RED MAPLE AND SILVER MAPLE GROWTH EVALUATED 10 YEARS AFTER APPLICATION OF PACLOBUTRAZOL TREE GROWTH REGULATOR

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Abstract. Trees treated with soil-injected paclobutrazol tree growth regulator (TGR) were compared to untreated trees 10 years after treatment. Red maple and silver maple were treated in 1984, 2 months after being trimmed, with 0.5, 1.0, or 2.0 g of active ingredient (gai) per inch diameter at breast height (dbh). The volume of delivery varied for silver maple (300, 1500, or 3000 mL per tree); however, red maple were all treated at 1500 mL per tree. The untreated trees required trimming again in 1988 and 1990. No information was collected at these trimming dates. All trees, treated and untreated, were then trimmed in 1994; the biomass removed and the time taken to trim and chip the trees were recorded for each tree. Treated trees had significantly less biomass removed than did untreated trees. Considering that the untreated trees had been trimmed an additional two times, further separation between the treated and untreated trees was evident. Reductions in biomass correlate well with reductions in time required to trim the trees and chip the biomass removed. Differences among application volumes demonstrated the importance of proper TGR placement for best results. At higher application volumes, there were no significant differences between the 1- and 2-g rates.

Tree-related power outages represent a significant expense and loss of revenue for electric utility companies. In an unpublished survey of northeastern electric utilities, Wells found that one utility had 3012 tree-caused outages (excluding danger trees and storm work) in 1994 at an estimated cost of over $400 per outage. In addition to the cost of repair, this utility experienced 447,652 lost revenue hours as a result of these outages. Outages are influenced by the lack of time that utility crews are able to devote to tree trimming to maintain an acceptable tree-to-line clearance. In addition, many homeowners are resistant to the frequent trimming that is required for some of the faster growing species of urban trees. Rapidly growing species pose a particular problem when maximum line clearance is dictated by local or state regulations, or by a compromise with the homeowner. In addition to the difficulty in meeting tree trimming requirements, many utilities are facing difficulty in disposing of the chips (biomass) removed from trees (1).

Tree growth regulators (TGRs) such as paclobutrazol (PROFILE 2SC tree growth regulator, DowElanco) are being used by utility foresters to slow the growth of trees to enable foresters to better manage trim cycles and reduce outages. To justify the use of TGRs, utility managers have sought ways to quantify the benefits that these products deliver. Recently, researchers have attempted to quantify TGR effects by measuring tree crown area, biomass removed during trimming, and/or the time required to trim and chip the biomass (3,4). TGRs have reduced the amount of biomass removed from trees and in doing so, have reduced the amount of time needed to trim and chip the treated trees (3). Unfortunately, few studies have used these techniques to measure TGR results, and the longest study reported thus far is 3 years. While differences between treated and untreated trees in the 3-year study were quite large, much of the benefit may be missed without considering longer-term effects.

PECO Energy (formerly Philadelphia Electric Company) has been evaluating TGRs on their system for over 20 years with the goal of obtaining long-term evaluations to help drive economic decisions. The study reported here was initiated over 10 years ago, and with PECO Energy's cooperation, afforded

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the opportunity to evaluate their original design using unbiased measurements of biomass and trim and chip time. The objectives of this study were to 1) evaluate the performance of paclobutrazol applied to the soil around fast growing urban trees; 2) evaluate a potential rate response for paclobutrazol; and 3) evaluate the effect of application volume around the base of the tree.

Materials and Methods

Two tree species, red maple (*Acer rubrum*) and silver maple (*Acer saccharinum),* located in a residential area of Norristown, Pennsylvania (part of the PECO Energy system), were selected for this study. Red maple is classified as having a medium-to-fast growth rate (18 to 25 feet for 10 years), and silver maple has a very fast growth rate (25 to 35 feet for 10 years) (2). The study was initiated in September 1984, when trees were trimmed to PECO Energy specifications to clear the electric distribution line. The treatments applied and number of trees per treatment are outlined in Table 1.

Initial diameter at breast height (dbh) measurements averaged 9 inches for red maple and 12 inches for silver maple. The TGR was applied to the soil around the target trees in November 1984 using a pressure soil injector that delivered the solution in volume increments that would allow a minimum of 4 injection points around the base of the trees. The TGR solution was injected at a soil depth of 6 inches, as close as possible to the root collar, at a delivery pressure of 150 psi.

