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Effect of Transplanting and Paclobutrazol on Root Growth of 'Green Column' Black Maple and 'Summit' Green Ash[1]

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Abstract

'Summit' green ash (*Fraxinus pennsylvanica* 'Summit') and 'Green Column' black maples (*Acer nigrum* 'Green Column') were transplanted and treated with paclobutrazol (PBZ) to study its effect on root growth after transplanting. PBZ increased root extension growth of transplanted 'Green Column' maples in the first year after treatment, prior to the onset of above-ground growth regulation. Root growth of transplanted 'Summit' ash was not affected by PBZ. Transplanting reduced extension growth of regenerated roots in the first year for 'Green Column' maples with no effect on root dry weight. In 'Summit' green ash transplanting increased root extension growth in the second year, and root dry weight in both years.

Index words: growth regulators, root regeneration.

Species used in this study: 'Summit' green ash (*Fraxinus pennsylvanica* 'Summit'); 'Green Column' black maple (*Acer nigrum* 'Green Column').

Plant growth regulators used in this study: Profile (Paclobutrazol) (R*,R*)-(±)-β-[(4-chlorophenyl)methyl]-α-(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol.

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Significance to the Nursery Industry

Transplanted trees must regenerate roots quickly to establish in the landscape with minimal stress. Paclobutrazol can increase extension growth and dry weight of regenerated roots of transplanted, field-grown trees under some circumstances. Increasing the rate at which roots elongate and grow back to their original spread could reduce establishment time. The data from this study suggest that a more difficult-to-establish tree with more slowly regenerating roots, such as black maple, may benefit from PBZ treatment after transplanting. PBZ did not reduce above-ground growth more than transplanting alone, for either species tested. Further study is needed to determine optimum rates and which species might benefit the most.

Introduction

Gibberellin inhibiting tree growth regulators, such as paclobutrazol (PBZ), have been shown to reduce shoot elongation, leaf expansion, and stem diameter growth of many tree species (2, 7). More recently, PBZ has been shown to increase root growth (14) and increase root-shoot ratio (10, 12, 13), though the PBZ was not applied to the root system.

Root balls of field-grown trees, dug according to the American Standards for Nursery Stock (1), contain 5–18% of the fine absorbing roots (5, 6, 17). Trees must replace these lost roots quickly to ensure establishment with minimal stress. This re-growth can take several years, especially on larger trees (3, 8, 9). In northern climates, this establishment period has been found to be 1 year for each caliper inch (16). Increasing the rate at which roots elongate and grow back to their original spread could reduce establishment time. In an experiment with potted elm seedlings, basal drench PBZ treatment increased the length/weight ratio of regenerated roots, even when total regenerated root weight was reduced by excessive top-growth regulation (15). The objective of this experiment was to evaluate a method to increase root growth after transplanting, especially extension growth, on field grown trees of easy and difficult to transplant species.

Materials and Methods

A large existing plot of trees at the Morton Arboretum, Lisle, IL, planted on 4.9 m (16 ft) centers was utilized. A total of 30 'Summit' green ash (*Fraxinus pennsylvanica* 'Summit'), 7.0–9.0 cm, 8.0 cm average (2.75–3.5 in, 3.1 in average) caliper and 20 'Green Column' black maples (*Acer nigrum* 'Green Column', 7.5–10.0 cm, 8.7 cm average (3.0–4.0 in, 3.4 in average) caliper, likely grafted on sugar maple (*Acer saccharum*) root stock, but not confirmed), were available for the experiment.

Trees that were to be part of the transplanting treatment were moved to grid locations in between non-transplanted trees where smaller, less-vigorous trees had been removed. Transplanting was done in early December with a 1 m (40-in) diameter tree spade. PBZ treatments were assigned randomly within the transplanted and non-transplanted tree groups. Paclobutrazol (Profile 2SC) was applied as a basal drench the following April, prior to bud break, at rates of 0.6 and 1.2 g active ingredient (a.i.)/cm (1.5 and 3.0 g a.i./in) caliper for the ash and 0.8 g a.i./cm (2.0 g a.i./in) caliper for the maples. Rates were within ranges listed on the product label for each species. The concentrate was diluted to a consistent total volume of 600 ml (20 oz) for each tree. There were five replications of each of the 4 treatment combination in a 2 × 2 factorial arrangement of the treatments.

A 3 m (10 ft) square area around each tree was mulched with 10.0 cm (4 in) of wood chips. The transplanted trees were hand watered as needed, up to three times per week in hot dry weather, for the first two summers, with approximately 58 liters (15 gal) of water each time, directed at the root ball.

