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# REDUCING SURFACE ROOTING OF TREES WITH CONTROL PLANTERS AND WELLS[1]

by J. Alan Wagar

**Abstract.** *Control of surface rooting was explored in a study of fruitless mulberry (Morus alba) and zelkova (Zelkova serrata).* After 3½ growing seasons, average amounts of roots were reduced substantially in the top 8 inches of soil by PVC control planters and by wells that placed trees 18 inches below grade. Among trees in planters and wells, however, amounts of surface roots differed greatly, and the tendency of roots to return to surface layers may be partly associated with soil compaction and poor aeration. Mulberry roots returning to the surface layers were, on the average, smaller and zelkova roots fewer than the unconstrained roots of control trees of the two species. For a given trunk size, mulberry roots were much more massive than zelkova roots. Avoiding species with massive roots remains extremely important in selecting street trees.

One of the costliest operations associated with municipal trees is repairing sidewalks damaged by tree roots. The cost of repairing damage by one tree is often $500 or more per occasion. And, once started, damage often recurs at about 5-year intervals. If cities do not repair the walks, they may face even higher costs when sued for injuries caused by broken or misaligned sidewalks (4, 8).

Various efforts have been made to control root damage to sidewalks. Some cities plant trees below grade in wells so roots at least begin at greater depths. Rigid PVC plastic control planters and other barriers to contain roots have been developed, and, in Australia, polyethylene sheet plastic and fumigants have been tested for stopping roots (6). This paper reports a study of wells and control planters for controlling surface roots of fruitless mulberry and zelkova trees. Sidewalks and soil amendment effects on root development were also examined.

## Procedures

In 1980, in cooperation with the University of California Department of Environmental Horticulture, we planted 32 fruitless mulberry trees *(Morus alba)* and 32 zelkova trees *(Zelkova serrata)* in a formal experimental arrangement, along with 8 extra trees for practice excavation and possible replacement of trees that might die. Trees were arranged in 12 rows of 6 trees each with 18-foot spacing between trees and between rows (Fig. 1). Mulberry was selected because it grows rapidly and is notorious for the amount of damage its roots do. The zelkovas were planted as a contrasting species expected to do less damage. Containerized trees of 5-gallon size were used and were planted in square holes 30 inches on a side. For each species, eight "control" trees were planted without constraints on their roots, eight trees were planted in PVC planter boxes (hereafter called "planters"), eight were planted in wells, and eight were planted with 5-mil polyethylene around the sides of the square planting holes. Wells were 18 inches in diameter and 18 inches deep and lowered root systems 18 inches while still leaving the trunk and root crown exposed to air. Planting holes were 24 inches deep for all treatments but wells, which required planting holes 42 inches deep.

1. Presented at the annual conference of the International Society of Arboriculture in Quebec City, Canada in August 1984.

In each treatment, four trees were planted adjacent to sidewalks and four away from sidewalks (Fig. 1). Among each of these sets of four trees, the planting holes or planters for two trees were filled with the native soil (a clay loam). The other two holes or planters were filled with a mixture having equal parts of sand, peat, and the native soil. For the planters, we followed the manufacturer's recommendation and use ¾-inch gravel to backfill between the planter and planting hole and to cover the planter.

Trees were planted in July of 1980, and that fall we established a lawn of perennial ryegrass between the trees to simulate the conditions under which many city trees grow. The lawn and trees were fertilized and sprinkler irrigated each summer through 1983, providing three and a half seasons of growth. The trees reached heights of 12 to 20 feet and diameters of 2 to 5½ inches.

When laying out the study area and planting the trees, we learned that parts of the field had compacted soil at various depths. These layers caused water logging in some areas, and some tree wells filled with water and remained full for days or even weeks at a time. Three of the zelkovas planted in wells died. Although the nonuniform planting site reduced the study's precision, it provided some information on the importance of soil aeration. A second difficulty, however, provided no such benefit. In rototilling to prepare the soil for seeding to grass, we managed to tear the top few inches off many of the polyethylene barriers, essentially destroying one of the treatments.

