TREE ROOT SYSTEM ENHANCEMENT WITH PACLOBUTRAZOL

by Gary W. Watson

Abstract. Paclobutrazol 2SC (PBZ) was injected into the soil at the base of the trunk at 2 g a.i. per inch dbh. Surface fine root densities near the base of the trees were naturally higher than in the rest of the root system and were adequate to absorb the compound. PBZ treatment was effective in stimulating fine root development in pin oaks (*Quercus palustris*) and white oaks (*Quercus alba*). Pin oak fine root densities were increased significantly in high-quality topsoil. White oak fine root densities were increased significantly by PBZ alone and in combination with high-organic replacement soils. The treatment may be effective in stabilizing declining trees with insufficient fine root development.

Root development of mature landscape trees can be inadequate to support the crown (23). Root space is often more constricted in the landscape than crown space. Soil quality in the already limited root space can deteriorate over time from numerous causes, including raking leaves, which removes organic matter and nutrients; foot and equipment traffic, which compacts the soil; alkaline runoff from paved surfaces, which can raise the pH; and vigorous competition from turfgrass, which can directly reduce the number of tree fine roots in a limited root space. More directly stated, tree crowns can grow too large for the quality and quantity of root space available, resulting in decline and dieback. Root system enhancement and crown size control are 2 approaches to restoring the balance between the crown and root system.

Root system enhancement can be accomplished by improving the soil, but direct substitution or addition of soil in the root zone of existing trees will cause considerable damage to roots. Traditional surface mulch is effective for improving the soil and increasing root development over time (10), but is not a viable option in all situations. Vertical mulching, and a more extensive procedure called soil replacement (24), can also be effective in improving root development on a limited basis.

The growth regulator paclobutrazol (PBZ), a gibberellin biosynthesis inhibitor, has been shown to reduce the shoot growth of many species (6), and is commonly used to control the regrowth of trees under utility lines. This growth regulator has promise for use in the landscape wherever control of plant size is needed. Reports of its effect on root systems have been mixed. Reports range from increased root growth (1,2,6,20) to decreased root growth (2, 9,14,15), but nearly always include an increase root:shoot ratio (12,15,17). Most PBZ studies have used plants in pots or solution culture in which the PBZ is applied directly to the entire root system, so this information is of limited application to mature landscape trees. The current commercially available formulation of PBZ is applied as a basal soil injection or drench. Only a few roots at the base of the tree are in direct contact with the PBZ. Little information is available on how this type of PBZ application affects root development in the rest of the root system. Virtually nothing is known about the root response of plants in the landscape. The few published studies in which the PBZ was applied to leaves or stems of greenhouse plants reveal that root growth was generally unchanged (6,13,25) or reduced (11,16), and root:shoot ratio was increased (16,25,26) or unchanged (4,11).

Soil conditions are often a limiting factor in root growth of urban trees. If chemical enhancement of tree root systems is possible with PBZ, it is likely to be limited by soil quality. The objective of this study was to test the response of landscape tree roots to a basal application of PBZ in existing soils and improved soils.

Methods

The PBZ 2SC formulation (Profile 2SC, DowElanco, Indianapolis, Indiana) is applied as a basal soil injection or drench, within 20 cm of the trunk base. A Series 3600 Soil Injection Closed System (Springfield Specialties Co., Springfield, Pennsylvania) was used to inject the diluted (79 mL/L) solution into the soil in 250 mL aliquots for a total of 2 g of active ingredient (100 mL dilute solution) per caliper inch.

With the basal injection or drench methods listed on the label, the chemical is delivered to the upper 15 cm of soil. To confirm that a sufficient density of fine roots was present at the soil injection site, the horizontal distribution of fine roots in the upper 15 cm of soil was investigated. Core samples 15 cm deep by 6.5 cm diameter were collected at 20, 40, 60, 80, 100, 120, 240 and 365 cm from the base of 8 trees of each species that were of similar size and growing in similar conditions as the treated trees.

Experiment 1. Two rows (7 trees each) of pin oak (*Quercus palustris*) trees, between 21 and 27 cm dbh, were selected from the middle of a large, evenly spaced block of trees on the grounds of the Morton Arboretum. The 2 rows were separated by a row of unused trees. The trees were in excellent condition. One row of trees was treated with PBZ on August 28, 1989; the other row served as untreated controls.