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In August of each year for four years after transplanting, two mid-crown lateral branches on opposite sides of each tree were pruned off and used to measure terminal twig growth (TG) and leaf area (LA) of three fully expanded leaves on a Delta-T (video) Area Meter (Delta-T Devices, Burwell, Cambridge, England).

Because roots are difficult to remove from the soil without damage, areas of sand were created where the roots could grow and be harvested more easily. In March, following December transplanting (soils were frozen all winter and no root growth could occur), a galvanized sheet metal box filled with washed mason sand was buried in the ground at the edge of each root ball in the northwest quadrant. These boxes were 30 cm (12 in) wide, 20 cm (8 in) deep, and 90 cm (36 in) long, with the top edge at grade. The end toward the root ball and the top were open. After each was filled with sand, a piece of geotextile fabric was placed over the top, under the mulch. To compare regenerated root growth of transplanted trees to those that were not transplanted, boxes were also installed on non-transplanted trees. A small area of roots (9% of the circumference) was cut at the same distance from the trunk as the edge of the root ball, and the same sheet metal boxes were installed, filled with sand, covered with geotextile fabric and similarly mulched.

In September, the boxes were uncovered and the sand was carefully removed by hand. The longest root was measured, and then all the roots were collected in 15 cm increments starting at the edge of the root ball, oven dried and weighed. The sand was returned to the boxes after harvesting the roots in the first year, and the process was repeated in the second year. Also in September of the second year, one core sample (36 cm (14.5 in) deep, 7 cm (2.7 in) diameter) was taken 2 m (80 in) from the trunk of each non-root-pruned tree, with and without PBZ treatment, to measure changes in the undisturbed root density (cm root length/cc soil).

Twig growth, leaf area, root length and dry weight from the boxes were compared using two-way analysis of variance (ANOVA) with transplanting and PBZ as factors. Means were compared using the Studen-Newman-Keuls test ($P \leq 0.05$) when the main effect was significant at the 5% level. A t-test was used to compare root density cores of PBZ treated and untreated trees that were not transplanted ($P \leq 0.05$).

Results and Discussion

Black Maple

Top growth. Twig growth (TG) and leaf area (LA) were measured each year in order to be able to relate root system responses to above-ground growth reduction from transplanting and PBZ treatments. TG was reduced by transplanting each of the four years measured. TG was least the second year after transplanting and then gradually increased (Table 1). This pattern has been reported before for transplanted trees (16), and attributed to large buds being formed without stress in the nursery prior to transplanting, whereas buds for second year growth formed under stress and are smaller. Leaf area was reduced by transplanting for the first three years (Table 2).

There was no regulation of top growth from PBZ in the first year (Table 1). PBZ was applied in early spring, before shoot growth began, but these data suggest that there was not enough time for the PBZ to be effective on the first season's growth. The PBZ must enter the roots, be transported in the xylem to the shoot tips, and inhibit new gibberellin production in time to reduce cell expansion in growing shoots and leaves (4, 11). It has no effect on existing gibberellins in plant tissues.

In the second year, TG was significantly reduced by transplanting whether the trees were treated with PBZ ($P = 0.04$) or not ($P = 0.001$). PBZ reduced TG only if the trees were not transplanted ($P = 0.001$) (Table 1). There was a significant interaction between transplanting and PBZ treatments for TG (Table 1). TG reduction from PBZ did not persist after the second year, while TG reduction from transplanting persisted for four years.

PBZ treatment did not reduce LA in the first year, but caused a reduction in subsequent years (Table 2). The only significant interaction between PBZ and transplanting treatments occurred in the fourth year. LA was reduced significantly only when trees were both transplanted and treated with PBZ ($P = 0.01$).

Root growth. Root extension growth, based on length of the longest regenerated root, was significantly reduced by transplanting in the first year in trees that were not treated with PBZ (Table 3). The longest root of transplanted trees was 58% shorter than trees that were not transplanted. Interaction between transplanting and PBZ treatments was significant. When transplanted trees were also treated with PBZ, root extension growth was not reduced compared to untreated trees (Table 3). The PBZ treatment was able to counteract

Table 1. Twig growth (cm) of black maples after transplanting and treatment with PBZ.

