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Growth Retardants: A Promising Tool for Managing Urban Trees

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Trees and shrubs often grow too large for the available space in urban areas. In the past, costly mechanical trimming was the sole method available to arborists and utility foresters to reduce tree and shrub size. Consequently, chemical growth retardants were developed as an inexpensive approach to limit size and the growth rate of trees and, at the same time, to enhance their tolerance to the harsh environmental conditions of urban areas.

History of Tree Growth Retardants (TGRs)

Utility arborists were the first among those caring for trees to peer over the fence at agricultural and horticultural fields and ponder the potential of growth regulators used in those cropping systems as a tool for tree maintenance. Mechanical trimming, which was the sole means to combat the unrelenting growth of trees into overhead electrical wires, was a costly operation and a chemical alternative was very attractive. Hence, the electric utility industry provided funding in the late 1950s for research on chemical control of tree growth following trimming for electric line clearance. Results of that early research led to the use of napthaleneacetic acid (NAA), a synthetic auxin, painted onto the surface of pruning wounds. Although effective in reducing the regrowth of branches, coating each cut surface high in the crown of trees took a lot of time and was not cost effective. Hence, in the 1970s new TGRs and more economical application techniques were sought.

The first major breakthrough in the commercial feasibility of TGRs on a large scale was the formulation in the late 1970s of the cell elongation inhibitors, paclobutrazol, uniconazole, and flurprimidol for trunk injection. Due to their low water solubility, it was considered necessary to dissolve the new generation of growth retardants in either methyl or isopropyl alcohol. The active ingredients of these formulations were unquestionably effective in reducing tree growth. After several years of use throughout the United States in the 1980s, problems associated with trunk injection begin to appear. Cracks in the bark and cambium, weeping from injection holes, and internal wood discoloration due to the alcohol carriers led to disenchanted utility arborists and their customers. A decline in use of TGRs followed. Uniconazole was even removed from the tree care market. However, in spite of these problems, interest among utility arborists continued in a chemical tool to reduce trimming frequency and the amount of wood waste removed from trees.

Flurprimidol, sold as Cutless Tree Implants®, was pressed into tablets for insertion into shallow holes drilled in tree trunks. Concern about drilling holes into trees and the apparent compartmentalization around the tablets that prevented continued slow release of flurprimidol into the transpiration stream resulted in limited use of the implants. Hence, flurprimidol was removed from the tool kit of arborists about two years ago.

Today, only one growth retardant for use on trees remains, paclobutrazol. Satisfactory performance of paclobutrazol as a growth retardant, as well as several benefits to tree health, revealed through recent research that resulted in a rebound in use of this TGR today by some electric utilities and spurred an active expansion of the market to commercial landscapes and general arboricultural tree care.

This publication has been reviewed by:
Dr. Jeff Stringer, Un. of Kentucky; Dr. George Parker, Purdue University; Dr. Burnell Fischer, IDNR Division of Forestry; Dr. John Kershaw, Un. of New Brunswick; Mr. Ron Rathfon, Purdue University

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Treatment is Easy

Paclobutrazol, formulated as Cambistat 2SC® or Profile 2SC®, is applied as a water suspension. Both formulations are approved by the EPA for soil injection or application as a basal drench. The dose rate, which is species specific, is determined by measuring trunk diameter. The water suspension of paclobutrazol can either be injected at about 150 psi into the soil to a depth of approximately 6 inches as close to the tree trunk as possible (Fig. 1) or simply poured into a shallow trench around the base of each tree (Fig. 2). The product label provides detailed information for proper application. Treatments can be made anytime the soil is not frozen or saturated with water.

***Figure 1.** Soil injection method for applying paclobutrazol.*

***Figure 2.** Basal or soil drench method of applying paclobutrazol.*

Actually paclobutrazol and other growth retardants with the same mode of action are currently used in the nursery industry for production of compact and hardy bedding plants and on golf courses to reduce growth of turf and the frequency of mowing fairways. The dose rate for turf is lower than that applied to trees. Consequently, the grass in a narrow ring around the base of paclobutrazol-treated trees may be notably shorter. However, this could be a benefit because the serious problem of mower and string trimmer damage to tree trucks is less likely without the need to mow close to trees. Since paclobutrazol in very immobile in soils, there is no need for concern about over-regulation of turf more than a few inches away from the treatment zone.

