Soil Applied Paclobutrazol Affects Root Growth, Shoot Growth, and Water Potential of American Elm Seedlings[1]

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Abstract

Paclobutrazol (PBZ), a gibberrellin biosynthesis inhibiting plant growth regulator, was applied as a soil drench to potted American elm (*Ulmus americana* L.) seedlings in three greenhouse experiments. All plants were grown for one season in a #SP5 container and then transplanted to a larger #5 container before PBZ application in order to simulate planting in the landscape. In a test of the effects of PBZ on growth, a rate of 1.0 mg per plant reduced new shoot weight, shoot extension, and root weight (75, 38 and 63 percent, respectively) compared to controls, but new root elongation was unaffected. Root pruning, similar to that which occurs when transplanting field-grown nursery stock, resulted in a greater decrease in shoot growth from PBZ treatment at the moderate rate of 1.0 mg per plant, but for a shorter period of time, compared to non-root pruned, PBZ-treated plants. Shoot growth on all plants was unaffected by 0.5 mg PBZ per plant. Shoot growth was greatly reduced on both root pruned and non-root pruned plants at 2.0 mg PBZ per plant. After 10 weeks of drought stress, stem water potential of elms treated with 1.0 mg PBZ per plant was the same as that of the well watered controls, whereas the stem water potential of drought-stressed elms lacking a PBZ treatment was significantly lower (more negative). These effects of PBZ may be able to aid in the establishment of newly planted trees.

Index words: root growth, drought stress, growth regulation, paclobutrazol.

Species used in this study: American elm (*Ulmus americana* L.).

Growth regulator used in this study: paclobutrazol (PBZ).

Significance to the Nursery Industry

A paclobutrazol (PBZ) soil drench treatment at planting time may be able to stimulate elongation of roots and reduce water stress of trees after transplanting. More rapid elongation of roots growing out from the root ball would likely result in more rapid access to additional soil moisture associated with the larger volume of soil occupied by the roots, less stress, faster establishment and better survival of new plantings. Developing appropriate rates that will stimulate root growth without excessive reduction of shoot growth after transplanting is needed.

Introduction

Maintaining favorable water status is crucial for successful establishment of newly planted trees in the landscape. Both increased root development and a reduction in water loss can contribute to a more favorable water status. Limited evidence indicates that the growth regulator paclobutrazol (PBZ), a gibberellin biosynthesis inhibitor, can increase root development while reducing water loss of plants.

Paclobutrazol reduces shoot growth of many species (5) and is commonly used on trees under utility lines to control the rapid re-growth after line clearance pruning (3). Reports of the effect of PBZ on root growth when applied directly to roots have been mixed, ranging from increased root growth (1, 2, 16), to decreased root growth (2, 6, 11, 12), but nearly always include an increase in root:shoot ratio (8, 12, 14). In these studies, PBZ was applied directly to entire root systems in pots or solution culture. These results, however, may not apply to larger trees in the landscape where only a few roots at the base of the tree are in direct contact with PBZ after a basal soil drench application.

Studies involving PBZ applied to only the leaves and stems may produce results more similar to the landscape situation where only a small fraction of the root system is within the soil where the PBZ was applied. The root system effects in these studies are also mixed. Root growth was generally unchanged (5, 10, 19) or reduced (8, 13), and root:shoot ratio was increased (13, 19, 20) or unchanged (4, 8).

[1]Received for publication December 5, 2000; in revised form May 5, 2001. The author would like to thank Patrick Kelsey of the Morton Arboretum for assistance with potting soil design and statistical analysis. This research was funded, in part, by grants from **The Horticultural Research Institute, Inc., 1250 I Street, N.W., Suite 500, Washington, DC 20005** and the **J. Frank Schmidt Family Charitable Foundation, P.O. Box 189, 9500 S.E. 327th Avenue, Boring, OR 97009.**

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One recent study (17) reported an increase in fine root density throughout the root system of mature white oaks (*Quercus alba*) and pin oaks (*Quercus palustris*) after basal treatment with PBZ. Though this evidence based on root weight and root density points to an increase in root development resulting from PBZ treatment, the effect on root elongation is unknown. Increased root elongation could result in faster establishment of transplanted trees through more rapid replacement of the original root spread, and earlier access to a larger volume of soil and soil moisture than in untreated trees.

PBZ has been used primarily on trees with a high root-shoot ratio after line clearance pruning. Transplanted balled and burlapped trees have a low root-shoot ratio after loosing the majority of the root system in the digging process (7, 18). The effect of tree root-shoot ratio on the effectiveness of PBZ treatments is unknown.

