EFFECTIVENESS OF THREE BARRIER MATERIALS FOR STOPPING REGENERATING ROOTS OF ESTABLISHED TREES

by J. Alan Wagar and Philip A. Barker

Abstract. In a search for effective barriers to prevent tree root damage to sidewalks, a tough nylon fabric, copper screen, and Biobarrier were tested against regenerating roots in 9-year-old plantations of hybrid cottonwood *(Populus trichocarpa X deltoides)*, black cottonwood (*P. trichocarpa*), and paper birch (*Betula papyrifera*). Roots were severed flush against vertical walls 3.5 feet from trees. Barrier panels were installed against the severed roots of some wall sections and control sections were left without barriers. Three years after installation, amounts of roots coming through all three kinds of barriers were substantially less than amounts coming through equivalent control sections. Both the nylon and copper greatly stunted roots by constricting them to the size of openings in barrier materials, approximately 1/26- and 1/16-inch, respectively. Biobarrier, designed for slow release of the herbicide trifluralin, stopped all birch roots but let a few cottonwood roots through, apparently those of the most vigorous root systems.

Repairing sidewalks and other pavements damaged by tree roots is a major cost in many cities, and some spend hundreds of thousands of dollars per year for such repairs. If damage is not repaired, cities and similar jurisdictions risk being held liable for injuries associated with broken or uplifted sidewalks. A usual remedy has been to remove the damaged sidewalk, sever and remove the offending roots, and pour a replacement section. Increasingly, a trench is dug along the sidewalk edge nearest the tree, and a barrier is installed to block regenerating roots. Otherwise such roots may cause damage again within a few years.

Impervious barriers usually divert rather than stop roots and may block moisture movement. Also, roots getting under such barriers can grow back toward the surface, especially if the underlying soil is compacted or otherwise marginal for root growth (6). Therefore, we tested permeable barriers that seemed likely to stop roots either by engaging and constricting them or by chemically inhibiting them.

In an earlier and unpublished study conducted near Concord, California, a tightly-woven polypropylene fabric and a 6-ounce polypropylene felt (technically, a spun-bonded fabric) were tested for their effectiveness in stopping the roots of Balm-of-Gilead poplar (*Populus candicans*) and London plane (*Platanus acerifolia*). The woven fabric deflected the roots. The felt engaged rather than deflected the roots, and, in going through the felt, many roots created only small openings and were constricted and substantially stunted. Other roots, however, created larger openings and were less stunted, and a few roots seemed little affected by the felt. Having material that engaged and constricted the roots seemed advantageous, and additional options seemed worth exploring.

Three promising alternatives to the materials mentioned above were tested (Fig. 1): 1) a stiff nylon fabric (Q899 nylon fabric with extra firm finish from Jason Mills, Westwood, NJ), 2) 16-mesh copper screen, and 3) Biobarrier (from REEMAY, Inc., Old Hickory, TN). The nylon fabric has holes approximately 1/26-inch square separated by strands approximately 1/26-inch thick, with the strands fused together. This was the best of the 20 fabrics tested with roots of potted *Eucalyptus globulus* in an earlier trial (7). Copper screen was chosen because copper had been shown as effective in controlling the roots of seedlings (2,5). Biobarrier is a commercial product developed specifically to control roots and consists of a felt-like spun-bonded polypropylene fabric to which polyethylene pellets are attached at 1 1/2- by 1 1/2-inch spacing. These pellets are impregnated with the herbicide trifluralin and release it slowly over time.

Tests were in 9-year-old plantations of hybrid cottonwood (*Populus trichocarpa X deltoides*),

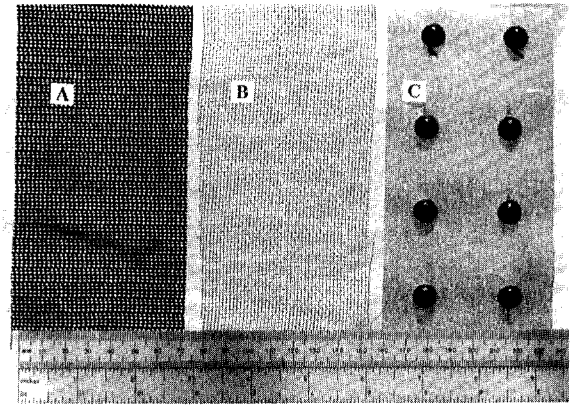

Figure 1. The barrier materials tested in this study were A) a tough nylon fabric, B) 16-mesh copper screen, and C) Biobarrier.