Mode of Action

Suppression of growth by paclobutrazol occurs because the compound blocks three steps in the terpenoid pathway for the production of the hormone gibberellin by binding with and inhibiting the enzymes that catalyze the metabolic reactions (Fig. 3). One of the main roles of gibberellins in trees is the stimulation of cell elongation. When gibberellin production is inhibited, cell division still occurs, but the new cells do not elongate. The result is shoots with the same numbers of leaves and internodes compressed into a shorter length. For many years this was considered to be the sole response of trees to treatment with paclobutrazol.

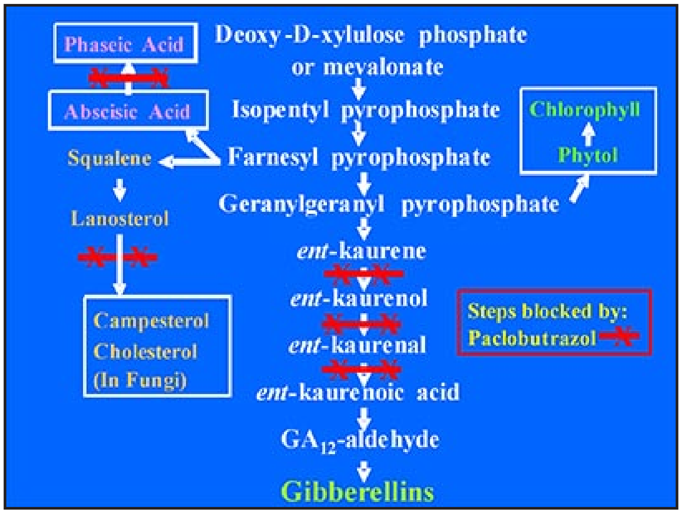

***Figure 3.** Terpenoid pathway for biosynthesis of gibberellins, abscisic acid, phytol, and steroids, and path for degradation of abscisic acid. Steps blocked by paclobutrazol indicated with ~~X—X~~.*

However, recent research has demonstrated that blocking a portion of the so-called terpenoid pathway causes shunting of the accumulated intermediary compounds above the blockage. The consequence is increased production of the hormone abscisic acid and the chlorophyll component phytol, both beneficial to tree growth and health (Fig. 3).

The unique structure of paclobutrazol that allows it to bind to an iron atom in the enzymes essential for the production of gibberellins also has the capacity to bind to enzymes necessary for the production of steroids in fungi as well as those that promote destruction of abscisic acid (Fig. 3). The consequence is that paclobutrazol treated trees have greater tolerance to environmental stresses and resistance to fungal diseases. Morphological modifications of leaves induced by treatment with paclobutrazol such as smaller stomatal pores, thicker leaves, and increased number and size of surface appendages on leaves may provide physical barriers to some fungal, bacterial, and insect infestations.

Growth Reduction

Shoot Growth

Although growth reduction is dose sensitive and varies widely among species, all evergreen and hardwood species, and even palms, respond in some degree to treatment with paclobutrazol. Treated trees have more compact crowns and somewhat smaller and darker green leaves, but otherwise look normal. The amount of shoot growth reduction ranges from a low of 10 percent to a high of 90 percent, with average growth reduction being 40 to 60 percent when recommended dose rates are applied. As a consequence of the reduced growth in height, there is a parallel reduction in biomass removed when trees eventually require trimming.

Cambial Growth

Although the principal focus of research with paclobutrazol has been on growth in length of shoots, reduced growth in diameter of the trunk and branches of woody plants also has been found. Expansion of cells produced by the vascular cambium also depends on gibberellins just like cells in stems and leaves. This could have significance in urban areas for trees planted in wells, above ground containers, and in the parkway between sidewalk and curb. Up to 30 percent of trees planted in the city cause sidewalk and curb damage due to expansion in girth of the trunk and roots, requiring significant portions of annual tree budgets for costly repairs. Suppression of diameter growth of tree trunks and roots at least forestalls costly damage and the creation of hazards.

Root Growth

Effects of paclobutrazol on root growth vary from enhancement to inhibition and are far from being clearly defined and understood. In almost all cases, however, the response in paclobutrazol-treated trees is an increase in root to shoot ratio. Gary Watson at the Morton Arboretum conducted one of the few studies on large mature trees exposed to paclobutrazol. Soil injection at the base of white and pin oaks caused fine root densities to be 60 or 80 percent higher, respectively, near the trunk base. It is unclear whether the responses observed in roots of treated trees are a direct effect of paclobutrazol on root growth or an indirect effect resulting from shoot growth modification and a shift in carbohydrate allocation to the roots. Root response to paclobutrazol is an important question because root growth and vigor influence not only water uptake but many other aspects of tree health.