Table 1. Species and treatment combinations for soil-applied paclobutrazol in Norristown, PA, 1984.

Species	Paclobutrazol rate (g/in dbh)[1]	No. of trees treated	Total appl. vol. (paclobutrazol + water)
Red maple	0	3	
	0.5	4	1500
	1.0	6	1500
	2.0	3	1500
Silver maple	0	11	
	0.5	5	1500
	1.0	6	1500
	1.0	8	3000
	2.0	4	300
	2.0	6	1500
	2.0	3	3000

[1]grams of paclobutrazol per inch of diameter at breast height (dbh)

The untreated control trees had to be trimmed again in April 1988 and again in August 1990 to maintain line clearance, while the treated trees required no trimming at either of these dates. No biomass or any other evaluations were taken at the 1988 or 1990 dates. All trees were then trimmed to PECO Energy specifications (PECO Energy internal document: Vegetation Management Operations and Maintenance Manual) in November 1994, with green biomass for each tree being collected, weighed, and recorded. In addition, the time required to trim and chip the biomass was recorded for each tree. Biomass and time data were analyzed using analysis of variance and mean separation by LSD at the 0.05 significance level.

Because biomass and time measurements were not taken in 1988 and 1990, estimates for the biomass removed from the untreated trees over the 10-year period were obtained by multiplying the 1994 measured response by 3. This procedure was assumed to be logical because the trees were always trimmed to the same PECO Energy specifications for clearance. However, the methods for trimming changed over the 10 years of the study. In 1984, 1988, and 1990 the whole tree was trimmed, often referred to as "rounding over," while in 1994 the directional trimming technique was used. The primary impact of this change in technique was that the whole-tree method produces more trimming biomass than does the directional trimming technique. Therefore, the estimates of biomass removed over 10 years for the untreated trees are probably conservative relative to the actual amount removed over the 10 years. A 10-year percent reduction in biomass removed during trimming was estimated using the following formula:

Percent Reduction in Removed Biomass =
(1 - (treated tree biomass removed/untreated tree 10 yr accumulated biomass removed)) * 100

This equation represents a standard calculation used for percent reduction and/or percent control (5). No statistical comparisons were made on the percent reduction values. The relationship of biomass removed to trim and chip time in minutes was evaluated using simple linear regression.

Results and Discussion

Biomass reduction. In 1994, significantly less biomass was removed from trees treated with paclobutrazol than from the untreated controls; however, there were no significant differences between the rates of paclobutrazol applied. The average biomass removed from the untreated red maples in 1994 was 327 lb (Figure 1). The average biomass removed from treated trees, for all rates combined, was 139 lb. The estimated amount of biomass removed from the untreated trees over the 10-year period was 981 lb. Thus, the amount of biomass removed from treated trees over the 10-year period was estimated to have been reduced by 85% (Table 2).

The average biomass removed from untreated silver maples in 1994 was 778 lb per tree (Figure 2). Again, no differences were established between rates; however, all paclobutrazol treatments had biomass removals that were significantly lower than those of the untreated controls. The average biomass removed for all rates combined was 266 lb per tree. The estimated 10-year total for biomass removed from the untreated controls averaged 2335 lb. The estimated percent reduction in biomass removed from the treated trees over the 10-year period was 88% (Table 2).

An 85 to 88% reduction in the amount of biomass requiring disposal can represent a significant cost savings in chip hauling and an additional benefit of reducing the amount of chips being disposed of in landfills.

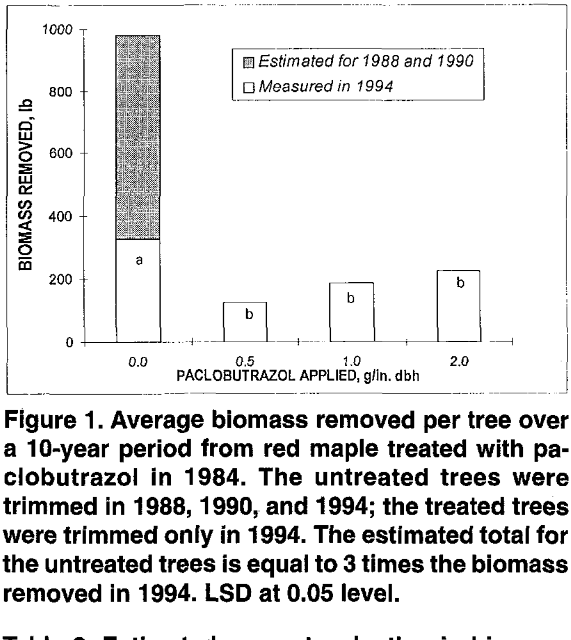

Figure 1. Average biomass removed per tree over a 10-year period from red maple treated with paclobutrazol in 1984. The untreated trees were trimmed in 1988, 1990, and 1994; the treated trees were trimmed only in 1994. The estimated total for the untreated trees is equal to 3 times the biomass removed in 1994. LSD at 0.05 level.