black cottonwood (*P. trichocarpa*), and paper birch (*Betula papyrifera*) at the University of Washington's Pack Forest, approximately 80 miles southeast of Seattle at an elevation of 800 feet where the annual growing season lasts about 6 months. The trees have 12- by 12-foot rectangular spacing (Fig. 2) and were originally planted to test their response to fertilizing with municipal sewage sludge. These trees, especially the cottonwoods, provided a ready supply of vigorous roots and were in many ways equivalent to the maturing street trees that cause enormous sidewalk damage and expense for many cities.

In the fall and winter of 1988, when the study was established, the hybrid cottonwoods averaged about 8 inches dbh with some roots up to 4 and 5 inches in diameter (Fig. 3). The black cottonwoods were a bit smaller but also had many large and vigorous roots. The birches were considerably smaller, averaging about 4 inches dbh and had much smaller roots than either type of cottonwood.

Figure 2. Nine-year-old hybrid cottonwood plantation at Pack Forest, near Eatonville, Washington.

Procedures

Within each plantation, trees were selected for approximate uniformity, and any that were noticeably smaller than average were rejected. Forty-five hybrid cottonwoods, 26 black cottonwoods, and 43 birches were judged suitable and chosen.

As a basis for measuring the effectiveness of treatments, roots at each tree were collected for two carefully defined treatment zones, both before treatments were installed and again after three growing seasons. Procedures for defining the treatment zones and excavating roots from them were as follows:

At each selected tree a trench was dug approximately 5 feet from the tree, using a backhoe. At the edge of the trench, soil was removed for a depth of 1 foot to create a vertical wall 4.0 feet from the tree. Roots were cut flush against this wall and discarded. Additional soil was then removed, again for a depth of 1 foot, to a second wall 3.5 feet from the tree. (Placing treatments on a line 3.5 feet from

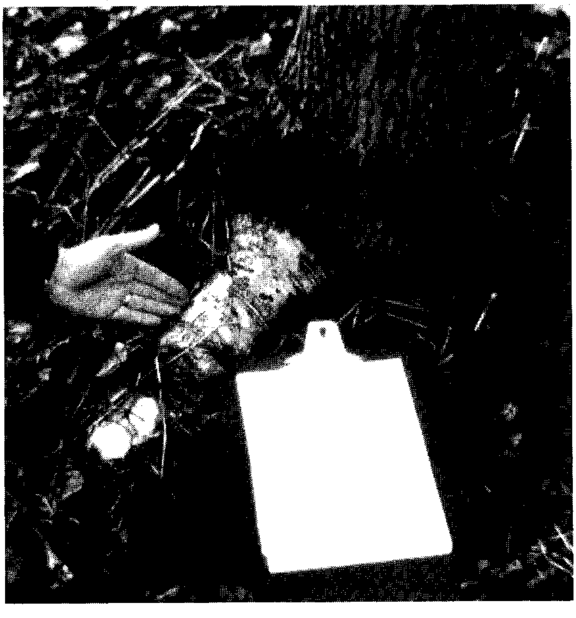

Figure 3. Large root on 9-year-old hybrid cottonwood.

each tree seemed a realistic representation of where a sidewalk might be located.) On this new wall, two treatment zones were marked (shaded in Fig. 4), each 2 feet wide and 1 foot high with the two zones separated by a 1- by 1-foot section centered on the tree. Roots were then cut flush against this new wall, with the approximately 6-inch lengths of roots coming through the treatment zones saved to provide a measure of original root abundance at each treatment location.

Two treatments per tree were assigned at random, and trenches were refilled with soil after treatments were installed. A small flag was placed at each end of each treatment to facilitate finding and re-excavating it. Treatments and replications for the three species were as follows:

	hybrid cottonwood	black cottonwood	birch
Control	15	9	15
Nylon fabric	15	9	15
Copper screen	15	9	15
Biobarrier	15	9	15
Biobarrier at 2"	15	8	13
Biobarrier at 4"	15	8	13

For Control treatments, sections of vertical wall were left with no barrier. For the Nylon fabric, Copper screen, and Biobarrier treatments, vertical panels of these materials were installed directly against the cut root stubs.

