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STRATEGIES TO PREVENT DAMAGE TO SIDEWALKS BY TREE ROOTS†

*Philip A. Barker** and *Paula J. Peper**

Summary

Several types of root barriers tested in field experiments in northern California inhibited development of shallow tree roots. The need for an improved barrier design to prevent development of potentially harmful circling roots inside a barrier was indicated. The performances of various currently marketed root barriers with internal vertical ribs were compared to augment product descriptions by their manufacturers.**

Introduction

Radial growth of tree roots often warps and cracks overlying sidewalks, creating 'lips' by uneven displacement of adjoining sections of sidewalks. Such damage impedes safe usage of the sidewalks, resulting in pedestrian accidents, commonly classified as 'trip and fall,' and claims for damages by injured victims. Root damage to sidewalks is economically important in U.S. cities (BARKER, 1983; SOMMER *et al.*, 1992, WAGAR and BARKER, 1983) and elsewhere, including Mexico (BENAVIDES, 1992) and England (WONG *et al.*, 1988).

Contrary to common viewpoint, sidewalks apparently promote rather than deter development of shallow tree roots (BARKER, 1988). A concrete sidewalk prevents soil moisture loss by either evaporation or transpiration and blocks percolation of rainwater into the soil as well. Moreover, a sidewalk warms rapidly and radiates heat to the soil beneath. It likewise cools more rapidly than underlying soil. Consequently, moisture from the soil condenses on the underside of the sidewalk, only to evaporate back into

†This paper, adapted from BARKER (1994) and PEPER and BARKER (1994), was prepared and written by U.S. Government employees in official time, and is therefore in the public domain and not subject to copyright.

*Research Horticulturist and Biological Technician, respectively, Western Center for Urban Forestry Research, Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, c/o Department of Environmental Horticulture, University of California, Davis, CA 95616-8587; 916/752-5867.

**Materials and specifications for each product described have changed substantially since 1994.

the soil whenever heat buildup of the sidewalk again outpaces that of the soil (HARRIS, 1992).

The timeframe between the planting of street trees and their damage to adjacent sidewalks undoubtedly is substantially shorter for trees that develop shallow rather than exceptionally deep roots. This is because the forces generated by radial growth of deep roots, compared to those of shallow roots, should dissipate throughout a larger volume of soil before impacting any overlying sidewalks.

Research on Tree Root Development

In cooperation with Solano Community College, the Forest Service, United States Department of Agriculture, operates a 5-acre site in northern California as the Solano Urban Forestry Research Area (SUFRA) for conducting field research on control of rooting depth of trees (Figure 1). Being about 15 km north of the delta region and mouth of the Sacramento River and a similar distance inland, across a range of low mountains, from the north end of San Francisco Bay, the climate at this field facility is under a maritime influence. Winter temperatures rarely go below freezing, and

FIGURE 1. Three growing seasons after the trees in an experiment have been outplanted as container-grown stock approximately 2 m tall, the roots of each tree are excavated to a depth of about 35 cm in an area within a 1 m radius from trunk center. Treatment effects are determined from dry weights of the roots that have been harvested from within each excavation pit.

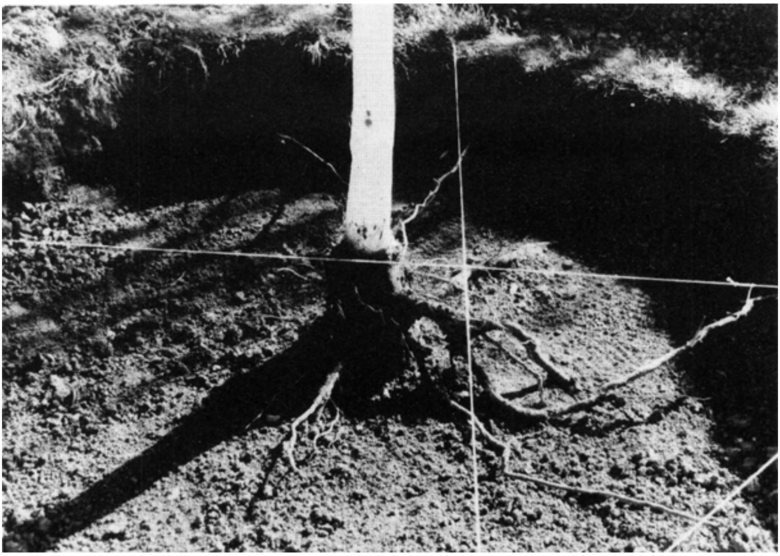

FIGURE 2. Roots are excavated manually by first trenching around the perimeter of an intended excavation area, then dragging soil from the excavation area into the trench and alternately filling and emptying the trench until the circular excavation pit is at the desired depth.

rainfall averages about 40 cm annually, occurring primarily from October through to April.