Table 2. Estimated percent reduction in biomass over the 10 years from 1984 to 1994.

	Paclobutrazol (g/in)[1]			
Species	0.5	1.0	2.0	All rates combined
Red maple	96	81	77	85
Silver maple	85	88	90	88

[1]rate applied as grams of active ingredient per inch of diameter at breast height

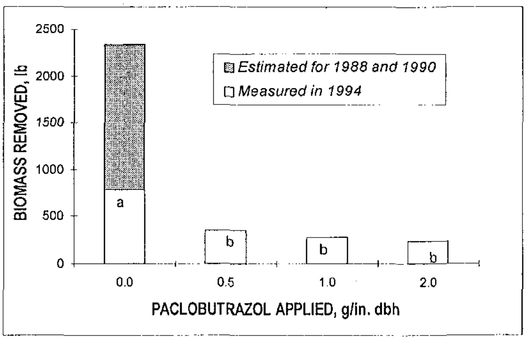

Figure 2. Average biomass removed per tree over a 10-year period from silver maple treated with paclobutrazol in 1984. The untreated trees were trimmed in 1988, 1990, and 1994; the treated trees were trimmed only in 1994. The estimated total for the untreated trees is equal to 3 times the biomass removed in 1994. LSD at 0.05 level.

Trim and chip time reductions. The time taken to trim and chip the trees showed a trend among treatments similar to that of the biomass weight differences. However, despite the significant weight differences, there were no significant differences in 1994 between the times required to trim and chip treated and untreated red maple trees (Figure 3). The estimated 10-year total for trim and chip time averaged 67 minutes for untreated trees versus an average of 16 minutes for treated trees. This difference represents an estimated reduction of 76% over

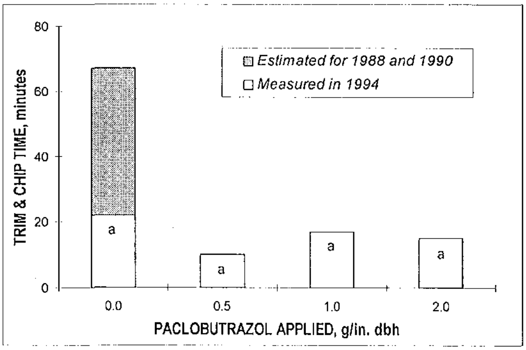

Figure 3. Average trim and chip time per tree over a 10-year period for red maple treated with paclobutrazol in 1984. The untreated trees were trimmed in 1988, 1990, and 1994; the treated trees were trimmed only in 1994. The estimated total for the untreated trees is equal to 3 times the trim and chip time in 1994. LSD at 0.05 level.

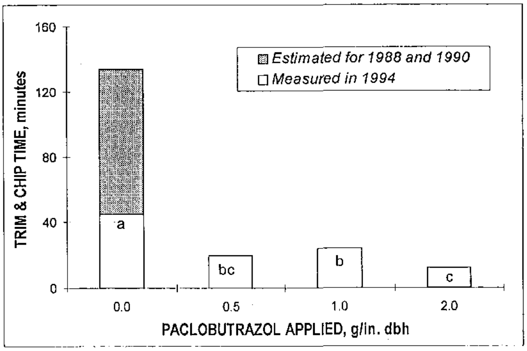

Figure 4. Average trim and chip time per tree over a 10-year period for silver maple treated with paclobutrazol in 1984. The untreated trees were trimmed in 1988, 1990, and 1994; the treated trees were trimmed only in 1994. The estimated total for the untreated trees is equal to 3 times the trim and chip time in 1994. LSD at 0.05 level.

the 10 years (Table 3). The trim and chip times for the silver maple trees more closely followed the biomass results with significant differences between the untreated and treated trees. There was also a significant difference in trim and chip times between the 2- and 1-g rates (Figure 4). The estimated 10-year total for trim and chip time was 134 minutes for untreated trees versus a treated tree time of 12 to 24 minutes. This represents an estimated reduction of 86% in trim and chip time over the 10 years (Table 3).