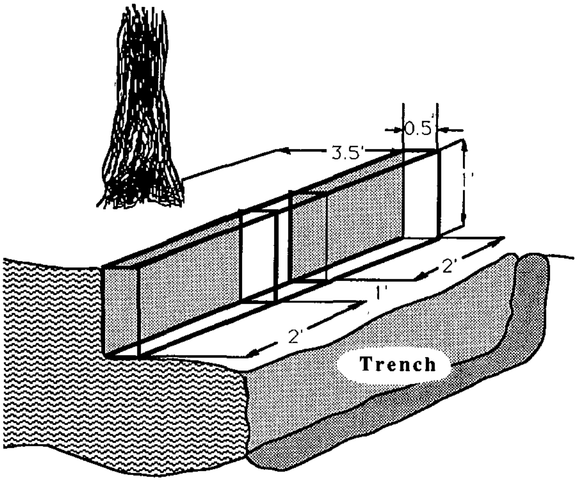

Figure 4. Treatment zones (shaded) and the 1- by 2- by 0.5-foot volumes in which roots were measured.

Only the first four treatments were part of the formal experimental design. However, to explore whether the distance between Biobarrier and the cut ends of roots would affect callus growth, vertical panels of Biobarrier were also installed at 2 and 4 inches, respectively, from the cut root stubs.

In the fall of 1991, after three growing seasons, the excavation procedures described above were repeated and roots that had come through the treatment zones were collected from the same 1- by 2- by 0.5-foot soil volumes from which roots had been collected during installation of the study.

Amounts of roots were expressed as 1) dry weight of all roots in each 1- x 2- x 0.5-foot soil volume and 2) the combined cross-sectional area for the three largest roots coming through any treatment zone, as measured 1 inch beyond the treatment. Analyses of covariance were used to test for differences in the amounts of roots getting through barriers. (Using weight of initial roots as a covariate helped correct results for the fact that some treatment zones had more roots than others.)

To test the possibility that different responses of roots to Biobarrier might result from different amounts of soil organic matter, which is known to tie up trifluralin, a soil sample was collected for each Biobarrier treatment. Each sample was collected adjacent to the center of the biobarrier panel for an inch or two toward the tree, and samples were analyzed for organic matter.

Results

For hybrid cottonwood, black cottonwood, and paper birch, the nylon fabric, copper screen, and Biobarrier all greatly reduced amounts of roots, with amounts of roots growing through these barriers being significantly less than amounts growing through equivalent control areas with no barriers. The probability that these differences occurred by chance ranged from .0001 to .0012. However, differences among the barriers were not statistically significant (at P = .05), and the rank ordering of the barrier treatments shifted somewhat depending on whether amounts of roots were expressed by weight or cross-sectional area (Figs. 5 and 6). Table 1 shows the largest roots getting through the various treatments.

The fabric and copper screen constricted roots to the size of openings (Fig. 7). Beyond the constrictions, roots were greatly stunted except for knobs that formed against the barriers.

Although Biobarrier greatly reduced amounts of roots as compared with control treatments (Figs. 5 and 6), a few cottonwood roots penetrated it. For hybrid cottonwood 20 percent of Biobarrier panels were totally effective (9 of 45, including 30 that were 2 or 4 inches from cut stubs), and for black cottonwood 32 percent of the panels were totally effective (8 of 25, including 16 that were 2

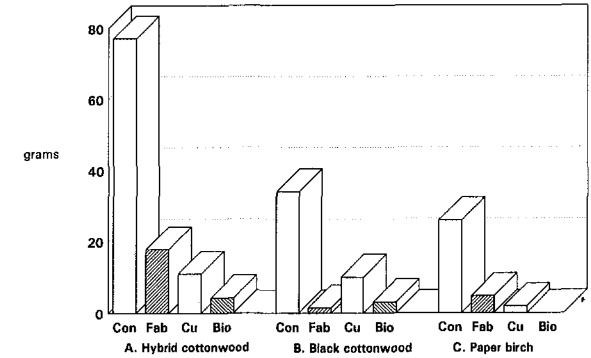

Figure 5. Dry weights of roots in soil volumes 0.5 foot beyond the 1- by 2-foot treatment zones for A) hybrid cottonwood, B) black cottonwood, and C) paper birch. Treatments were control (Con), nylon fabric (Fab), copper screen (Cu), and Biobarrier (Bio).