During the time when a transplanted tree is reestablishing a full root system, water conservation is also important in maintaining a favorable water status. PBZ can increase leaf water potential, decrease stomatal conductance (1), reduce water use (13, 15), and could contribute to more successful transplanting.

This study, using small potted trees, was a first step in learning if the application of PBZ to a small volume of soil adjacent to the root flare of small trees can increase root growth, including root extension, and reduce stress after planting.

Materials and Methods

American elm seedlings were chosen as the test plant for the experiments because they grow rapidly and respond readily to PBZ (unpublished data). Elm seeds from a single tree were collected and germinated in #SP5 containers filled with a seed germination mix and grown for one season in the greenhouse at ambient light and temperature, then overwintered in the greenhouse at 10C. Fresh seeds were collected in the spring of 1996 and 1997 and germinated for use as 1-year-old seedlings the following season. At the start of each experiment, seedlings were planted into #5 containers filled with 90 percent medium sand (predominantly 0.25–0.50 mm particle size) and 10 percent composted organic matter (leaves) by weight. This soil could be easily separated from the roots without damaging them. Supplemental fertilization was not needed. PBZ was always applied as a soil drench. Five ml of solution was applied slowly to the soil at the base of the plant, which wetted only a small volume of soil in the immediate area.

Effect of PBZ on growth. Ten-cm-tall seedlings were planted into the larger pots in May 1998. Half of the plants were treated with 1.0 mg active ingredient (a.i.) PBZ per plant. Five plants each of PBZ treated and non-treated control plants were arranged in a completely randomized design. Plants were grown in the greenhouse until early October (20 weeks), at which time the stems were cut at soil line. Current season twig growth was separated from old stems, the length of the current season growth measured (cm), and both were first air-dried for a week and followed by oven-drying for 24 hours at 80C and then weighed. The soil was shaken and then washed from the roots. Once the soil was removed, the perimeter of the original root ball roots was easily distinguished. The lengths of the five longest roots growing out of the original root ball were measured on each plant. Roots growing outside and inside the original root ball were separated, dried as above, and weighed. Total root and shoot dry weights were used to calculate the root/shoot ratio. T-tests ($P \leq 0.05$) were used to distinguish treatment differences using SigmaStat 2.0 (SPSS Science, Inc, Chicago, IL).

Effect of root pruning on speed and magnitude of growth regulation. Containerized seedlings were planted into the larger pots before breaking dormancy in the greenhouse in late February of 1997. At that time, half of the root balls were trimmed to 4 cm in diameter to simulate root loss from balled and burlapped transplanting (85 percent root loss estimated by soil volume reduction). Rates of PBZ used were 0, 0.5, 1.0 or 2.0 mg a.i. per plant. Five plants of each combination of the four PBZ rates and the two root pruning treatments were arranged in a completely randomized design (40 plants total). The experiment was concluded after three months of active growth in the greenhouse. The distance between the start of the current season growth and each leaf node on the central stem was recorded. Consecutive leaf node measurements were subtracted to calculate individual internode lengths with minimum error in total length. The first leaf marked the end of the internode number one. The remainder were numbered consecutively to the tip of the shoot.

Effect of PBZ on water status. Containerized seedlings were planted into the larger pots in May 1998. PBZ was applied at a rate of 1.0 mg a.i. per plant. A drought stress treatment, consisting of withholding water until the early stages of incipient wilt could be observed, was initiated after plants had been well watered for 10 weeks. Stem water potential was measured after 10 weeks of drought using a pressure bomb (PMS Instruments, Corvalis, OR). The terminal 10-cm stem from each plant was used for a single water potential measurement at the end of the experiment. Individual leaves on some plants were too small to be used for measurements. Five plants of each treatment (well-watered, drought stress, and drought stress plus PBZ) were arranged in a completely randomized design on a greenhouse bench. Treatments were compared with a one-way ANOVA ($P \leq 0.05$) using SigmaStat 2.0. Separation of means was accomplished with the Student-Newman-Keuls test ($P \leq 0.05$).

Results and Discussion

Effect of PBZ on growth. The 1.0 mg rate of PBZ was expected to produce minimal shoot growth regulation based

Table 1. Effects of PBZ on mean root and shoot growth of potted elm seedlings after 3 months.