Originally, we planned to spend the summer of 1984 excavating root systems. We learned, however, that high velocity dynamite can be used to excavate and study tree roots (7). Dynamite permitted excavating at the end of the 1983 growing season, providing results a year earlier without sacrificing a growing season. Because dynamiting was known to change the vertical position of roots, we excavated first with hand tools to expose and map the top 8 inches of each root system. A licensed blaster then coordinated the use of high velocity dynamite — in sticks 1 inch in diameter and 8 inches long — to loosen the remaining soil around each root system.

We placed dynamite around each tree in 12 holes 30 to 36 inches deep and spaced 2 to 3 feet apart. At first we used half to two-thirds of a stick in each hole but did not get quite enough loosening. Thereafter we used 12 full sticks per tree, a little more than one stick per cubic yard of soil. All 12 sticks for a tree were detonated simultaneously.

Although dynamiting worked very well except where the soil was heavily compacted, it really was not necessary. We gained almost all our information from measurements of roots exposed with hand tools in the top 8 inches of soil. We expressed the "amount" of these roots in terms of their cross-sectional area, number, and average diameter — all as measured in a doughnut-shaped zone 8 inches deep and extending from 2 to 3 feet from the center of the tree. For each tree, cross-sectional area was totalled for all roots in the doughnut-shaped zone, with each root measured at the greatest diameter attained and measured at only one point, even if branched. Only roots at least ¼ inch in diameter were considered.

Data were analyzed using the t and Bonferroni t tests with General Linear Models procedures from the Statistical Analysis System (3). The t tests establish a probability (P) that a single difference — as between means of the control and well treatments — may be due to chance. The Bonferroni t test is considerably more conservative and provides an adjusted probability ($P_b$) reflecting the increased likelihood, when several differences are to be tested, that one or more is due to chance (1). For cross-sectional area of roots, basal area of stems, average number of roots, and average diameter of roots, respectively, six pre-planned comparisons were made (Table 1). A t test was

**Figure 1. Fruitless mulberry and zelkova trees on the study site, University of California at Davis.**

**Table 1. Differences in average root cross-section, stem basal area, number of roots, and diameter of roots among mulberry and zelkova trees grown in planters, wells and as control trees, 1980-1983.[1]**

| | *Root cross-section* | | | *Stem basal area* | | | *No. of roots* | | | *Diam. of roots* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Species and comparison* | *Diff. (sq in)* | *P* | $P_b$ | *Diff. (sq in)* | *P* | $P_b$ | *Diff. (no.)* | *P* | $P_b$ | *Diff. (in)* | *P* | $P_b$ |
| **Mulberry** | | | | | | | | | | | | |
| Control vs. planter | 10.73 | ◄.01 | ◄.05 | 28.74 | ◄.05 | NS | 3.00 | NS | NS | .42 | ◄.05 | NS |
| Control vs. well | 11.14 | ◄.05 | ◄.10 | 7.64 | NS | NS | 4.15 | ◄.10 | NS | .53 | ◄.05 | NS |
| Control vs. plant. + well/2 | 10.94 | ◄.01 | ◄.05 | 18.20 | NS | NS | 3.56 | ◄.10 | NS | .48 | ◄.05 | NS |
| Planter vs. well | .42 | NS | NS | −21.10 | NS | NS | 1.15 | NS | NS | .11 | NS | NS |
| Soil amendment vs. no amend. | 1.72 | NS | NS | −0.92 | NS | NS | .50 | NS | NS | .24 | NS | NS |
| Sidewalk vs. no walk | −1.70 | NS | NS | 1.96 | NS | NS | −1.00 | NS | NS | .02 | NS | NS |
| **Zelkova** | | | | | | | | | | | | |
| Control vs. planter | 1.02 | ◄.05 | NS | 4.21 | NS | NS | 5.02 | ◄.05 | NS | .17 | ◄.10 | NS |
| Control vs. well | .84 | ◄.10 | NS | 1.71 | NS | NS | 5.02 | ◄.05 | NS | .10 | NS | NS |
| Control vs. plant. + well/2 | .93 | ◄.05 | NS | 2.96 | NS | NS | 5.02 | ◄.05 | NS | .14 | ◄.10 | NS |
| Planter vs. well | −.18 | NS | NS | −2.50 | NS | NS | .00 | NS | NS | −.07 | NS | NS |
| Soil amendment vs. no amend. | .44 | NS | NS | 1.47 | NS | NS | 1.37 | NS | NS | −.12 | NS | NS |
| Sidewalk vs. no walk | −.16 | NS | NS | −6.92 | NS | NS | −.51 | NS | NS | −.13 | ◄.10 | NS |

[1] Probabilities that differences are due to chance rather than treatment are indicated by P for standard t tests and by $P_b$ for the more stringent Bonferroni t tests.

applied to the logarithms of root-area/stem-area ratios to test for a difference between control trees of mulberry and zelkova.