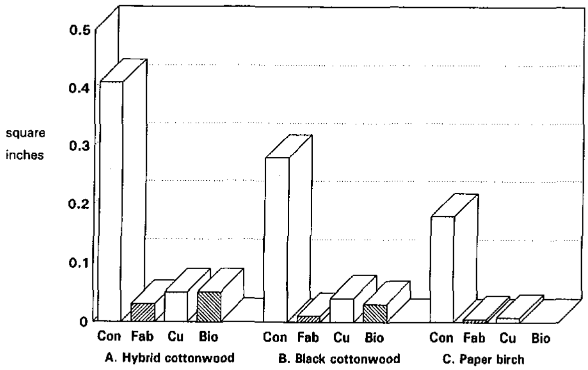

Figure 6. Cross-sectional area of three largest roots in soil volumes 0.5 foot beyond the 1- by 2-foot treatment zones for A) hybrid cottonwood, B) black cottonwood, and C) paper birch. Treatments were control (Con), nylon fabric (Fab), copper screen (Cu), and Biobarrier (Bio).

Table 1. Diameters (inches) of the largest three roots coming through panels of barrier materials. (Values in each box are from the same tree.)

Species	Treatment					
	Control	Fabric	Copper	Bio	Bio 2"	Bio 4"
Hybrid cottonwood	1.012	.212	.225	.400	.175	.375
	.838	.200	.212	.325	.175	.200
	.750	.200	.175	.300	.162	.188
Black cottonwood	.562	175	.265	.350	.162	.425
	.525	.125	.225	.188	.162	.300
	.550	.125	.212	.150	.150	.225
Paper birch	.550	.088	.125	.000	.000	.000
	.438	.075	.125	.000	.000	.000
	.450	.075	.100	.000	.000	.000

or 4 inches from cut stubs). Biobarrier was 100 percent effective for birch, with no birch root getting through any of 40 Biobarrier panels (including 25 that were 2 or 4 inches from cut stubs).

Amounts of soil organic matter were approximately the same for all three species. Ranges were 6.1 to 26.1 percent for hybrid cottonwood, 4.1 to 24.1 percent for black cottonwood, and 6.5 to 18.6 percent for birch. The respective means were 14.0, 14.9, and 13.4 percent. Plotting the weights of roots getting through Biobarrier, in combination with organic matter and original root abundance, showed no clear relationship (Fig. 8). Regressions on these three variables had R^2 values of .38 for hybrid cottonwood and .33 for black cottonwood, indicating that about two-thirds of the variance remained unexplained.

Distances between Biobarrier and the severed root stubs had no discernible effect on callus formation in either type of cottonwood. Among hybrid cottonwoods, 88 percent of root stubs (21 of 24) that were directly against Biobarrier had callus, and amount of callus averaged 58 percent (expressed as percent of stub circumference

Figure 7. Root constricted by copper screen. Distance across constriction is approximately 1/16 inch.

callused over). Two inches from Biobarrier, 82 percent of root stubs (28 of 34) had callus covering an average of 71 percent of stub circumference. Four inches from Biobarrier, 77 percent of root stubs (24 of 31) had callus covering an average of 42 percent of stub circumference. Results were similar for black cottonwood. Callus was not measured for birch.

Discussion

Although the roots studied were primarily those regenerating from roots that had been cut back on existing trees, results would seem to apply as well to roots of newly planted trees. Two processes were operating: 1) physical constriction of roots and 2) chemical inhibition of root growth.

All three barrier materials greatly reduced the amounts of roots that could damage sidewalks and should substantially reduce the costs of such damage. But none of them totally stopped all roots.