In September 1992, fine root development was measured using root density cores. One 35 cm deep, 7 cm diameter core was taken 1.5 m from the base of each tree. Cores were cut into 5 cm segments and stored at 4°C until processing. Soil was washed from the roots, and oak roots were separated from other roots and debris by hand. Roots were digitized at 300 dpi resolution, and root surface area was measured with Image Pro for Windows software. T-tests were used to compare root densities at each soil depth ($p < 0.05$) using SigmaStat Version 2.0 for Windows.

Experiment 2. Sixteen mature white oaks (*Quercus alba*) were identified on the grounds of the Morton Arboretum. They were from 50 to 70 cm dbh with large open-grown crowns and located within 500 m of each other. All were in a state of decline as judged by the amount of dieback, tufted growth, and chlorosis in the crown.

Soil replacement in a pattern of radial trenches has been shown to increase root and crown growth (24). In this study, soil replacement was combined with PBZ treatments. There were 16 trenches around each tree, 45 cm deep and alternating between 2 and 4 m long, with the distant end of each trench positioned 7.5 m from the trunk. Alternate length trenches were necessary to prevent the near ends of the trenches from being too close together and causing excessive root damage. The trenches were filled with a 50/50 v/v site topsoil and leaf compost mix.

The 4 treatments were PBZ soil injection, soil replacement trenches (SRT), PBZ soil injection plus SRT, and control. PBZ treatments were injected on August 28, 1989, and trenches were installed in June 1990. Four trees received each treatment combination.

Fine root development was measured using the same root density coring and sample processing procedures as in Experiment 1, and at the same time. Two cores per tree (8 cores per treatment) were taken in the middle of the larger trenches, and at a similar distance from the trunk for the other treatments.

Two-way ANOVA was used to compare root density of treatments to the control ($p < 0.05$) using SigmaStat Version 2.0 for Windows. Student-Newman-Keuls Method was used as a multiple comparison procedure.

Results

Pin oak surface fine root densities were 80% higher within 60 cm of the trunk base compared to the other sampling locations (Table 1). White oak fine root densities were 60% higher within 20 cm of the trunk base. The reason for this elevated fine root density at the base of the tree is unknown, but the data show that an adequate density of fine absorbing roots are present near the base of the tree to absorb PBZ applied there.

Table 1. Horizontal distribution of pin oak and white oak fine root density (mm^2 fine root surface area per cm^3 soil) in the upper 15 cm of soil.

	Distance (cm) from base of trunk							
	20	40	60	80	100	120	240	365
Pin oak	9.8	9.3	8.0	5.3	4.2	4.3	5.0	6.4
White oak	11.7	7.1	6.7	7.1	4.9	6.1	5.1	2.9

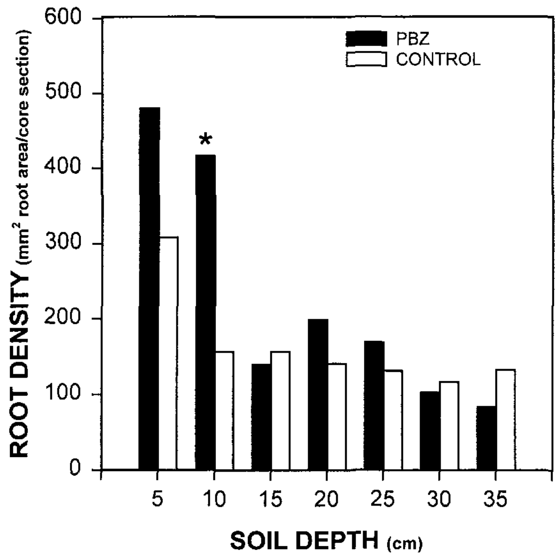

Figure 1. Fine root development of pin oaks after paclobutrazol basal injection treatment (PBZ). Roots were sampled 1 m from soil injection site. An abrupt change from organic topsoil to clayey subsoil occurs below the 10 cm sampling depth. An asterisk (*) indicates treatment value significantly different from the control at $p < 0.05$.