There was a strong correlation between biomass removed and trim and chip time, as demonstrated by regression analysis. The correlation coefficient obtained was 0.93 and the R-square for the simple linear model was 87% (Figure 5). This model predicts that every 100 lb of biomass removed requires approximately 5 minutes of trim and chip time. While it is not expected that TGRs will always provide 10 years of growth suppression, these relationships demonstrate that costs of tree trimming can be reduced as reductions in tree growth and biomass removed are achieved.

Table 3. Estimated percent reduction in trim and chip time over the 10 years from 1984 to 1994.

	Paclobutrazol (g/in)[1]			
Species	0.5	1.0	2.0	All rates combined
Red maple	85	75	78	76
Silver maple	85	82	91	86

[1]rate applied as grams of active ingredient per inch of diameter at breast height

Application volume effects. When the silver maple data were analyzed to determine effects of application rate and volume, the

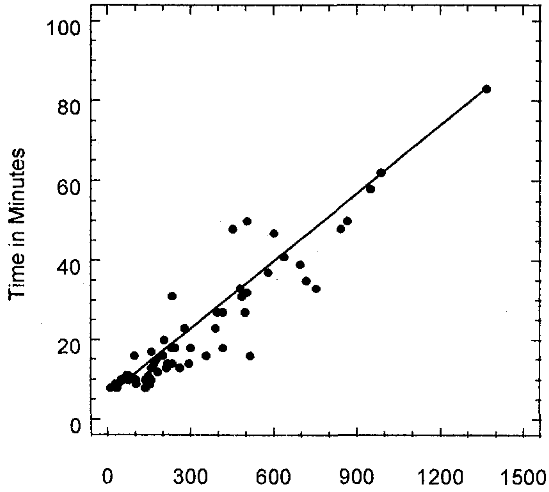

Figure 5. Relationship of green biomass removed in 1994 to the time required to trim and chip in minutes. Model: Time in minutes = 5.0 + (0.053 (biomass in pounds)); R-square = 87%; correlation coefficient = 0.93.

interaction between these two factors was significant. At 1500 mL of application volume, there was a significant difference between the 1- and 2-g rates of active ingredient per inch dbh (Figure 6). At 3000 mL of application volume, the response was not different between the 2 rates. These results suggest 2 important factors: first, paclobutrazol is more available for root uptake if the active ingredient is dispersed so as to contact more root area, and second, that subsequent rainfall and soil moisture do not move significant amounts of product from the application site to contact more root surfaces. These relationships are further illustrated by Figure 7, which shows the 2-g rate only, but compares application volumes of 300, 1500, and 3000 mL of solution. The variance decreased as the volume of application increased. The mean of biomass removal decreased as well with increasing application volume, further demonstrating the importance of the initial placement of the product. Because of the low solubility of paclobutrazol, it does not disperse with soil moisture; therefore, it appears that paclobutrazol cannot be applied in a manner that limits volume and placement points.

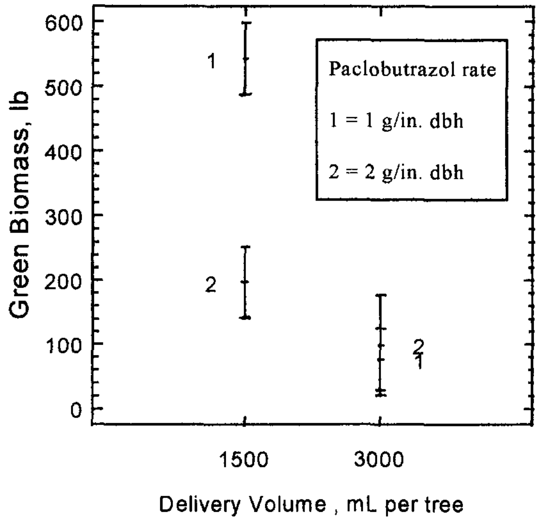

Figure 6. Plot of silver maple biomass removed in lb/tree during trimming in 1994 as affected by the interaction between paclobutrazol rate and application volume.