(Logarithmic transformation adjusted for unequal variances and the non-normal distribution of ratios.)

An estimate of soil aeration was added — after analysis was begun — as a covariant that might explain some of the variability observed in different root systems. Aeration was coded as 1 (good), 2 (fair), or 3 (poor), based on mapping of standing water on several occasions and on apparent compaction encountered when we drilled holes for dynamite. Both measures had limitations. Water logging was visible primarily in tree wells, and difficulty in drilling was affected by soil dryness as well as compaction. Once excavation of the root systems had begun, however, time did not permit measurement of other soil variables, and, if made, additional measurements might easily have been biased by what we had already observed of root systems.

## Results and Discussion

On the average, our two surviving treatments — planters and wells — both reduced the amount of roots in the top 8 inches of soil and between 2 and 3 feet from the trunk. Control trees had a greater mass of surface roots than did trees in planters or wells, and mulberries produced a much greater mass of roots than did zelkovas (Figs. 2, 3, 4; Table 1).

Root barriers may affect amounts of top growth differently for different species. When size was expressed as basal area of trunks, mulberries grown in planters and wells averaged somewhat smaller than did control trees planted without constraint, but zelkovas grown in planters and wells differed little from those grown without barriers (Fig. 5). Among basal area differences, only the difference between control and planter treatments for mulberry was statistically significant (P .05) and then only for the standard t test (Table 1).

For a given trunk size (expressed as basal area) mulberry control trees had more massive roots than zelkova control trees (P .01). The surface roots of mulberry were almost equal in cross-sectional area to the stem (Fig. 6). For zelkovas, however, the cross sectional area of the surface roots averaged only 18 percent of the stem area.

Although planters and wells greatly reduced average amounts of surface roots, rooting patterns differed enormously from tree to tree. Some differences may have been genetic: the zelkovas were propagated from seed, and the mulberries were on seeding rootstock. The site was also highly variable, and our measure of aeration — which was not statistically significant in any of the analyses — probably did not adequately reflect site variability. At least part of the variation in surface rooting may have resulted from differences in

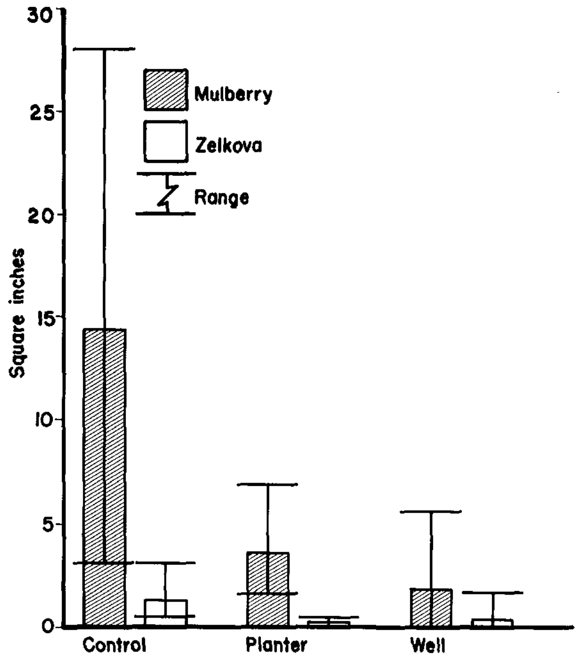


Figure 2. Average amount of surface roots for mulberry and zelkova trees with control, planter, and well treatments. Amounts of roots are expressed as total cross-sectional area of roots within 8 inches of surface and between 2 and 3 feet from stem.