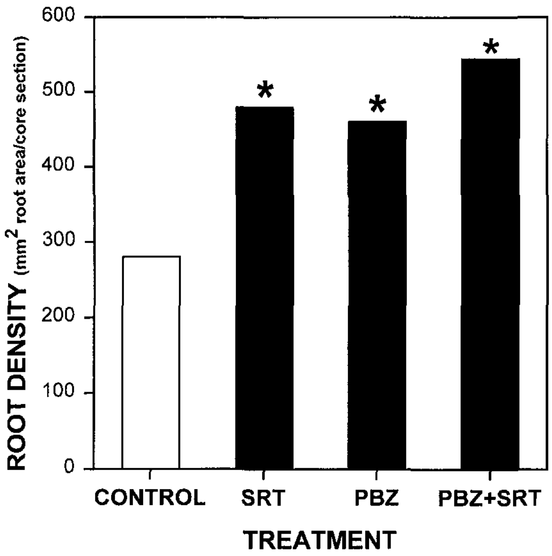

Figure 2. Fine root development of white oaks after paclobutrazol basal injection (PBZ) and soil replacement treatments (SRT). An asterisk (*) indicates treatment value significantly different from the control at $p < 0.05$.

Experiment 1. PBZ increased fine root density of pin oaks by 64% in the upper 5 cm of soil, and significantly increased the fine root density between 5 and 10 cm. At approximately 10 cm, there was an abrupt change to more dense and clayey soil horizon. Increases in root density were inconsistent and not significant in this subsoil. Increases in root densities between 15 and 25 cm depth were as much as 41%. Root density appeared to decrease between 30 and 35 cm depth (Figure 1).

Experiment 2. Root density of white oaks was increased significantly by all treatments (Figure 2). There was no significant difference among the different depths, nor was there a significant interaction between treatment and depth. As in a previous study (24), replacing the existing site soil with a soil/compost mix resulted in complete colonization of the new soil by new tree roots. The fine roots in the replaced soil were 70% denser than the undisturbed control. PBZ alone, applied in the root crown area, increased fine root density similarly in areas away from the point of application. The improved soil mix in the trenches combined with PBZ resulted in the greatest increase in fine root density, nearly double that of the undisturbed control. This greater root development (although not significantly greater than the other 2 treatments) of PBZ treated trees in high-quality soil is similar to the greater root response in the high-quality topsoil in the first experiment.

Discussion

In both experiments, fine root density was increased after application of PBZ. This technique could have application in many landscape situations for which sufficient fine root development is lacking. Fine root enhancement of the pin oaks was greatest in the high-quality topsoil and in the replacement soil trenches around the white oaks.

PBZ was applied as a soil injection near the root crown. PBZ is absorbed by roots and translocated in the xylem only, towards the branch tips (5). The stimulation of fine root development must be an indirect effect, since the chemical is never in contact with roots more than 20 cm from the base of the tree. Photosynthesis is not reduced by PBZ treatments (8,14,21). Increases in root

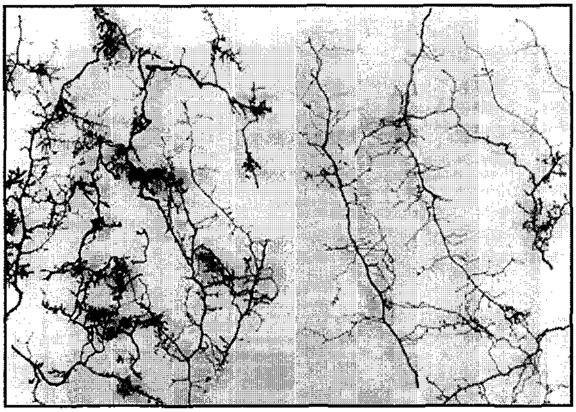

Figure 3. Pin oak fine roots from a tree treated with paclobutrazol basal injection (left) and an untreated control (right). Paclobutrazol was applied as a basal injection, and roots were sampled 1.5 m from trunk.

growth may be due to increased carbohydrate supply to roots resulting from reduced demand for growth above ground (7,20).

It could not be determined from this study if the increase in fine root density was due to an increase in root branching, elongation, or both. Visual observation suggested that the fine roots were more profusely branched (Figure 3). Increased fine root branching has been reported previously (1,9), as well as root thickening (18) and increased root initiation (6,20). Adventitious and lateral root formation processes are similar. PBZ can reduce root elongation (9,20). A smaller unsuberized length of the root tip (26) also implies slower elongation. The specific effect of PBZ on root growth and morphology is an important question in relation to future applications of this technology in the landscape. In cases in which roots have been severed and must grow long distances to reestablish the original root spread, a rapid elongation rate is very important. In contrast, where the major roots are intact, increasing the fine root density through more frequent branching could be more beneficial.