The deep, well-drained alluvial soil, with a pH range of 6.5–7.6 and electrical conductivity, representing soluble salts, of 300–500 micromhos/cm on a dry soil basis, is a dark brown, generally silty clay loam, without mottling, typical of soils in the Class I Yolo Series (SOIL CONSERVATION SERVICE, 1977).

Trees planted with different treatments to the root systems are grown three or more years with turfgrass cover and sprinkler irrigation. Afterwards, the roots of each tree are excavated and harvested to an approximate depth of 30 cm within a 1 m radius from trunk centre (Figure 2) to determine their dry weight.

Root Barriers

Root barriers made of rigid plastic materials or of rhizotoxic fabric, namely Biobarrier*, and installed as planting hole liners to approximately 30 cm

*Use of trade or firm names in this paper is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

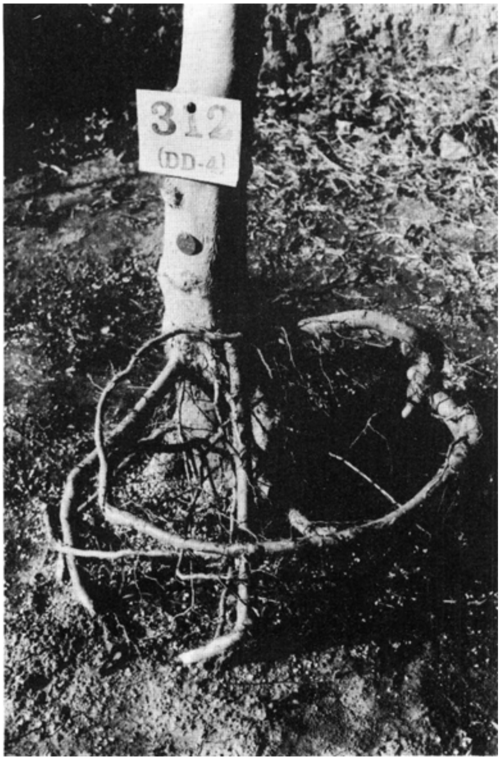

FIGURE 3. Barrier-induced circling roots were a common problem in an experiment that tested the effectiveness of three 30 cm deep root barriers in inhibiting development of shallow roots. Circling roots developed inside rhizotoxic root barriers but were particularly abundant inside plastic barriers which lacked internal vertical ribs.

deep have effectively reduced root growth in the excavated zone by one half to one tenth compared with no root barriers (Barker, unpublished data). However, circling roots induced by several types of barriers that have been tested (Figure 3) have indicated the need for a barrier designed to retard such root development.

Numerous kinds of root barriers are commercially available. Most of them have internal vertical ribs intended to direct roots downward and thus retard development of circling roots. An early root barrier, introduced in 1976, is marketed as the Standard Deep Root Planter (*U.S. Patent No. 4019279*). Made of extra thick plastic, this sturdy barrier is approximately 45 cm deep and 55 and 74 cm square at the top and bottom, respectively.

TABLE 1 Manufacturers, materials, and prices of various sizes of five ribbed root barriers, listed alphabetically by manufacturer.

Manufacturer	Material[1]	Panel depth[2] ft.	cm[3]	Quoted retail price per linear foot[4]
Bumble Bee Products, Inc.,	Polyethylene,	1.0	30	$1.70
3260 Industry Dr.	high-density,	2.0	60	3.25
Signal Hill, CA 90806	injection-molded			
310-597-7933				
Century Products	Polystyrene,	1.5 × 69	45 × 175	2.74
1401 N. Kraemer Blvd. #B	extruded	1.5 × 120	45 × 305	2.56
Anaheim, CA 92806		2.0 × 69	60 × 175	3.44
714-632-7083		2.0 × 120	60 × 305	3.06
Deep Root Partners, L.P.	Polypropylene,	1.0	30	2.18
345 Lorton Ave. # 305	injection-molded	1.5	45	3.28
Burlingame, CA 94010		2.0	60	4.10
800-458-7668				
Shawtown Industries, Inc.	Polystyrene,	1.0	30	2.25
4550 Calle Alto, Unit D	tan color,	1.5	45	3.50
Camarillo, CA 93010	extruded	2.0	60	4.60
800-772-7668		4.0[5]	120	
Vespro, Inc.[6]	Polyethylene,	1.0	30	—
40 Belvedere St., Unit 2	low density,	1.5	45	—
San Rafael, CA 94901	extruded	2.0	60	—
415-459-7311				—