Treatment	Year 1	Year 2	Year 3	Year 4
Control	32.0	24.4[zy]	27.5	22.0
PBZ	28.1	9.2[z]	11.9	23.0
Transplanting	9.7	1.8	1.9	8.2
PBZ + transplanting	11.4	1.4	3.5	3.9
PBZ	NS[x]	*	NS	NS
Transplanting	*	*	*	*
PBZ × transplanting	NS	*	NS	NS

[z]Indicates significant difference between transplanted and non-transplanted trees within a PBZ treatment, $P \leq 0.5$

[y]Indicates significant difference between PBZ and non-PBZ treated trees within a transplanting treatment, $P \leq 0.5$

[x]Nonsignificant (NS) or significant at the $P \leq 0.5$ level (*)

Table 2. Leaf area (cm^2) of black maples after transplanting and treatment with PBZ.

Treatment	Year 1	Year 2	Year 3	Year 4
Control	154	159	142	126
PBZ	137	122	123	123[z]
Transplanting	71	87	113	134[y]
PBZ + transplanting	84	49	62	79
PBZ	NS[x]	*	NS	NS
Transplanting	*	*	*	NS
PBZ × transplanting	NS	NS	NS	*

[z]Indicates significant difference between transplanted and non-transplanted trees within a PBZ treatment, $P \leq 0.5$

[y]Indicates significant difference between PBZ and non-PBZ treated trees within a transplanting treatment, $P \leq 0.5$

[x]Nonsignificant (NS) or significant at the $P \leq 0.5$ level (*)

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Table 3. **Longest regenerated root (cm) of black maples after transplanting and treatment with PBZ.**

Treatment	Year 1	Year 2
Control	81.6[z]	62.3
PBZ	67.2	55.5
Transplanting	34.9[y]	50.2
PBZ + transplanting	66.3	46.9
PBZ	NS[x]	NS
Transplanting	*	NS
PBZ × transplanting	*	NS

[z]Indicates significant difference between transplanted and non-transplanted trees within a PBZ treatment, $P \leq 0.5$

[y]Indicates significant difference between PBZ and non-PBZ treated trees within a transplanting treatment, $P \leq 0.1$

[x]Nonsignificant (NS) or significant at the $P \leq 0.5$ level (*)

Table 4. **Root dry weight (gm) of black maples after transplanting and treatment with PBZ.**

Treatment	Year 1	Year 2
Control	9.4	8.0
PBZ	15.2	9.0
Transplanting	7.6	5.9
PBZ + transplanting	13.5	11.1
PBZ	NS[z]	NS
Transplanting	NS	NS
PBZ × transplanting	NS	NS

[z]Nonsignificant (NS) or significant at the $P \leq 0.5$ level (*)

the reduction of root extension growth from transplanting black maples. At the slightly less rigorous $P \leq 0.1$, PBZ increased root extension growth of transplanted trees (Table 3). Root dry weight was not affected by either treatment in the first year (Table 4). In the second year, neither transplanting nor PBZ significantly affected root extension growth or dry weight.

Root density cores taken in the second year to measure effects of PBZ on density of fine roots of undisturbed trees showed no difference ($P \leq 0.05$) between PBZ treated (0.95 cm/cm^2 soil) and control groups (1.35 cm/cm^2 soil). The substantial above-ground growth regulation in the second year may have affected root density as well as root extension growth. This is contrary to earlier data for white and pin oaks (14) that showed an increase in root density after PBZ treatment. Above-ground growth regulation was minimal on the oaks when the root density measurements were taken. Root density increases from PBZ may only be measurable when growth regulation is not so extensive as to reduce demands on the root system.

Green Ash

Top growth. TG was reduced all four years by transplanting (Table 5). LA was reduced by transplanting for the first two years (Table 6). TG was the least the second year after transplanting and then gradually increased, similar to the black maples and the pattern previously reported (16).

PBZ also reduced TG the first year, but not in the second year. This may be a reflection of unexplained reduced TG of the controls, compared to the other three years, rather than a lack of growth regulation from PBZ. There was a significant interaction between treatments in both the third and fourth year after treatment (Table 5). In both years, both rates of PBZ alone reduced TG compared to untreated trees. Transplanting reduced TG regardless of PBZ treatment. PBZ did not reduce TG more than already reduced by transplanting alone.

PBZ reduced LA significantly in the second year only, with no interaction between treatments. The difference was only 10 and 20% (5 and 10% reduction in length) for the 0.6 and 1.2 gm (1.5 and 3.0 g a.i./in) treatments, respectively. This small reduction for one year would not be of practical significance.

Root growth. Transplanting alone increased root extension growth in the second year (Table 7). The trend was similar in the first year, but differences were not significant. Root dry weight was increased by transplanting in both years (Table 8). Ash root growth was stimulated by transplanting alone. There there may be little opportunity for PBZ to increase it further. Green ash is usually considered very easy to transplant. This may be one reason for it.