Crown response was not quantified in either experiment. The visual difference in appearance between treated and control pin oaks in Experiment 1 was negligible and limited to a slightly greener leaf color. All of these trees were healthy at the start. The first sign of crown improvement (greener color) of the white oaks was observed the second year after treatment. At the time of the root sampling, 3 years after the treatments were applied, the crowns of the declining white oaks were showing signs of improvement. Color and vigor was improving. Unfortunately, at that time, the majority of the trees included in the study were cut down for reasons unrelated to the study, and too few remained for meaningful crown development data to be collected. Of the trees that did survive, one that was treated with PBZ and replacement soil trenches continued to show crown improvement through 1995, 6 years after a single treatment. New growth was deep green and vigorous. The crown has become fuller each year (Figure 4). In 1994 and 1995, the leaves were much less scorched by mid-summer than a neighboring tree that received only SRT without PBZ (Figure 5). Leaves of PBZ treated trees were not noticeably smaller.

The increase in fine root development implies a more favorable root/crown balance and less stress in treated trees. Improved water status has been reported after treatment with PBZ (17,21). Apparent improvements in vigor, color, and drought resistance may be related to a greater capacity of the root system to absorb moisture and mineral nutrients from the soil. Reduced water use has also been reported (16,19).

Root development was not assessed until the crown began to show visible signs of improvement, 3 years after treatment. It is not known how fast the root system responded to the PBZ treatment, or which came first, crown or root improvements. The deep green leaf color characteristic of PBZ treatment persisted in both species through at least 6 years in this study. One study reports effects persisting for 10 years (3).

Both SRT and PBZ treatments were effective in increasing root development. If the existing soil around a tree is of sufficient quality to support additional root growth, then PBZ may be the treatment of choice. It is relatively inexpensive (less than US$20 per tree for the material), can be applied rapidly (less than 5 minutes per tree), causes no root damage, and benefits the entire root system. The concentration of roots at the base of the trees would seem to provide for excellent uptake. Additional data (G.W. Watson, unpublished)

Figure 4. These 2 white oak trees were treated with soil replacement trenches (*top and bottom*) and *paclobutrazol basal injection* (*bottom*). Photos were taken prior to treatment (*left*), 3 years after treatment—at the same time root systems were sampled (*middle*), and 6 years after treatment (*right*). The 2 treatments combined resulted in better crown improvement. Deadwood was inadvertently pruned from the trees during the course of the study.

Figure 5. Leaves of white oak trees treated with paclobutrazol (right) showed less marginal and interveinal leaf scorch than did untreated controls (left).

showed that American elms (*Ulmus americana*) also have fine roots concentrated at the base of the trunk, so this may occur in more than just oaks.

Because urban soils are often of poor quality, PBZ treatments may have to be combined with other soil-improving techniques. Soil replacement is costly and potentially destructive to roots and should be used only when other options are not available. Surface mulching alone can improve soil quality and increase fine root density (10,22). PBZ application combined with surface mulching may hold the greatest potential for fine root development.

These treatments are not quick cures for declining trees. It will take several years for any visible crown response to develop. Declining trees could die before the treatment would have a chance to stabilize them. PBZ treatments may prove to be more valuable as preventive maintenance on mature but still healthy trees, than on trees already in a state of decline.

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Résumé. Du paclobutrazol 2SC (PBZ) a été appliqué par injection dans le sol à la base des arbres. La densité de radicelles à la surface du sol près du tronc des arbres, là où le paclobutrazol a été injecté, était naturellement plus élevée que le reste du système racinaire et était adéquate pour l'assimilation du composé chimique. Le traitement au PBZ s'est avéré efficace pour stimuler le développement des radicelles du chêne des marais (*Quercus palustris*) et du chêne blanc (*Quercus alba*). Les densités en radicelles du chêne des marais étaient significativement accrues par l'usage du PBZ seul et par l'emploi de celui-ci en combinaison avec des sols de remplacement à forte teneur organique. Le traitement pourrait arriver à être efficace pour la stabilisation d'arbres dépérissants comportant un développement insuffisant de radicelles.