Greener Leaves

Trees treated with paclobutrazol generally have leaves with a rich green color suggesting higher chlorophyll content (Fig. 4). There are two possible explanations for this response. One is that the leaves of both treated and untreated trees contain the same number of cells, but because the cells in leaves of treated trees are smaller, the chlorophyll is more concentrated in the reduced cell volume. In addition, however, there is evidence that the amount of chlorophyll is actually increased too because

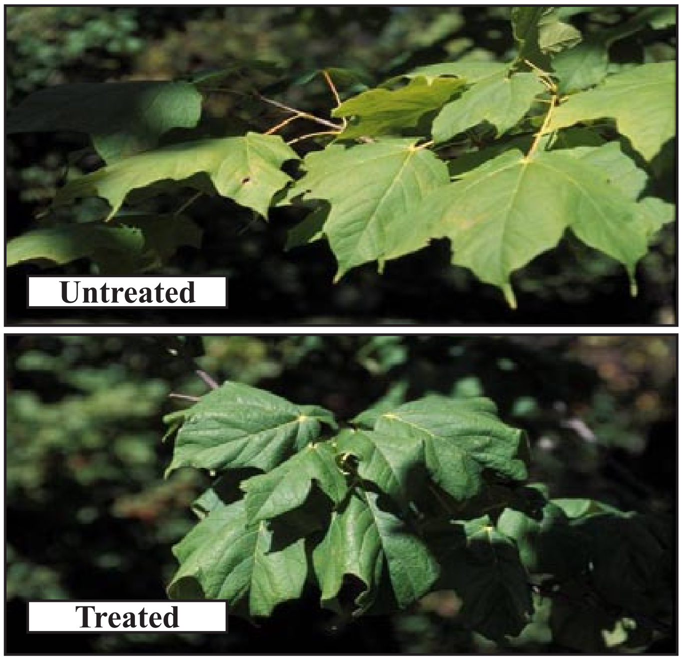

Figure 4. *Sugar maple leaves from trees untreated or treated with paclobutrazol showing higher chlorophyll content (From Gary Watson).*

phytol, an essential part of the chlorophyll molecule is produced via the same terpenoid pathway as gibberellins. Paclobutrazol treatment, which blocks the production of gibberellins, results in a shunting of the intermediate compounds from gibberellin synthesis to the production of even more phytol (Fig. 3). An analogy might be an accident blocking the flow of traffic on a major highway causing more drivers to divert to alternate routes.

Reduced Water Stress

In addition to interfering with gibberellin production, paclobutrazol is known to affect the synthesis of the hormone abscisic acid. Abscisic acid also is made via the terpenoid pathway (Fig. 3). Unlike the inhibiting effect on gibberellin synthesis, treatment with paclobutrazol promotes the production of abscisic acid much like it promotes the production of phytol. When gibberellin synthesis is inhibited, more precursors in the terpenoid pathway accumulate and are shunted to the production of abscisic acid.

Paclobutrazol also interferes with the normal breakdown of abscisic acid. The mode of action involves another iron containing enzyme to which the paclobutrazol will attach, preventing its activity. The combined effect on both the production and breakdown processes results in enhanced concentrations of abscisic acid in leaves. One of the functions of abscisic acid is to cause stomates to close, reducing water loss from leaves through transpiration.

Improved water relations in trees could arise from a combination of increased abscisic acid contents that physiologically reduce stomatal opening, reduced shoot growth resulting in less leaf and stem surface area for transpiration, more fine roots to absorb water, and structural changes in leaves that provide physical barriers to moisture loss. Fig. 5 shows dramatic scanning electron microscope images of thicker leaves and masses of hairs on leaf surfaces of cherrybark oaks in response to treatment with paclobutrazol.

The improvement of water relations in paclobutrazol-treated trees is an important secondary benefit of using a TGR.

