153–1159.
11. Mackie-Dawson, L.A., and Atkinson, D. 1991. Methodology for the study of roots in field experiments and the interpretation of results. **In:** Atkinson, D. (ed.). Plant Root Growth. Blackwell Scientific Publications,Oxford, England. pp. 25–47.
12. Minter, W.F., Meyers, R.K., and Fisher, B.C. 1992. *Effect of tree shelters on northern red oak seedlings planted in harvested forest openings.* Northern J. Appl. For. 9: 58–63.
13. Potter, M.J. 1988. *Tree shelters improve survival and increase early growth rates.* J. For. 86: 39–41.
14. Schuurman, J.J., and Goedewater, M.A.J. 1971. Methods for Examination of Root Systems and Roots. 2nd ed. Pudoc, Wagenningen, The Netherlands.
15. Smith, H.C. 1993. Development of red oak seedlings using plastic shelters on good-to-excellent hardwood sites in West Virginia. Res. Pap. NE-672, PA: U.S.D.A. Forest Service, Northeastern Forest Experiment Station. 7pp.
16. Svihra, P., Burger, D.W., and Harris, R.W. 1993. *Treeshelters for nursery plants may increase growth, be cost effective.* Calif. Agric. 47(4): 13–16.

University of California
Cooperative Extension
1682 Novato Blvd., Suite 150B
Novato, CA 94947

Résumé. Les protecteurs de troncs d'arbres type Tubex (tube en polypropylène de 10 cm de diamètre et de 1,2 m de hauteur) ont un effet inhibiteur sur le développement des racines des séquoias toujours-verts, *Sequoia sempervirens.* Les séquoias non protégés par des protecteurs de troncs produisaient des masses humide et sèche plus importantes de racines. Les arbres entourés de protecteurs de troncs produisaient des racines de plus petits diamètres. Ces données laissent à penser que l'environnement créé par les protecteurs de troncs d'arbres pourrait empêcher les séquoias d'atteindre un développement racinaire optimal et un ancrage ferme. Les semis de séquoias toujours-verts ne sont pas de bons sujets pour l'emploi de protecteurs de troncs d'arbres.

Zussammenfassung. Die Wurzelentwicklung von Mammutbäumen *(Sequoia sempervirens)* wurde durch Baumschutzhüllen der Marke Tubex (polypropylene-hüllen, 10 cm Durchmesser under 12 cm hoch) gehemmt. Ungeschützte Mammutbäume ohne Baumschutzhüllen erreichten mehr Wurzelmasse sowohl im Frisch- als auch im Trockengewicht. In Baumschutzhüllen gezogene Bäume produzierten Wurzeln mit geringerem Durchmesser. Die erhobenen Daten ergaben, daß die Umweltbedingungen in Baumschutzhüllen die Mammutbäume davon abhalten, eine optimale Wurzelentwicklung und eine gute Verankerung zu erreichen. Die Sämlinge von Mammutbäumen sind keine geeigneten Kandidaten für die Aufzucht in Baumschutzhüllen.