[1]Except as noted otherwise, all barriers are black in color, apparently formulated with lamp black, an ultraviolet inhibitor.
[2]Approximately 60 cm (24 inches) except as noted for Century Products non-panel barriers.
[3]Approximate metric equivalent.
[4]Reduction in prices likely now that the patent has expired for the Standard Deep Root Planter (*U.S. Patent No. 4019279*).
[5]Special order.
[6]Retooling to produce a root barrier of improved design.

Other barriers now being marketed in the United States are designed for ease of packaging and shipping. These are either flat panels for connecting together at point of use to make whatever length is desired or continuous barriers that are rolled up for shipping and may or may not be pre-cut to a specified length. Either type of barrier may be installed linearly along sidewalks or cylindrically as planting hole liners. U.S. manufacturers continue to design and produce new barriers, and additional companies are entering the marketplace for the first time. As competition and barrier variety increase, consumers need unbiased sources of information to determine whether or not to use barriers and, if they are to be used, which barrier will best suit particular site requirements. The following information is based on observations during and following installation of the panel type barriers with internal vertical ribs in a field experiment at SUFRA and on observations of the continuous barriers in actual use.

Important in selecting a barrier is the material from which it is made and various design features, notably the way in which either the panels or the ends of continuous barriers are connected together. As indicated in Table 1, the panels may be made of polyethylene, polypropylene, or polystyrene. Among these three thermoplastics, polyethylene in the high density formulation is recognized in the plastics industry as the most resilient and durable. By comparison, polypropylene is slightly harder and therefore eventually may chip or crack easier. Polystyrene, on the other hand, readily crystallizes in the presence of sunlight, in which case its durability is compromised. Various types of polymers are often added to these thermoplastics to improve their durability.

Panels of most barrier designs are joined together with various types of

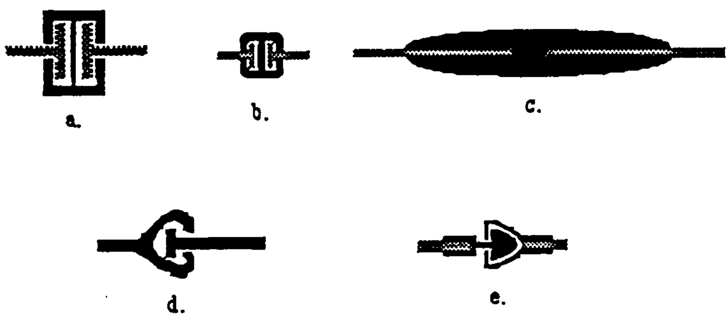

FIGURE 4. A schematic illustration of cross sections of connectors, at comparative sizes, that join root barrier panels. Panels of the Deep Root (a) and Bumble Bee (b) barriers each are held together with connectors that slide into T-shaped panel ends. Panels of the Century (c) barrier are held together with connectors bonded to the panels with chloromethane solvent. Vespro (d) and Shawtown (e) have interlocking couplings that are either extruded with the panels or heat-bonded to the panels during manufacturing.

plastic coupling strips whereas others are glued together with chemical bonding agents (Figure 4).

Panel Barriers

We installed forty-six each of the panel-type Bumble Bee, Deep Root, and Vespro barriers in the studies at SUFRA in May 1993. Each barrier, installed as a planting hole liner, consisted of three vertical-ribbed panels that were coupling-connected rather than glued. The purpose of this particular experiment was to compare how well the three types of barriers prevent circling roots and inhibit shallow root development. Two-year-old, bare root seedling red mulberry (*Morus rubra*) each approximately 2 m tall, were planted by backfilling with unamended soil inside the barriers after which gaps between the exterior of the barriers and the planting holes were collapsed with a shovel. When a tree was completely planted, the top edge of each barrier remained about 2 cm above ground level. The experiment will be maintained for three growing seasons before final results are taken. In the meantime, eight barriers of each type were selected randomly and examined three months after the experiment was installed.

Important features that have been found for each barrier are discussed below according to the alphabetical order of the manufacturer's name.