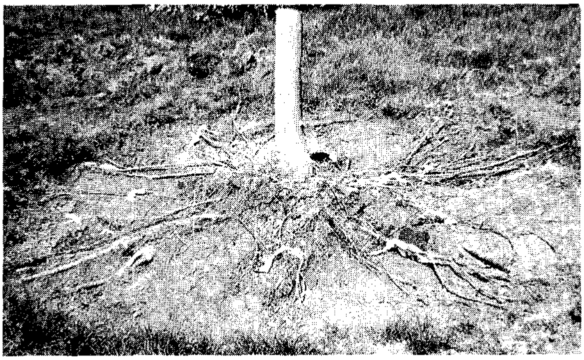

Figure 3. Fruitless mulberry with surface root cross-sectional area of 14.8 square inches, approximately the average shown in Figure 2 for mulberry "control" trees.

Figure 4. Zelkova root system with surface root cross-sectional area of 1.7 square inches, slightly more than the average shown in Figure 2 for zelkova "control" trees.

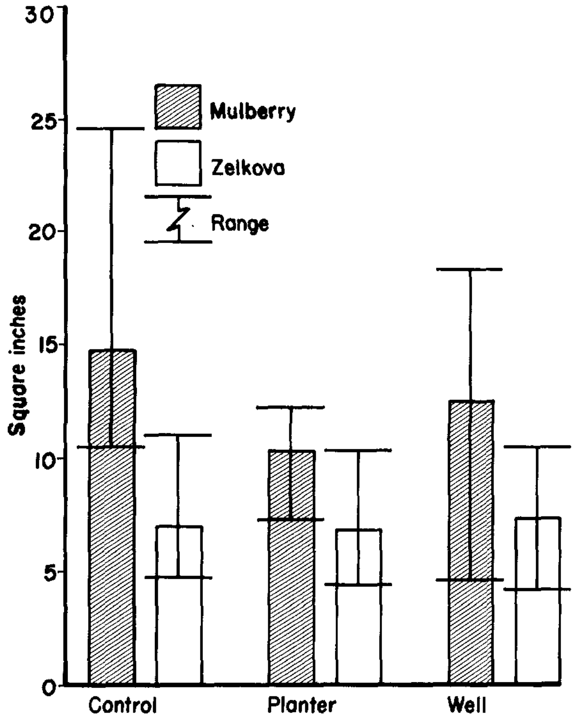


Figure 5. Average cross-sectional area of stems (1 foot above ground) for mulberry and zelkova trees with control, planter, and well treatments.

soil compaction and aeration. Where the soil showed no evidence of either compaction or water logging, roots that were forced deep tended to stay deep. Where compaction and water logging were especially severe, roots tended to come back to the surface (Fig. 7). Statistical tests, however, showed no significance for this pattern.

Reductions in the total mass of surface roots can be related to either the size or number of roots. For mulberry but not zelkova (Fig. 8) roots that grew back into surface layers after being forced deep averaged somewhat smaller than the roots grown without constraint (t test only, P .05, Table 1). For zelkova, planter and well treatments were associated with significant reductions in average numbers of surface roots (t test only, P .05, Table 1).

Although damage from rototilling prevented formal analysis of root response to barriers of polyethylene, we could still observe some effects. First, thin plastic is subject to damage from anything that disturbs the surface layers of soil. The buried polyethylene showed no signs of deterioration and roots did not penetrate it unless it had been punctured or torn during installation. Where the top of the barrier was damaged, roots tended to concentrate in surface layers, just the opposite of what we intended. Where the barrier remained intact, roots were contained and tended to circle like roots left too long in containers. And where the barrier intersected a poorly aerated layer that prevented permanent rooting, we had, for all practical purposes, a potted plant.

We found no effects of soil amendment on either the total number or the average diameter of roots, probably because the original soil (a clay loam) was — except where compacted and poorly aerated — about as good a root environment as the amended soil. Amended soil (equal parts of sand, peat, and the original clay loam) did seem to help in one situation. Mulberry trees growing in wells had a rather small mass of surface roots even without soil amendment, but surface roots were even further reduced when planting holes were backfilled with the amended mixture (Fig. 9). Soil aeration and drainage may have been improved by sand and peat in the amended planting mix.