Effects on Fungal Diseases

Protection from fungal diseases that attack urban trees is now recognized as another secondary benefit of using paclobutrazol. There are numerous observations of reduced incidence of common fungal diseases such as anthracnose following treatment with paclobutrazol. Karel Jacobs at the Morton Arboretum has shown

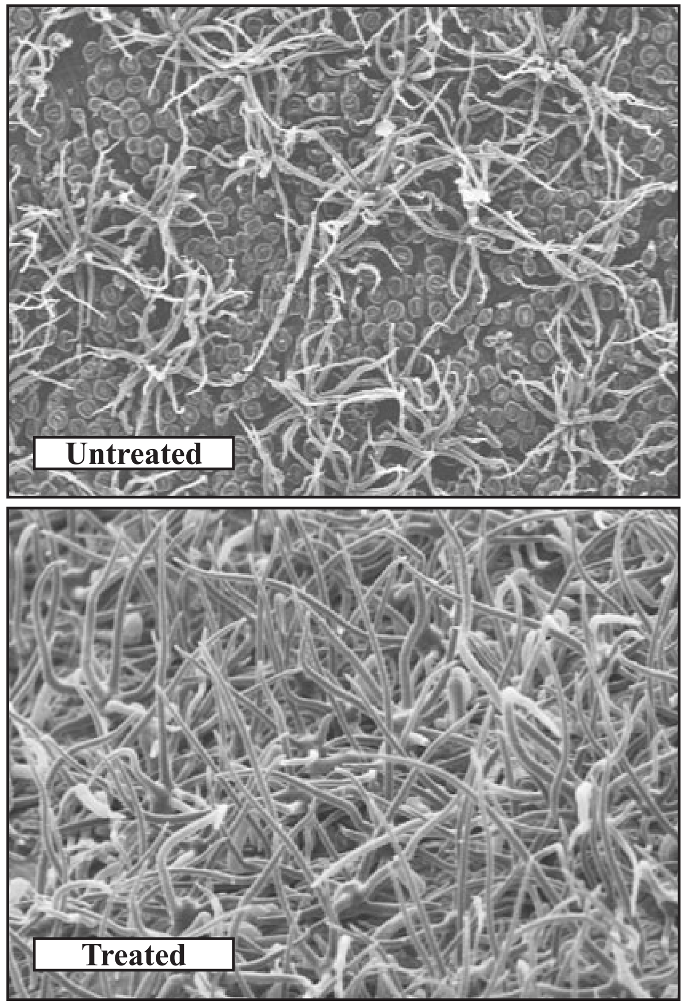

Figure 5. *Scanning electron micrographs of the lower surface of leaves of cherrybark oak untreated or treated by the soil injection method with paclobutrazol. (From Yadong Qi and William Chaney)*

paclobutrazol to significantly reduce the growth of eight fungal pathogens in laboratory cultures. More and more data from field trials is being published to substantiate the fungistatic benefit of using paclobutrazol. Bruce Fraedrich with Bartlett Tree Expert Company has recently demonstrated that even bacterial leaf scorch is markedly reduced in red oaks following a soil drench application of paclobutrazol.

The fungistatic property of paclobutrazol is due to the inhibition of steroid production in fungi, also via the terpenoid pathway (Fig. 3). This is the same mode of action that accounts for the fungistatic property of the class of fungicides known as SBIs or steroid biosynthesis inhibitors. Steroids are essential constituents of membranes.

The increased resistance of paclobutrazol-treated trees to bacteria is not thought to be a direct effect on the pathogen, but rather due to alteration in leaf surface structure (Fig. 5) or even the size of stomatal pores that make infection more difficult.

Conclusions

The many benefits of paclobutrazol can be explained based on an understanding of its ability to combine with iron containing enzymes and to inhibit, as well as foster, production via the terpenoid pathway of several important compounds for tree growth and development. Because of its many positive effects on trees, paclobutrazol is quickly evolving from use solely on trees under electric distribution lines to an important tool for commercial landscape and arboricultural practices where both growth suppression and improved tree health are desired.

Recommendation for Homeowners and Disclaimer

Commercial formulations of paclobutrazol have been registered with the EPA and are rated as General Use Pesticides. They carry a Caution Toxicity label, the lowest assigned by the EPA. Although these products may be obtained form the manufacturers for use by do-it-yourselfers, it is highly recommended and advisable that they be applied by an experienced and certified pesticide applicator who is familiar with the technology and the identification of woody plants. Any person using products mentioned in this publication assumes full responsibility for their use in accordance with current directions of the manufactures. This publication is for information only and not a promotion for any particular commercial product.

Sources of Additional and More Detailed Information.

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