Bumble Bee Barrier (Patent No. 4995191). The circular shape of this high-density polyethylene barrier was easily maintained while the trees were being planted. Of particular importance, neither the panels nor the connectors or coupling strips were predisposed to slipping out of alignment while the soil was being backfilled.

The eight randomly selected trees for further examination exhibited no signs of chipped or broken rim above ground level. Uneven settling of panels was not apparent; however, but a few of the internal vertical ribs were found to protrude above ground and were chipped or torn—probably due to impacts by mower wheels. Ribs on any type of barrier are intended to redirect root growth downward. Broken ribs provide an opportunity for roots to grow in a circular pattern until they meet an intact rib.

In a 3-year-old installation of these barriers at the University of California in Davis, some of the panel connectors had already cracked or ruptured above ground. The manufacturer now makes these connectors with a more durable polystyrene.

Deep Root Barrier. The circular shape of this polypropylene barrier was easily maintained while a tree was being planted. On the other hand, because of looseness of fit of the installed panel connectors, they had to be held in place and often repositioned to line up with the top edge of the panels as the soil was being backfilled.

Three months later individual panels of one of the eight randomly selected barriers had settled to where they were only visible about 1 cm above grade level. 'Anti-lift pads,' which are small tabs located at three levels on the inside of these barriers to stabilize the panels and keep them from lifting once installed, may actually have had a reverse effect. Gravity, along with weight of the water-saturated soil inside the barrier may have caused them to settle. Also, the top edge or rim on one of the barriers had a 10-cm long tear at ground level, obviously resulting from a mower wheel hitting the protruding part of the barrier.

Deep Root barriers installed approximately 3 years ago at a nearby city park revealed minor chipping and cracking above grade level.

Shawtown Barrier. Samples have recently been installed at SUFRA to observe the long-term effects of environmental exposure, particularly sunlight, on these barriers, made of polystyrene. During installation, the circular shape of the barriers was easily maintained. The interlocking coupling on the barrier is bonded to the panels at the factory, and no panel slippage was experienced after they had been assembled.

Vespro Barrier. Among the three types of barriers used in the field studies at SUFRA, the Vespro barrier was the most cumbersome to handle. Because it was made of low-density polyethylene, it was extremely malleable, becoming more so as temperatures increased during the day. During installation, therefore, one person had to hold it continuously in a circular shape while another person backfilled the soil within the barrier. Even with this extra help, the installed barrier had an uneven undulating shape, which complicated the mowing and edging of turfgrass surrounding the barrier.

The coupling device of this barrier is extruded as part of each panel and despite its simplicity and, therefore, ease of connecting the panels, separation of the panels after barrier installation posed a problem. When two tree stakes were inserted in the backfill soil inside the barrier after the tree had been planted, the panels separated. This required panel replacement and replanting of the tree. A close examination of the coupling revealed that it was uneven because of faulty extrusion. It was also possible to separate connected panels by pulling them apart by hand. In short, the pliancy of this barrier compromises its structural integrity.

Two of the eight Vespro barriers examined 3 months after installation had vertical tears at the internal ribs in the 2-cm above-grade segment. Individual panels on four of the barriers had settled unevenly, but still remained above grade level. There was no evidence of further separating of panel connectors; however, undulation of the cylindrical shape of the barriers had become more pronounced.*

Continuous Barriers. Continuous or linear barriers are an alternative to surrounding the roots of trees with circular or enclosure barriers. Linear barriers are installed alongside a sidewalk or other paved surface, either during replacement of a damaged sidewalk and simultaneous pruning of offending tree roots or when new trees are planted. Their effectiveness has yet to be tested quantitatively. However, samples of linear barriers marketed by Shawtown Industries, Inc., and Century Products were installed at SUFRA in June 1993 to observe long-term durability. Both barriers maintained their shape as trees were being planted.

*Subsequent work with this barrier has revealed that the barrier begins separating at the top edge when bumped by the wheel of a lawnmower or when walked on by pedestrians. New Root Solutions, Inc. barriers currently available from Vespro, Inc. sport a sturdier connecting device.

Century Barrier. Assembly of these barriers as they were being installed required use of chloromethane (methylene chloride) solvent to bond the locking mechanism to the panels. Although easy to use, chloromethane may pose health hazards to installers. Failure to glue the coupling or connector to the barrier ends could allow separation of the barrier ends when or shortly after a tree is planted and growth of tree roots through the gap. There is no experimental evidence that the hollow triangular tubes glued on to the inside wall of this barrier will prevent circling roots, as intended. Nor is there experimental evidence that soil aeration and water application is effectively enhanced with these tubes or with larger watering tubes that are sometimes glued on to the outside wall of this barrier.