Growth parameter	1.0 mg a.i. PBZ	Control
New shoot weight (gm)	3.26****	13.05
New root weight (gm)	1.92****	5.20
New shoot length (cm)	8.56**	13.70
Longest roots (cm)[z]	53.48	52.32
Root elongation/root weight	23.19***	10.14
Root/shoot ratio (total plant)	1.20*	0.73

****Significantly different from control at $P \leq 0.001$.

***Significantly different from control at $P \leq 0.01$.

**Significantly different from control at $P \leq 0.05$.

*Significantly different from control at $P \leq 0.10$.

[z]Newly produced roots.

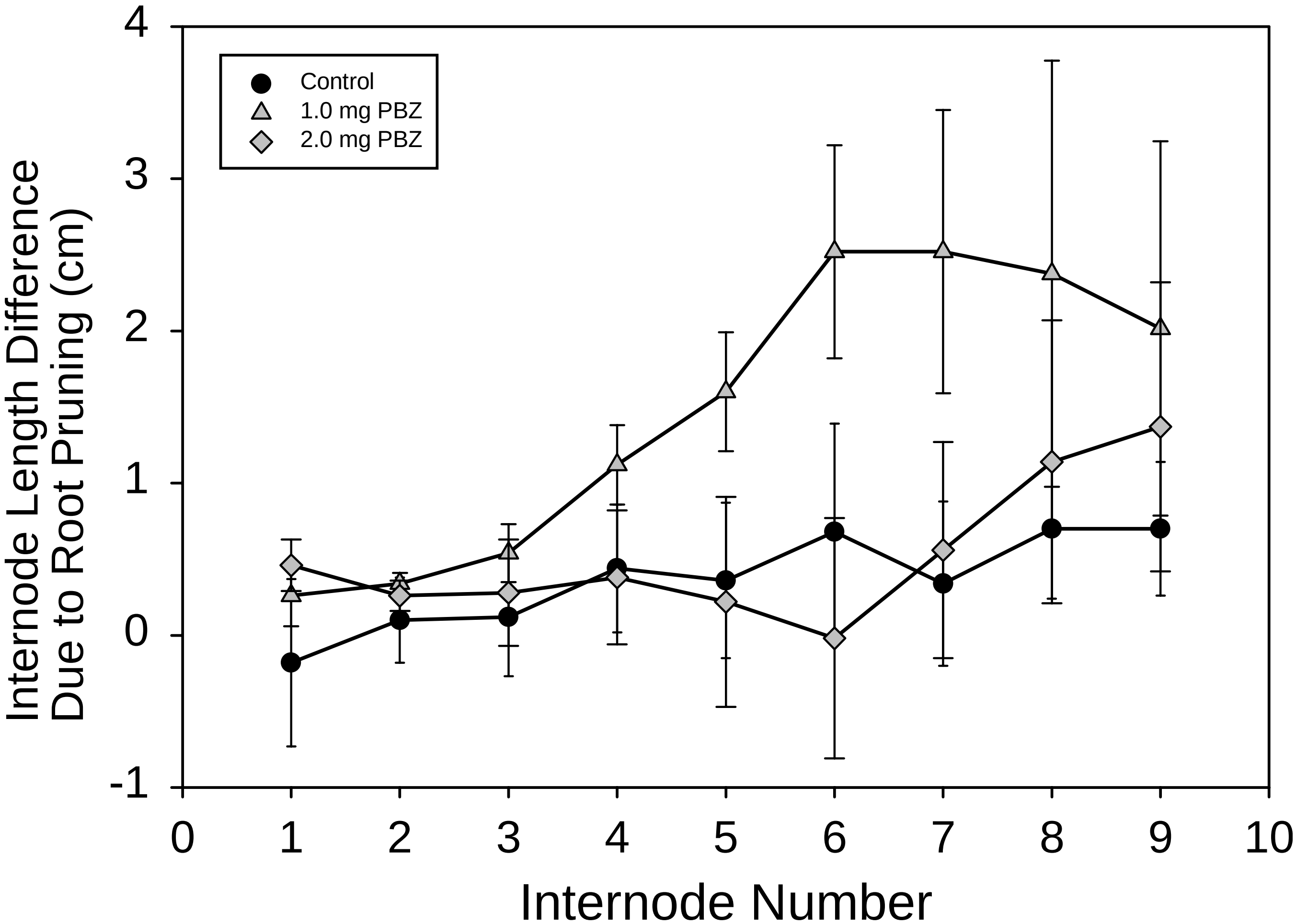

Fig. 1. Shoot growth differences due to root pruning or PBZ treatment. Internode number one is located adjacent to the previous season's growth, with numbers increasing toward the shoot tip. Values are differences in treatment means (non-root pruned minus root pruned at the same PBZ rate). A larger value indicates that the internode length of root pruned trees was smaller (more regulated) than non-root pruned trees treated at the same rate of PBZ. Vertical bars represent standard errors of the means. Data for the 0.5 mg treatment was similar to the control but left out for clarity.

