A Paclobutrazol Treatment Can Leave a Tree More Stress Tolerant

By William R. Chaney

Trees are an important part of the golf course landscape and frequently provide the distinct features that make a golfer's experience memorable and enjoyable. Well-groomed fairways and greens are expected and quite frankly don't vary too much from one course to the next. The trees, however, can really enhance the golfing experience through their beauty, appeal and often the challenges they present to golfers.

Preserving tree beauty and health should be a priority of good golf course management. To that end, paclobutrazol, a chemical growth retardant that provides more than just regulation of growth, could be of great benefit. The product has been used by utility foresters for several decades to manage trees growing under electric distribution wires and is now being adopted rapidly by arborists for care of amenity trees in urban landscapes.

Soil injection and basal drench are methods of applying paclobutrazol.

Trees treated with this compound are 1.) more tolerant of drought conditions, 2.) resistant to several common fungal and bacterial diseases, 3.) less sensitive to air pollutants, and 4.) usually darker green in color. All of these effects would enhance the appearance and health of trees in golfscapes.

Paclobutrazol is applied as a water suspension 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 or simply poured into a shallow trench around the base of each tree.

The product label provides detailed information for proper application. Treatments can be made anytime the soil is not frozen or saturated with water.

Mode of action

Suppression of growth by paclobutrazol occurs because the compound blocks three separate steps in the terpenoid pathway for the production of gibberellins. 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. However, research has demonstrated that blocking a portion of the 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 phytyl, both beneficial to tree growth and health.

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. The result is that paclobutrazol-treated trees have greater tolerance to environmental stresses and resistance to fungal disease infections. 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 infections.

Although growth reduction is dose-sensitive

and varies widely, evergreen and hardwood species (with few exceptions), and even palms grow less when treated with paclobutrazol. Treated trees have more compact crowns and somewhat smaller and darker green leaves but otherwise look normal. As a consequence of the reduced growth in height, there is a significant reduction in weight and size of branches removed when trees eventually require trimming.

Expansion of cells produced by the cambium, which is responsible for increases in girth of the trunk and roots, also is dependent on gibberellins. Hence, the trunks and basal roots of paclobutrazol-treated trees do not grow as much in diameter. Up to 30 percent of city trees cause sidewalk and curb damage because of expansion in girth of the trunk and roots, requiring significant portions of annual tree budgets for costly repairs.

At least some of the trees on golf courses will be near cart paths or other hardscape fixtures. Suppression of diameter growth of tree trunks and roots would at least forestall 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 percent or 80 percent higher, respectively, near the trunk base.

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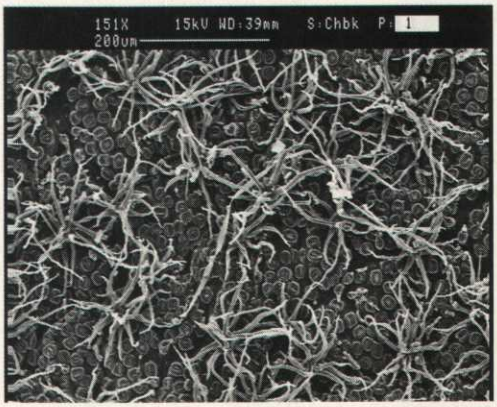
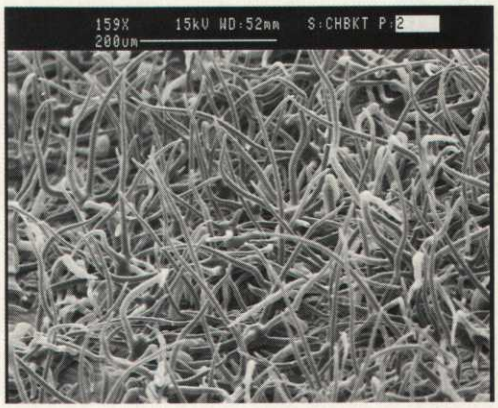
It is unclear whether the responses observed in roots of treated trees are a direct effect of paclobutrazol on root growth or an indirect effect resulting from shoot growth reduction and a shift in carbohydrate allocation to the roots. Root response to paclobutrazol is an important question because root growth and vigor influence not only water uptake but many other aspects of tree health.

Trees treated with paclobutrazol generally have leaves with a rich green color, suggesting high chlorophyll content .





Electron images of cherrybark oak leaf surfaces before paclobutrazol treatment (top) and after, illustrating thicker leaves and masses of hairs on treated surfaces.

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 the chlorophyll is more concentrated in the reduced cell volume because the cells in leaves of treated trees are smaller. In addition, however, there is evidence that the amount of chlorophyll is actually increased too because phytyl, 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 for gibberellin synthesis to the production of even more phytyl. An analogy might be an accident blocking the flow of traffic on a major highway causing drivers to divert to alternate routes.

Reduced water stress

In addition to interfering with gibberellin production, paclobutrazol is known to increase the production of the hormone abscisic acid, which also is made through the same pathway as gibberellins. When gibberellin synthesis is inhibited, more precursors in the ter-

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Sugar maple leaves from trees untreated (top) and treated with paclobutrazol. The treated leaves show higher chlorophyll content.

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penoid pathway accumulate and are shunted to the production of abscisic acid.

In addition, paclobutrazol interferes with the normal breakdown of abscisic acid by complexing with the enzyme involved in that process. The combined effect on both the production and breakdown processes results in more abscisic acid in leaves.

One of the functions of abscisic acid is to cause stomates to close, reducing water loss from leaves through transpiration. Horticulturists applying paclobutrazol to ornamental perennials and annual bedding plants have reported a similar enhanced tolerance to drought stress. Reduction of transpirational water use could become a valuable tool for superintendents to improve water-use efficiency in the face of persistent droughts and water shortages.

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, more fine roots to absorb water, and structural changes in leaves that provide physical barriers to moisture loss.

Yadong Qi at Southern University in Baton Rouge has dramatic scanning electron images showing thicker leaves and masses of hairs on leaf surfaces of cherrybark oaks in response to treatment with paclobutrazol.

There are numerous observations of reduced incidence of common fungal diseases such as anthracnose and apple scab following treatment with paclobutrazol.

Karel Jacobs at the Morton Arboretum has shown 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 Co. has recently demonstrated that even bacterial leaf scorch is markedly reduced in red oaks following a soil drench application of paclobutrazol.

The fungistatic ability of paclobutrazol is due to the inhibition of steroid production in fungi, also via the terpenoid pathway. This is the same mode of action that accounts for the fungistatic property of the class of fungicides known as steroid biosynthesis inhibitors (SBIs). Steroids are essential constituents of fungal 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 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 has evolved from use solely on trees under electric distribution lines to an important tool for commercial landscape and arboricultural care where both growth suppression and improved tree health are desired. These same benefits could also easily yield more aesthetically pleasing and healthier trees on golf courses too.

William R. Chaney is a professor of tree physiology at Purdue University in the department of forestry and natural resources, with responsibilities in teaching and research. He received a bachelor's degree in plant and soil science from Texas A&M University and a Ph.D. in botany and forestry from the University of Wisconsin. He has authored more than 160 scientific articles and book chapters that have contributed to the basic understanding of the growth of trees and their physiology.