Shawtown Barrier. Observations of Shawtown linear barriers installed in 1992 along a sidewalk in Fresno, California, revealed extensive breakage from rim tops to ground level. This was no surprise because elsewhere polystyrene barriers have been observed to break and crumble within one or two years, because of the tendency of this type of thermoplastic to crystallize and become brittle when exposed to sunlight.

Materials Testing

Pamphlets distributed by the manufacturers to advertise barriers provide information on the tensile, flexural, and impact resistance properties of their products (Table 2). This information is based on the results of plastics engineering tests run in accordance with American Society for Testing and Materials (ASTM) guidelines (AMERICAN SOCIETY FOR TESTING AND MATERIALS, 1992). What do these tests reveal to consumers? The ASTM guidelines repeatedly state that results of stress and flexural tests conducted on plastics under laboratory test conditions *do not* indicate that the same relationships

TABLE 2. Results of engineering tests reported in barrier manufacturers' brochures vary widely and provide unreliable information about comparative barrier qualities.

Barrier	Material thickness mils or 1/1000 in	(mm)	Tensile strength (ASTM D 638), psi	Flexural properties (ASTM D 790) Strength, psi	Flexural properties (ASTM D 790) Elasticity, psi	Impact resistance (ASTM 256) Izod., ft.-lb.	Impact resistance (ASTM 256) Gardner/ Rockwell in.-lb
Bumble Bee	80	(2.0)	2000	30,000	N/A[1]	N/A	N/A
Century	60	(1.5)	3800	6,500	3.0	2.0	70 (G)
Deep Root	80	(2.0)	3800	155,000	N/A	7.1	68 (R)
Shawtown	80	(2.0)	7400	13,200	400,000	8.5	102 (R)
Vespro[2]	70	(1.7)	2000	30,000	N/A	N/A	N/A

[1]N/A—not available.
[2]Currently retooling to produce a different style barrier.

TABLE 3. Observations about root barriers, made during and after they have been installed, are considered most reliable in indicating barrier qualities.

	Physical features					Installation features				
Barrier manufacturer	Rib span	Rib height, cm	Rib to wall angle, degrees	Panel connector[1]	Other features	Installation instructions	Maintains shape while being installed	Panel slippage or settling during or after installation	Connector slippage, settling, or failure	Possible problems[2]
Bumble Bee	Entire depth of panel	1.4	90	Separate extruded strip	Notched bottom for tearing by maturing roots	In sales brochure only	Yes	No	No	
Century	Entire depth of panel	1.6	45	Connector glued to panel with chloromethane solvent		In sales brochure only, no instructions for use of bonding agent	Yes	No	No	Health risk of inhaling chloromethane bonding agent, comparatively short life expectancy of polystyrene when exposed to sunlight

Deep Root	Ends 0.6 cm from bottom of panel	1.3	90	Separate extruded strip	Antilift pads to keep panels in place after installed	Printed on shipping carton and on inside of each panel	Yes	Yes	Must be adjusted during installation	
Shawtown	Ends 0.6 cm from top and bottom of panel	1.3	90	Attached inter-locking coupling	Tight fit of coupling deters panel slippage	Printed on shipping carton and on inside of each panel	Yes	No	No	Comparatively short life expectancy of polystyrene material exposed to sunlight
Vespro[3]	Entire depth of panel	Varies, 0.6 to 1.9	"agonic curl," 90° arc	Attached inter-locking coupling		In sales brochure only	No	Yes	Pulled apart, once installed	Highly malleable, easily loses circular shape: connector failure and above-ground portion of panels occasionally rip vertically

[1]Illustrated in Figure 4. [2]Besides possible breakage of above-ground portion of barrier by foot traffic, mower wheels, or other impacts. [3]Currently retooling to produce a different style barrier.

will exist under temperatures and other environmental parameters different from those of the test conditions. This is because of the high degree of sensitivity of many plastics to rate of straining under different environmental conditions. Nor are impact test results generally considered a measure of the abrasion or wear resistance of these plastic materials.

Overall, the significance and use of these tests is for quality control and specification purposes during production (AMERICAN SOCIETY FOR TESTING AND MATERIALS, 1992). Data derived from these tests and reported by barrier manufacturers in their advertising brochures and product labels do not provide consumers with information on how the barriers will resist the wear and tear of daily exposure to foot traffic and landscaping equipment or on other performance features. Until better information is available, on-site observations of barrier design and performance, as reported in Table 3, will be critical in determining which barriers best meet particular purposes.