on preliminary unpublished rate trials, but it reduced growth more than expected (Table 1). Shoot weight and length was reduced by 75 and 38 percent, respectively. Initial rate trials on small potted elms (unpublished data) and evidence from the literature on peach (6), indicate that greater shoot growth reduction resulting from higher rates of PBZ can decrease root growth. There was a 63 percent reduction in new root weight by PBZ. However, the length of the longest roots growing out of the root ball was unaffected. As a result, the root elongation:root weight ratio increased, indicating increased elongation for the same amount of root biomass produced. If the PBZ rate had been lower, producing minimal shoot and root growth reduction as intended, a similar increase in the root elongation/root weight ratio would have resulted in increased root elongation in treated trees. In the landscape, such a treatment could result in more rapid spread of the regenerated root system, leading to faster establishment and less stress of newly planted trees.

The root/shoot ratio was 60 percent higher for the PBZ treated plants, ($P = 0.10$). PBZ treatments have previously been reported to increase root:shoot ratio (9, 12, 13, 14, 19, 20). Higher root:shoot ratios may lead to increased stress tolerance and generally improved plant health.

Effect of root pruning on speed and magnitude of growth regulation. The amount of shoot growth reduction from PBZ treatment was compared between root pruned and non-root pruned treatments. For the 1.0 mg PBZ treatment, root pruning reduced shoot elongation between internodes 4 and 8 (Fig. 1). This reduction in shoot elongation indicates that uptake of the PBZ can be more rapid when plants are root pruned. The growth difference between root pruned and non-root pruned plants began to diminish after internode 8, indicating that the supply of PBZ in the soil was being absorbed faster and depleted sooner by root pruned plants.

Growth regulation at the 0.5 and 2.0 mg PBZ rates was similar in both root pruned and non-root pruned plants, but for different reasons. The 0.5 mg rate was too low to produce any growth regulation, with or without root pruning. The 2.0 mg rate resulted in an initially large shoot growth reduction for both root pruned and non-root pruned plants, and was apparently above the rate that effectively interacted with root pruning. The slope of the 2.0 mg line increased noticeably after node 6, just as the 1.0 mg treatment graph did after node 3. This response is an indication that PBZ absorption is enhanced by root pruning only after the large reservoir of 2.0 mg treatment PBZ in the soil was partially depleted, and PBZ was being absorbed at a rate similar to the 1.0 mg treated trees after node three.

Increased, but shorter-term, growth regulation from reduced rates of PBZ may have important implications for the possible use of PBZ on transplanted trees. Use of PBZ to stimulate root development and increase root-shoot ratio would be desirable, but to be accepted, top growth regulation should be moderate and short-term. Once established, trees are usually expected to grow rapidly.

Effect of PBZ on water status. The drought stress treatment decreased (made more negative) the stem water potential ($P \leq 0.05$) compared to well-watered controls (–3.44 and –2.48 Mpa, respectively). After 10 weeks of drought stress, the stem water potential of elms treated with 1.0 mg PBZ per plant was higher than ($P \leq 0.05$) drought-stressed elms not treated with PBZ (–2.24 and –3.48 Mpa, respectively), and was the same as ($P \leq 0.05$) the well watered controls (–2.24 and –2.48 Mpa, respectively).

The less negative water potential of drought-stressed plants also receiving PBZ treatment may have resulted from more efficient physiological regulation of water status, increased absorption of water from a larger root system, or both (1). All trees were growing in the same volume of well-watered soil before the drought-stress treatment was initiated. The root development and root:shoot ratio of both drought-stressed and non-drought stressed PBZ treated plants should have been similar, though not the same as the controls (see Table 1 for data from similar trees receiving the same PBZ treatment). If the root systems were similar, physiological regulation was probably responsible for the improved water status of drought-stressed plants also receiving PBZ treatment. Extreme drought stress may be needed to induce such improvements in water status (1), and obtaining similar results in field experiments on real landscape trees may be more difficult.

This study with potted elm seedlings demonstrated that PBZ may be useful in stimulating regenerated root elongation and reducing water stress of transplanted trees. Additional studies to determine appropriate rates that will produce similar results with larger trees without prolonged top-growth reduction are needed. The results show that field trials are warranted.

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