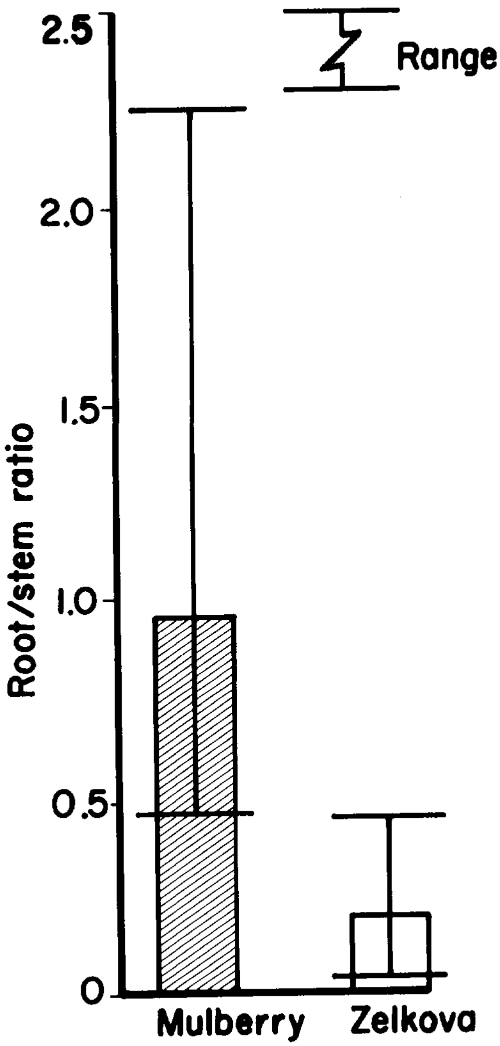


**Figure 6. Average ratios of surface root to stem cross-sectional areas for control trees of fruitless mulberry and zelkova.**

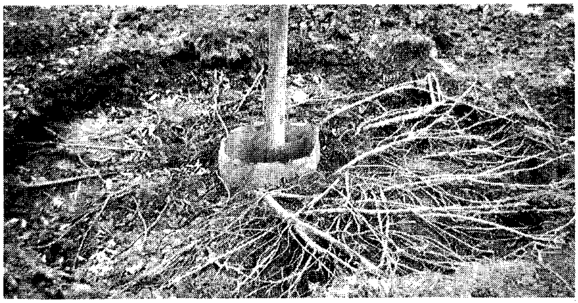

**Figure 7. The roots of this mulberry — planted below grade in a well in poorly drained soil — grew back up into surface layers.**

Sidewalks probably generate some of their own problems by creating an environment conducive to root growth. As we excavated roots in the upper 8 inches of soil, we noticed that roots of trees adjacent to sidewalks were more difficult to excavate than those of trees away from sidewalks, primarily because of many fine roots, most of which were smaller than the ¼-inch limit below which we did not record data. Branching of roots is known to be associated with good soil and growing conditions (5, 9) and with increased temperatures (2), and measurements from a study still in progress showed soil to be both warmer and moister under and near sidewalks than away from walks.

**Management Implications**

For the two species studied, both planters and wells substantially reduced surface rooting. Individual trees differed considerably, however, in the extent to which their roots returned to surface layers after having been forced to deeper layers. Root-control devices may be least effective where most needed, that is, where poor soil aeration or compaction encourages shallow rooting. Fortunately, roots returning to the surface from underneath barriers tend to be smaller or fewer, or both, than surface roots of trees with unconstrained root systems. Barriers can at least postpone the time when sidewalk repairs are needed, and, on a citywide basis, should reduce the annual cost of such repairs, especially if we consider well-drained as well as poorly drained

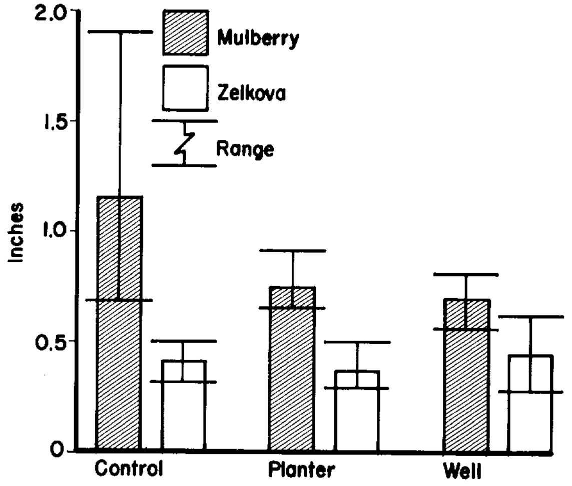


Figure 8. Average diameter of surface roots for mulberry and zelkova trees with control, planter, and well treatments. Averages are for roots within 8 inches of surface and between 2 and 3 feet from stem.

