As we hopefully manage to drag our selves out of winter over the next month we will start to see an uncovering of what the snow and ice has left for many of us. Concern has been rising amongst many of you for many reasons as the thaw begins. The depth of snow has varied of course and this is mainly impacted by wind and surfaces in exposed locations such as hillsides, open sites and southern facing areas may be more prone to the thinner layer of snow. The depth of snow has not been of huge concern however – the length of time it has stuck around however is maybe more problematic. The predominant turfgrasses in the region have different tolerances to the time of cover as well as temperature. The other issues are freezing and ice which, have two different effects will become more apparent as we go through the early to mid spring.

Freeze tolerance of plants is not constitutive but induced in response to low, nonfreezing temperatures (< 50 °F (10°C). This process is known as cold acclimation, which occurs during the fall or early winter, and explains why a plant species growing at a warm temperature then exposed to freezing is killed, while that same plant exposed to a cold acclimation period prior to sub-freezing temperatures survives.

Photograph 1. A common scenario for freeze injury is a warming (thawing) in late winter where the turf, in this case *Poa annua*, loses its cold hardiness, followed by water from precipitation or a poorly drained site where water stands followed by a rapid freezing. Water in the picture has formed an ice dam at the border of the green (lower) and the surround (higher) and frozen for a period killing turf underneath.

Scientists have identified and studied the roll of specific plant genes in freeze tolerance. A group of genes called cold-response (COR) genes apparently plays an important role. The activation of these genes requires a period of low but nonfreezing temperatures (32 to 50 °F (0 to 10 °C). The activation of these genes is then associated with the hardening or freeze tolerance of the plants. A possible reason why plants in effect die when exposed to freezing temperatures without a hardening period is due to the lack of COR gene activation. Interestingly, light in addition to low but nonfreezing temperatures is needed for gene activation, which may explain partially why we see turf in shade more susceptible to freeze injury (Danneberger, 2006).

Freeze Injury

Although turfgrasses undergo cold acclimation, freeze injury is a potential problem on cool season turfgrasses like annual bluegrass (*Poa annua*) and perennial ryegrass (*Lolium perenne*) Freeze injury and conversely tolerance is due in large part to how the turfgrass plant reacts to cell dehydration. As temperatures drop below freezing water within the plant freezes intercellularly (between cells) causing a decrease in water potential outside the cell. The cell begins to move out of the cell toward the ice crystals in the intercellular spaces and subsequently freezes. Thus, dehydration occurs within the cell. The colder the temperatures the more water travels down the gradient toward the frozen water. At 14 °F (-10°C), 90% of the osmotically active cellular water will move out of the cell into intercellular spaces (Thomashow, 1998).

Photograph 2. Water that freezes and thaws on greens during late winter is detrimental

As water leaves the cell, the plasma membrane contract and pull away from the cell wall. With the arrival of warm temperatures the ice present intercellularly melts and the water flows back into the cell where hydration takes place. If no damage has occurred to the plasma membrane (ex. punctured, ruptured) then the cell is alive and well. However, if the cell rehydrates and damage has occurred to the plasma membrane cell death is eminent. The most common type of freeze injury occurs at relatively high freezing temperatures 24° to 28° F (-2° to -4° C) during late winter/early spring. This type of freeze injury is sometimes described as "expansion-induced lysis" because it occurs during freeze/thaw cycles. In this freeze/thaw scenario, the plant loses its cold hardiness through warming temperatures which leads to the expansion of the plasma membrane.

Turf managers have some control of increasing the likelihood of winter survival by:

Provide drainage for removal of water from excessively wet areas. During freeze/thaw cycles the presence of excessive moisture can enhance freeze injury.

Reduce thatch. A significant thatch layer results in the plant's growing point to lose contact with the soil as it elevates into the thatch layer. This will expose the plant more readily to freezing temperatures.

Potassium fertilization. In turfgrasses potassium is often applied for increasing the chances of winter survival. Potassium is an ion that helps lower the osmotic potential of the cell decreasing water the potential for water flow from the cell.

Reduce the likelihood of excessive growth going into the winter. Overstimulation of growth promotes succulent high water content cells that are more likely to encounter freeze injury.

Reduce shading. Although not fully researched, a degree of correlation has occurred with freeze injury and degree of shading. Shading may contribute to increased freeze injury due to plant cells tend to be

1) more succulent in shade and have larger intercellular spaces,

2) lower carbohydrate levels, which may influence water potential, as well as the energy requirements of the turf

3) shaded areas tend to be wetter, which may contribute to the severity of freeze/thaw cycles in late winter.

The freeze injury is not the same however as ice formation and many of you have started to uncover various areas on the golf courses with very different types of ice as well as depths of ice – this will undoubtedly lead to unequal development of problems.

Intermittent ice formation on golf greens and fairways is a common event in northern temperate regions. Continual ice cover that persists for an extended time can cause injury to certain species of turfgrass. In addition the re-freezing of water into ice during freeze - thaw cycles during late winter/early spring can result in freeze injury. In this article the formation of ice and how it can cause injury is discussed.