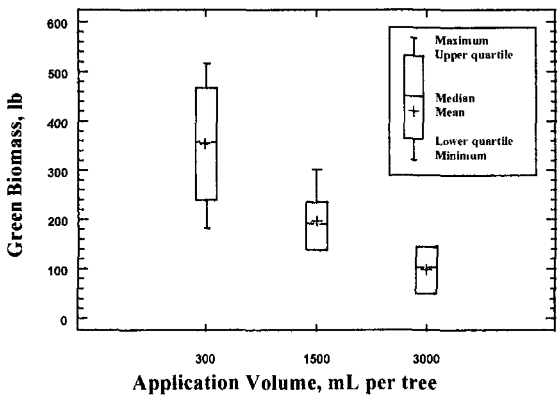

Figure 7. Box and whisker plots for silver maple at the 2-g rate of paclobutrazol illustrating the relationship between green biomass removed in 1994 and application volume.

Summary and Conclusions

When evaluating only the amount of biomass removed in 1994, there is a significant difference between treated and untreated trees. Considering that the untreated controls were trimmed an additional 2 times, further separation between the treated and the untreated trees is evident. Reductions in biomass correlate well with reductions in time required to trim the trees and chip the biomass removed. Other benefits, such as the reduction in hauling costs and reductions in disposal costs, were beyond the scope of this study, but should correlate with the reductions in biomass. TGRs are not considered to be a replacement for trimming, but rather as part of an integrated approach to help utility managers maintain a consistent trimming cycle.

The soil application method for paclobutrazol was shown to be effective in controlling tree growth. However, the effects of application volume demonstrate the importance of proper placement of the product for best results. At low application volumes, there was a significant advantage to using the higher rate of application. At higher application volumes, there was no significant difference between the rates. Because paclobutrazol has a very low water solubility, soil moisture cannot be considered a vector for moving the active ingredient to the tree roots. The volume and pressure of delivery should be sufficient to maximize the contact with roots for efficient uptake and utilization.

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Résumé. Des arbres traités par l'application dans le sol de paclobutrazol (régulateur de croissance) ont été comparés avec d'autres arbres non traités dix années après. Des érables rouges et argentés ont été traités deux mois après avoir été élagués en 1984. Le volume de la dose appliquée était variable pour l'érable argenté 300, 1500 ou 3000 ml par arbre alors que tous les érables rouges ont été traités avec une dose, par arbre, de 1500 ml. Les arbres non traités ont requis d'être de nouveau élagués en 1988 et 1990. Tous les arbres, traités et non traités, ont enfin été élagués en 1994. La biomasse coupée ainsi que le temps requis pour couper et déchiqueter les branches ont été notés pour chacun des arbres. Des différences significatives de biomasse coupée ont été observées entre les arbres traités et non traités. En considérant que les arbres non traités ont été élagués en supplément à deux reprises, la démarcation nouvelle entre les arbres traités et non traités était évidente. Les réductions de biomasse étaient bien corrélées avec les réductions de temps requis pour l'élagage des arbres et le déchiquetage de la biomasse coupée.

Zusammenfassung. Hier wurden Bäume, die mit Paclobutrazol-Baumwachstumsregulatoren in Bodenapplikation behandelt wurden, zehn Jahre nach der Behandlung mit unbehandelten Bäumer verglichen. 1984 wurden Rotahorn und Silberahorn zwei Monate nach einem Rückschnitt behandelt. Die Dosis variierte bei Silberahorn (300, 1500 oder 3000 mL pro Baum); die Rotahorne wurde alle mit 1500 mL pro Baum behandelt. Die unbehandelten Bäume erforderten 1988 und 1990 einen Rückschnitt. Alle Bäume, die behandelten und unbehandelten, wurden 1994 zurückgeschnitten. Die Menge an Schnittgut und die benötigte Zeit für Schnitt und Schreddern wurde für jeden Baum aufgezeichnet. Es wurden gravierende Unterschiede in der Menge des Schnittgutes zwischen behandelten und unbehandelten Bäumen festegestellt. Unter Berücksichtigung, daß die unbehandelten Bäume zweimal zusätzlich geschnitten wurden, wird der Unterschied zwischen den behandelten und unbehandelten Bäumen deutlich. Die verminderte Schnittgutmenge korreliert mit der weniger benötigten Zeit, die erforderlich ist, um die Bäume zu schneiden und das Schnittgut zu schreddern.