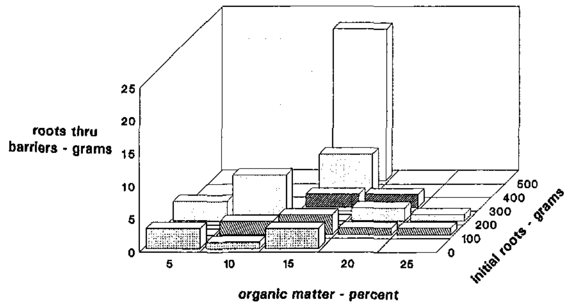

Figure 8. Effects of soil organic matter and initial root abundance on amounts of roots getting through Biobarrier.

Both the nylon fabric and copper screen constricted roots to the size of holes through the barrier materials, approximately 1/26- and 1/16-inch square, respectively. Roots growing through the nylon were more stunted than those growing through the copper, probably because their smaller constrictions left less tissue through which they could draw photosynthates for their energy needs.

In an earlier study (7), strands of a nylon window screen, which had about the same thickness as strands in the copper screen used in this study, were enveloped and embedded within growing roots. In this study, such rejoining of roots did not occur, apparently prevented by the thickness of strands in the nylon fabric and the toxicity of copper strands in the screen.

Other fabrics might be as suitable as the nylon tested in this study. The essential requirements would be 1) an unyielding material with openings small enough to greatly constrict roots but not so small that roots are deflected rather than engaged, 2) strands thick enough or toxic enough to keep swelling portions of a root from protruding through the fabric and rejoining to envelop the strands, 3) sufficient stiffness to avoid sagging when a trench is backfilled, and 4) long-term durability. If exposed to sunlight at the soil surface, black fabrics are less likely to be damaged by ultraviolet light than are light-colored materials. Although ultraviolet light is not a problem for material below ground, roots are likely to grow over the tops of barriers that do not extend to or above the soil surface.

It had been expected that copper screen would stop all roots. In a very limited earlier test conducted in El Cerrito, California, the roots of *Magnolia* *grandiflora* did stop growing upon touching copper screen. But the tips of magnolia roots had diameters larger than the openings through the screen. The growing tips of the cottonwood and birch roots were small enough to pass through the 16-mesh screen and thus were constricted rather than stopped. In future applications it may be desirable to use copper screen with smaller openings than those of the 16-mesh material used in this study. Fewer roots would be likely to grow through the material, and those that did would be more severely constricted and stunted.

As noted above and in contrast with copper screen, fabric barriers probably need openings large enough that root tips can grow through them.

It had also been expected that Biobarrier would completely stop all roots, since trifluralin works by stopping cell division. Two factors may explain why a few (never many) cottonwood roots penetrated some of the Biobarrier panels. First, organic matter in these forest soils averaged approximately 14 percent, considerably above what would be expected in most urban soils, and may have tied up much of the trifluralin. Second, a handbook provided by REEMAY, Inc. (4) shows another species of cottonwood (narrowleaf cottonwood, *Populus angustifolia*) as requiring, among all species tested, one of the highest concentrations of trifluralin for effective root control. A possible mechanism would be by vigorous roots producing large numbers of expendable cells in root caps in front of their growing tips. If the cells in a root cap tied up most of the trifluralin in a very localized volume of soil, the root might continue growing long enough to become suberized and insulated from additional trifluralin diffusing through the soil. Supporting this line of thought, Biobarrier panels were most effective for birch, which had the least vigorous root systems of the species tested, and were least effective for hybrid cottonwood, which had the most vigorous root systems of the species tested.

Because none of the barriers totally stopped roots, one is still left with some uncertainty and with judgments to make concerning costs, anchorage, access to moisture and nutrients, and amounts of damage to expect from large roots as compared with small ones.

The nylon fabric had about the same effectiveness as 16-mesh copper screen but, at a current price of 31 cents per square foot, costs only one-seventh as much. However, barrier materials are a fairly small part of repair costs, and copper screen might be worth the extra cost if obtained with a smaller mesh size that stopped a greater percentage of roots and more severely constricted any that penetrated. Biobarrier, at approximately $2.00 per square foot, completely stops roots of some species but may not stop all roots of especially vigorous or resistant species, such as the cottonwoods used in this study. So, users need to consider what local experience has been for various species and situations.