Continuous Ice Cover Injury

The first type of ice injury is the direct result of a continuous ice cover often referred to as freeze smothering. In the early to mid 1960's Jim Beard conducted controlled laboratory study where he looked at the survival rate of three cool season turfgrasses under a continuous ice cover and two turfgrasses under field conditions (Beard, 1964, 1965). He found that creeping bentgrass could survive 120 days of continuous ice cover, however annual bluegrass (*Poa annua*) loss occurred after 60 days with substantial loss around 75 days. In a more recent Canadian field study annual bluegrass and creeping bentgrass turf was subjected to 45 days of continuous ice cover and then the ice was removed. Seventy-five days after initiating the study and 30 days after removing the ice cover creeping bentgrass still maintained its cold hardiness, while annual bluegrass was dead (Thompkins et al., 2004). It would appear from this study that annual bluegrass under a continuous ice cover needs to be removed prior to 45 days.

The reasons commonly proposed for ice injury are the buildup of toxic gases and/or the development of anoxic conditions, and the loss of cold hardiness. It appears that carbon dioxide (CO_2) accumulation under ice cover is a major contributor to the death of herbaceous plants (Freyman and Brink, 1967). Intermittent thawing helped eliminate the CO_2 buildup and injury to the plants in this study did not occur (Freyman and Brink, 1967). The loss of cold hardiness under ice cover occurs and varies among turfgrass species. Under continuous ice cover annual bluegrass loses its cold hardiness, while creeping bentgrass is not affected (Thompkins et al., 2004). The loss of cold hardiness in annual bluegrass is likely due to the anoxia (lack of oxygen) conditions that develop under an ice cover (Thompkins et al., 2004).

Ice Formation in Association with Freeze Injury

In areas where continuous ice cover for over 45 days is unlikely due to winter weather patterns being broken due to intermittent periods of thawing, ice formation can play a role in freeze injury. Under this scenario a rapid drop in temperature resulting in freezing water around the growing point during late winter or early spring can cause freeze injury primarily to *Poa annua*.

The critical precursor to freeze injury is the loss of cold hardiness through dehardening and subsequent re-hydration of the annual bluegrass crown region. Continuous ice covers as previously mentioned contribute to the decline in cold hardiness. However, the most important factor regulating de-hardening is temperature (Tompkins et al., 2002). In annual bluegrass the de-hardening process can occur quickly when soil temperatures exceed 46 F (8°C) for 48 hours (Tompkins et al., 1996).


Credit: D. Dinelli

What cultural practices can be instituted to minimize ice injury and/or freeze injury? A thorough discussion is found in the 2004 November/December issue of the USGA Green Section Record in an article entitled "Winter Damage" by Keith Happ. Some of the key points are:

1) Produce a healthy plant going into the winter. A weak Poa annua plant with low carbohydrate storage is not going to tolerate ice cover or be resistant to freeze injury as a healthy plant. Shaded areas are more prone to freeze injury than sunny areas, probably due to the carbohydrate status of Poa annua (Rossi, 2003).

2) Eliminate poorly drained areas. Poa annua growing in areas where water accumulates is at high risk to rapid freezing during freeze/thaw cycles.

In conclusion, winter injury is normally a combination of several factors one of which is ice cover. A continuous ice cover can cause injury on *Poa annua* after 45 days. The formation of ice during freeze/thaw cycles in late winter can create a situation where excessive water in and around Poa annua crowns can create freeze injury from ice formed by a rapid drop in temperature.

When you are coming out of the freeze cycle do remember these three points and also use the video link attached

Remember to check for smell – sour/bitter is not a great sign / Poa warming and returning to growth quickly with new white roots is why its susceptible to dehydration and finally bentgrass will return to growth as quick as poa in the spring until temperatures are a lot warmer. It might be a good winter for killing poa but filling back in will be slow!

A USGA video on sampling can be found here -
http://www.youtube.com/watch?v=GrdqOtdwyp8&list=PLnU5qUEfww3cOAU8iTQTUpF5S4UqhXJka&feature=share&index=13

References:

Beard, J.B. 1964. Effects of ice, snow and water covers on Kentucky bluegrass, annual bluegrass and creeping bentgrass. Crop Science 4: 638-640

Beard, J.B. 1965. Effects of ice covers in the field on two perennial grasses. Crop Science 5: 139-140.

Danneberger, T.K. 2006. Another brick in the winter fortress. Golfdom 62(11):38.

Freyman, S. and V.C. Brink. 1967. Nature of ice-sheet injury to alfalfa. Agronomy Journal 59:557-560.

Rossi, F.S. 2003. New light on freeze stress. CUTT 14(3): 1,4

Thomashow, M.F. 1998. Role of cold-responsive genes in plant freezing tolerance. Plant Physiology 118:1-8.

Tompkins, D.K, C.J. Bubar, and J.B. Ross. 1996. Physiology of low temperature injury with an emphasis on crown hydration in Poa annua L. and Agrostis palustris. PTRC Report. web site: http://ptrc.oldscollege.ab.ca/researchreports.html

Tompkins, D.K., J.B. Ross, and D. L. Moroz. 2004. Effect of ice cover on annual bluegrass and creeping bentgrass putting greens. Crop Science 44:2175-2179.

Tompkins, D.K., J.B. Ross, and D.L. Moroz. 2002. Dehardening of annual bluegrass and creeping bentgrass during late winter and early spring. Agronomy Journal 92:925-929.

With Thanks to T.K. Danneberger and GlobalTurf Network at www.gogtn.org and D. Dinelli, Northshore CC.