This is quite different from the black maples where root extension growth was reduced by transplanting. Black maple, a close relative of sugar maple, is often grafted onto sugar maple root stock, and is usually considered much more difficult to transplant. Slower regeneration of the root system could be a contributing factor. Future work using PBZ to

Table 5. **Twig growth (cm) of green ash after transplanting and treatment with PBZ.**

Treatment	Year 1	Year 2	Year 3	Year 4
Control	23.0	14.2	30.8[zy]	26.7[zy]
0.6 g/cm PBZ	12.9	17.7	18.3[z]	16.4[z]
1.2 g/cm PBZ	15.3	11.0	15.9[z]	18.7[z]
Transplanting	11.4	3.2	3.8	7.5
0.6 g/cm PBZ + transplanting	5.3	3.5	5.2	10.4
1.2 g/cm PBZ + transplanting	6.7	3.5	5.7	12.9
PBZ	*[x]	NS	*	NS
Transplanting	*	*	*	*
PBZ × transplanting	NS	NS	*	*

[z]Indicates significant difference between transplanted and non-transplanted trees within a PBZ treatment, $P \leq 0.5$

[y]Indicates significant difference between PBZ and non-PBZ treated trees within a transplanting treatment, $P \leq 0.1$

[x]Nonsignificant (NS) or significant at the $P \leq 0.05$ level (*)

Table 6. **Leaf area (cm^2) of green ash after transplanting and treatment with PBZ.**

Treatment	Year 1	Year 2	Year 3	Year 4
Control	77	86	98	123
0.6 g/cm PBZ	82	82	93	104
1.2 g/cm PBZ	78	71	104	111
Transplanting	70	81	88	113
0.6 g/cm PBZ + transplanting	50	69	99	106
1.2 g/cm PBZ + transplanting	58	59	86	118
PBZ	NS[z]	*	NS	NS
Transplanting	*	*	NS	NS
PBZ × transplanting	NS	NS	NS	NS

[z]Nonsignificant (NS) or significant at the $P \leq 0.5$ level (*)

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Table 7. **Longest regenerated root (cm) of green ash after transplanting and treatment with PBZ.**

Treatment	Year 1	Year 2
Control	52.1	46.2
0.6 g/cm PBZ	57.3	39.8
1.2 g/cm PBZ	39.1	44.9
Transplanting	67.1	74.9
0.6 g/cm PBZ + transplanting	57.5	57.7
1.2 g/cm PBZ + transplanting	56.3	54.4
PBZ	NS[z]	NS
Transplanting	NS	*
PBZ × transplanting	NS	NS

[z]Nonsignificant (NS) or significant at the P ≤ 0.5 level (*)

Table 8. **Root dry weight (gm) of green ash after transplanting and treatment with PBZ.**

Treatment	Year 1	Year 2
Control	1.45	2.13
0.6 g/cm PBZ	2.02	2.97
1.2 g/cm PBZ	2.42	1.91
Transplanting	7.67	14.66
0.6 g/cm PBZ + transplanting	4.35	8.06
1.2 g/cm PBZ + transplanting	2.72	4.18
PBZ	NS[z]	NS
Transplanting	*	*
PBZ × transplanting	NS	NS

[z]Nonsignificant (NS) or significant at the P ≤ 0.5 level (*)

increase root growth of transplanted trees should focus on difficult to transplant species.

There was no effect of PBZ on regenerated root extension growth or root dry weight of ash in either year. PBZ treatment did not result in any change in fine root density of undisturbed roots by the second year (1.44, 1.08, and 0.98 mm/cm^2 soil for 0, 0.6, and 1.2 g/cm PBZ rate, respectively).

In conclusion, PBZ increased root growth of transplanted, field-grown black maple trees prior to the onset of visible top growth regulation. Root growth of green ash was not increased. Data from this study suggest that more difficult-to-establish trees with more slowly regenerating roots, such as black maple, may benefit more from PBZ treatment and establish more quickly after transplanting.

PBZ did not reduce above-ground growth more than transplanting alone, for either species tested. The growth regulation effects of PBZ should not limit the use PBZ on transplanted trees because of excessive or persistent growth regulation that consumers could reject because rapid growth is desired as soon as possible after planting.

Additional refinement of application rate will be important if the use of PBZ to stimulate root extension growth of transplanted trees is to become commonplace. Label rates for different species vary widely, and are generally intended for trees larger than typically transplanted. This information may be put to more immediate use on larger trees whose roots have been severed, such as where utility trenches have been installed. Increasing root extension growth of these trees would help them to replace their root systems faster and reduce stress sooner.

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