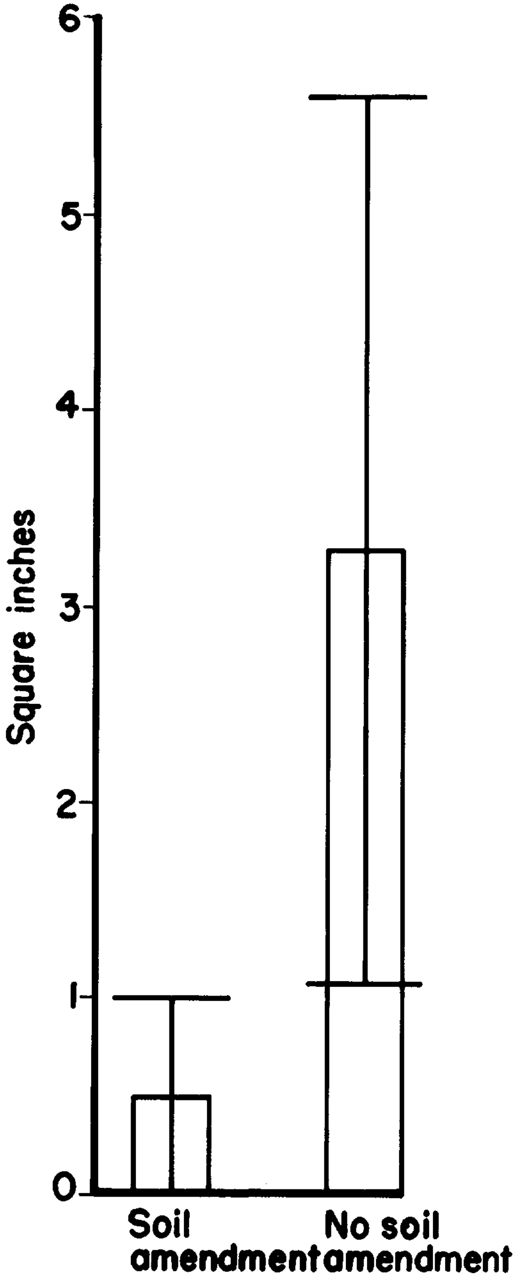


Figure 9. Apparent effect of soil amendment on amount of surface roots for mulberry trees with well treatment.

soils. Also, where soil aeration is poor, it may be possible to improve it with soil amendments or such special drainage facilities as vertical mulching or drilling through compacted layers.

Finally, the selection of trees still looks extremely important. For a given size of trunk, zelkovas had much less massive roots than mulberries, and such differences seem likely among a number of species. Yet, adjacent to sidewalks, some cities continue to plant camphors, liquidambars, mulberries, and other species with unusually severe root problems. If nothing else, our research may "document the obvious" and help city arborists recognize some of the worst troublemakers.

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## ABSTRACT

WINK, L. 1984. **Scientists search for clues to American chestnut mystery.** Am. Nurseryman 159(2): 93-94.

The American chestnut story unfolds like a biological murder mystery, complete with several incongruous elements that add to the intrigue. Dennis Fulbright, a Michigan State University plant pathologist, is attempting to unravel the biological phenomena that are producing the disease-fighting reaction so that synthetic vaccines can be produced. Eventually, he hopes to come up with natural inoculants to fight Dutch elm disease and stone fruit diseases. What intrigues Fulbright is that some Michigan trees have never been infected by chestnut blight. These healthy trees have been found both in isolation and in the midst of infected groves. At this point, scientists do not know how to protect healthy American chestnut trees other than by giving them a mild form of the blight, which causes scar tissue to form as a byproduct of immunity. Fulbright's investigations in the laboratory have now identified six virus-like molecules that are able to trigger the production of hypovirulent fungal strains.