CORNELL UNIVERSITY TURFGRASS TIMES

CUTT

Fall 2003 • Volume 14 • Number 3

New Light on Freeze Stress

Northern regions of the United States have experienced significant turf loss related to winter injury in the last few years. Historically, widespread winter-kill occurred no more than every eight to ten years. However, it appears to be a more common occurrence now, causing some to reflect on possible causes for the increase.

Many older courses simply have putting greens that are prone to damage due to susceptible grasses and poor drainage. There is growing concern that the lack of light as a result of evergreen tree shade may be exacerbating the problem, yet research is absent.

Over the years, research has focused on a variety of individual aspects of the problem. Studies have investigated ice formation, acclimation and deacclimation from low temperature and winter diseases. Few studies have investigated the role of shade and the effect it could have on acclimation.

To fully understand the role of light on winter-kill, it is vital to understand the complex interactions that occur in the winter. Once we more fully understand the problem, we will be able to effectively address the issue. It's not like we need *another* reason to remove trees!

Freeze Pops

Turfgrass injury from freezing stress is directly related to how, where and whether or not ice forms in cells of the turfgrass stem apex (a.k.a. crown), that region of the grass plant that overwinters. Specifically, if temperatures drop rapidly and water is available for freezing *inside* a plant cell, that cell will die. If several cells in the crown die, the grass plant may not be able to recover. This direct form of freezing injury is thought to be rare, because temperatures generally decline between 1–2° C per hour, allowing the cell time to adapt.

The more common scenario is when ice forms *between* the plant cells. As the ice crystal forms, it will draw water molecules from inside the cell to expand the size of the crystal. As water is drawn from the cell, it becomes dehydrated. Plants utilize various mechanisms to minimize ice crystal formation by holding water inside the cell tighter than the ice crystal can draw it out. The mechanisms of freezing stress resistance lie at the heart of developing strategies for survival.

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This Times

CUTT, "CORNELL UNIVERSITY TURFGRASS TIMES" is published four times per year by the Turfgrass Science Program at Cornell University, Ithaca, New York 14853. Address correspondence to: CORNELL UNIVERSITY TURFGRASS TIMES, 20 Plant Science Building, Cornell University, Ithaca, NY 14853; phone: (607) 255-1629; email: fsr3@cornell.edu.

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Freeze Stress

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Transition

It has become apparent over the last several years that the transitional period between winter and spring, characterized by fluctuating freezing and thawing events, is critical to understanding plant death as a result of freezing stress. During this time when plant energy reserves are low, the plant will respond to warming temperatures by stimulating growth. When growth is stimulated, several physiological changes occur. The most significant effect is the hydration of the tissue. The driving force for growth is water. Therefore, as the crown hydrates to grow it becomes more susceptible to freezing than it would be in a hardened state. Simply, more free water is available for freezing.

Researchers have speculated for years that one of the single most important aspects for enhancing winter hardiness is delayed deacclimation or breaking of dormancy. This is most difficult with annual bluegrass that is likely to break dormancy rapidly in the spring. In fact, researchers at the Prairie Turfgrass Research Center in Alberta, Canada have quantified the reduced hardiness of annual bluegrass following 48 hours of temperatures above 40° F. It was concluded that freezing tolerance was reduced 5–10° F following a slight warming.

Water

Remember from high school chemistry how water (or any liquid) will move from a higher concentration to a lower concentration? This is a way of understanding how water will move out of the cell to form an ice crystal. The cell membrane prevents any solutes, like energy sources (sugars and fructans), from leaving the cell and allows water (a liquid) to pass through. This is referred to as a semi-permeable membrane.

As the ice crystal forms it has a lower concentration of water than inside the cell and water moves out of the cell to enlarge the crystal. Maximizing solutes in the cell could reduce the concentration of water in the cell. This reduced concentration would prevent the water from passing through the membrane for ice crystal enlargement. Therefore, the cell would stay hydrated and survive.

Light

A critical aspect of minimizing cellular water that is available for freezing is thought to be related to the energy status of the plant. Energy status is a term used interchangeably with carbohydrate levels. Carbohydrates are the energy currency in the plant generated via photosynthesis.

Dense evergreens inhibit light penetration and may exacerbate injury.

Incipient freeze-thaw cycles and standing water reduce winter hardiness.

Professor George Hamilton of Penn State University recently completed his thesis addressing ice formation on putting greens. Hamilton's work focused on different types of ice, i.e., opaque or clear, dense or slushy, etc. An important conclusion was that ice type did not seem to influence turf injury, but rather the energy status of the plants. He speculates that carbohydrate levels might be the factor determining survival.

Hamilton's theory is supported by the severe winter-kill that damaged greens throughout New England in the 2002-03 winter. One such course was Apawamis Golf Club in Rye, NY. Golf course superintendent Bill Perlee had one area on his 13th green that was winter-killed. Apawamis is over 100 years old with mostly a mixed stand of bentgrass and annual bluegrass greens. The 13th green has two old evergreen trees about 20 feet off the edge of the surface and it appears that the severe winter-kill was associated with the shade from these trees.

Under reduced light conditions, especially when the sun is low in the sky in the shoulders of the northern season, plants produce significantly less carbohydrates. It could be hypothesized that these plants are most susceptible to winter injury due to low energy levels that reduce full acclimation to low temperature.

The turf and tree debate has renewed fervor, as it is likely that light penetration is as vital to turf health in the winter as it is during peak stress periods. Superintendents might wonder if tree removal is any easier to push through than complete reconstruction to improve drainage. It seems to me that it is an excellent first step.

Frank S. Rossi, Ph.D.

Editor's Note: Cornell's Urban Horticulture Institute has a number of publications and videos addressing tree selection and placement. See page 9 for more information.

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