Because effective control of roots may reduce a tree's stability, we need to consider anchorage. Otherwise, in reducing the risks of lifted sidewalks we may increase the risks of falling trees. Using barriers from the surface to a depth of 8 to 12 inches should prevent damage to sidewalks. If soil conditions at deeper layers are good, the roots developing in these deeper layers should provide ample anchorage. However, if deeper layers are compacted or poorly aerated, surface roots may be the only roots. Or, if soil conditions are not good, roots at deeper layers may grow poorly or may grow back toward the surface (6).

Because the alternate heating and cooling of pavements tends to "pump" moisture as vapor and then condense it on the under side of these pavements (1,3), soils immediately under pavements tend to be moist as well as warm and can be ideal for roots if reasonably porous and aerated. Thus, the location of compacted layers becomes important. If soil immediately beneath a pavement is porous and deeper layers are compacted, we can expect damage by invading roots if no barrier is present. If deeper layers are porous and those immediately under the pavement are compacted, such damage is less likely. If all layers under a pavement are compacted or otherwise unavailable to roots, anchorage and stability of the tree may be reduced, especially if the tree is quite close to the pavement.

Stunting but not totally stopping roots may offer advantages in some cases. Stunted roots, by extending a foot or two beyond barriers, can exploit increased volumes of soil for moisture and nutrients and may improve anchorage at least slightly. (Constricted roots have fairly good tensile strength but may not have much shear strength.) Problems and costs should be substantially reduced because stunting greatly reduces the total amount of roots (Figs. 5 and 6). It must be recognized, however, that aggregations of small roots can lift sidewalks.

As usual, we found no "magic bullet" that can be applied without thought. However, an increasing variety of materials and procedures are available for reducing costly damage to pavements by tree roots, including the three barrier materials tested in this study.

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Résumé. À la recherche de barrières efficaces pour prévenir les racines d'arbres d'endommager les trottoirs, un tissu de nylon résistant, un grillage de cuivre et du Biobarrier® furent testés contre des racines de végétaux plantés depuis neuf ans pour les espèces suivantes: peuplier hybride (*Populus trichocarpa X deltoides*), peuplier de l'Ouest (*Populus trichocarpa*) et bouleau à papier (*Betula papyrifera*). Les racines furent tranchées contre des murs verticaux à 3.5 pieds (1.1 m) des arbres. Les barrières furent disposées contre les racines tranchées. Des sections-contrôle furent laissées sans barrière artificielle. Trois ans après l'installation, la quantité de racines ayant passées au travers des diverses barrières fut substantiellement moindre que celle des sections-contrôle. Le nylon et le cuivre arrêtèrent grandement les racines en les restreignant aux ouvertures des matériaux utilisés. Le Biobarrier, conçu de façon à libérer lentement un herbicide, la trifluraline, arrêta toutes les racines de bouleau, mais en laissa passer quelques-unes des peupliers.

Zusammenfassung. Auf der Suche nach einer effektiven Barriere, um die durch Baumwurzeln entstehenden Schäden an Bürgersteigen zu verhindern, wurden ein dichter Nylonstoff, eine Kupferplatte und Biobarrier® gegen die sich neubildenden Wurzeln in einer 9 Jahre alten Pflanzung von Hybrid-Balsampappel (*Populus trichocarpa X deltoides*), Balsampappel (*P. trichocarpa*) und Papierbirke (*Betula papyrifera*) getestet. Die Wurzeln wurden direkt an einem vertikalen Wall in 1.1 m (3.5 Fuß) Abstand vom Stamm abgeschnitten. Hölzerne Trennwände wurden am Ende der Wurzeln installiert. Die Kontrollbereiche wurden nicht mit Berrieren ausgestattet. Drei Jahre nach der Installation war die Anzahl der Wurzeln, die durch alle Hindernisse durchdrangen, wesentlich geringer, als die Anzahl der Wurzeln in vergleichbaren Kontrollabschnitten. Sowohl Nylon-wie auch Kupferbarrieren führten zu Kümmerwuchs bei den Wurzeln durch die Wachstumsbegrenzung auf die Öffnungen im Material. Biobarrier®, entwickelt zur langsamen Abgabe des Herbizids Trifluralin, hemmte alle Birkenwurzeln, aber ließ einige Balsampappelwurzeln durch.