FIGURE 5. Any benefits that root barriers may provide, regardless of type, were nullified where even thin layers of soil covered a barrier's top edge. Root overgrowth is no less a problem where the top edge of a root barrier is obscured by mulch. With vigorously growing tree species, such as cottonwood, *Populus* sp., root overgrowth may occur even if the top edge of the barrier protrudes well above grade and never has been covered by mulch.

Other Considerations

A barrier's effectiveness is virtually nullified if its top edge is not permanently visible. Roots have readily overgrown barriers in experiments at SUFRA where the barriers had been accidentially covered with even thin layers of soil (Barker, unpublished data). This same problem has been identified in commercially installed landscaping where soil or organic mulch, regardless of depth, obscures the top edges of root barriers (Figure 5). Similarly, it is vital that barrier panels do not pull apart or crack because of faulty connectors. It may be no coincidence that the two barriers made of either high-density polyethylene or polypropylene and exhibiting superior sturdiness and durability were injection molded. Predisposition of all of the barriers to above-grade damage by foot traffic and landscaping equipment may be markedly altered by designing a wider, more durable top edge on the barriers, a feature that would require that they be made by injection molding instead of by extrusion. Manufacturers are aware of the above-grade wear and tear problem, and some are aggressively addressing it. Deep Root has recently started marketing a new barrier with a sturdy 1-cm wide top edge designed to support foot traffic and retard root overgrowth. Also, a barrier should not be installed so deep that development of a tree's critical anchor roots is compromised. Research with circular barriers at the Solano Urban Forestry Research Area has shown, as previously stated, that barriers only 30 cm deep effectively inhibit development of shallow roots; however, the effect may differ among soils and tree species. Until future research is done to identify optimum barrier depth, a prudent approach would favour installing a barrier too shallow rather than too deep.

Conclusions

While research at the Solano Urban Forestry Research Area has shown that root barriers of various types can inhibit development of shallow roots, implicit in these results is the need for follow-up research that includes such treatment variables as soils, tree species, and sidewalks. Rigorous experimentation continues to search for clear evidence that root barriers do not harm trees and do, indeed, reduce damage to sidewalks and other pavements under widely different environmental conditions. Moreover manufacturers continue to improve root barriers, driven not only by research results but by their own and consumers' experiences. Overall, root barriers are providing urban tree managers, landscape architects, and home owners with options for dealing with tree roots that grow differently than desired.

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Résumé

On a testé, au nord de la Californie, plusieurs modèles de barrière contre les racines des arbres. Quelques unes entre eux ont réussi à empecher le développement des racines peu profondes. On a remarqué la manque d'une barrière conçue d'empecher la ceinte des racines à l'interieur de la barrière. Dans le but d'augmenter les descriptions écrites par leurs manufacturiers, on a comparé les performances des barrières à nervures internes actuellement vendues.

Summario

Muchos tipos de barreras para raíces que fueron probadas en campos experimentales en la parte nortina de California inhibían el desarrollo de las raíces superficiales (aquellas dentro de un intervalo de 30 cm. de profundidad) del árbol. Una barrera de mejor diseño, que previníera el desarrollo de raíces potencialmente dañinas circulando dentro la barrera, era necessaria. El desempeño de varais barreras de raíces con varillas verticales corrientemente encontradas en el mercado fueron comparadas para aumentar las descripciones del producto dadas por sus fabricantes.

NOTES ON CONTRIBUTORS (*continued*)

PAULA J PEPER is a research associate with the USDA Forest Service Western Centre for Urban Forest Research and Education at the University of California, Davis, California. She is currently involved in research into the effect of root barriers on tree root development and into determining methods of measuring the foliar and woody biomass of urban trees. Her previous experience in the Toiyabe National Forest in California and Nevada included timber cruising, mounted backcountry patrol law enforcement and fire management. In 1988 Paula joined the National Park Service's Vegetation and Resource Management Division at Sequoia-Kings Canyon National Parks, where she installed monitoring plots and updated hazard tree inventories.

IAN WHITE served with the Parks Department (latterly the Recreation Department) of the Wokingham District Council for fourteen years from 1974. From 1988 to date, he has been employed with the Surrey Heath Borough Council, Camberley, Surrey in the Development Control section of the Planning and Community Services Directorate. He represented Associated members on the Council of the Arboricultural Association in 1987 and 1988.