THE GREATEST CHALLENGE

Coping with winter weather challenges northern golf course superintendents.

BY JIM SKORULSKI

Freeze injury can devastate annual bluegrass on northern putting greens, damaging 70% of the surface or more.

The most common forms of winter turfgrass damage are caused by snow mold diseases, wind desiccation, exposure to low temperatures (freeze injury) and suffocation under ice. If you're from the northern part of the country, you have likely experienced one or more forms of winter damage. Snow mold diseases are serious but can be managed relatively well with fungicides. Wind desiccation also is a concern where snow cover is sparse. However, the two most widespread and devastating forms of winter injury are associated with freeze injury and suffocation (anoxia). Ice damage is a more general term that often is used synonymously with freeze injury and anoxia when discussing winter damage.

Just how damaging and extensive are the ice-related types of winter damage? Those who have experienced its wrath will say it is the greatest threat facing their golf course. Golf courses with larger populations of annual bluegrass stand to suffer the most and often do, with 70-90 percent kill on greens, tees, and fairways alike. Newer golf courses with higher populations of creeping bentgrass or Kentucky bluegrass usually suffer less damage, but they, too, can experience turf loss when more severe weather occurs. Golf courses that have been extensively damaged often remain closed through spring, or play may be restricted to temporary greens, impacting revenues and testing the golfers' patience. Operating budgets can swell by as much as $100,000 or more for snow and ice removal and recovery efforts. Superintendents and maintenance staffs are worn out by early summer, and playing conditions can be impacted for the entire season and beyond.

What makes matters worse is that freeze injury requires very specific weather conditions, and the occurrence and extent of injury vary widely depending on location and site conditions. It is often difficult to determine how the damage occurred and even harder to explain. Many turf managers are unjustly blamed for its occurrence. Regardless, suffering extensive winter damage can be a traumatic experience for golfers and turf managers alike.

MECHANISMS OF WINTER INJURY

A basic understanding of the mechanisms behind freeze injury and anoxia is necessary to develop a successful winter management program, yet the mechanisms are extremely complex and are not fully understood. Freeze injury is thought to occur when a plant is subjected to extremely cold temperature or a rapid and severe drop in temperature. Exposure to the cold temperatures causes water to freeze within the plant. Ice crystals can form in and around the cells and, in doing so, can cause physical damage to cell membranes and cell organs. Turfgrass exposed to extremely cold temperatures is often damaged in this way.

Water can also be pulled out of individual cells while ice crystals form around the cells. The cells die from desiccation if enough water is lost. This form of freeze damage often occurs during periods of thaw or in later winter, and is commonly referred to as crown hydration injury. Both forms of freeze injury are implicated in much of the winter damage observed in the field. Rarely does the turfgrass plant recover when the cells in the crown region are damaged by freeze injury.

Suffocation or anoxia can also damage turf that is encased in ice or is under some type of impermeable cover for an extended period. Soil microbes and the plants under the ice cover utilize oxygen as they respire. An anaerobic condition develops as the oxygen is depleted. The anoxic condition can kill the plant directly or predispose it to freeze injury. The trapped gases produce a foul, unforgettable odor that is often referred to in the field as the "smell of death." Its presence in late winter or early spring is the first indication that big problems may lie ahead.

The duration of ice cover alone is not always a good indicator for predicting winter injury. Winter damage may mistakenly be attributed to ice encasement and anoxia because of the foul smell associated with the damage in spring. However, freeze injury probably kills far more grass each winter. The foul smell that is often present does indicate an anaerobic condition, but it may be a by-product of microbial respiration associated with the decay of dead plant tissue. The complexity of anoxia and freeze injury is just now being realized, and continued research will lead to better understanding.

COLD-TEMPERATURE HARDINESS

All plants develop a tolerance or hardiness to cold temperatures. That hardiness serves as a defense against freeze injury. The plants develop the hardiness by storing carbohydrates in cells found in crown and root tissues. The higher concentrations of these materials act as antifreeze that prevents ice crystals from forming within the cells. The carbohydrates or sugars also provide the energy that fuels respiration during the dormancy period. Moisture content in the plant tissues also decreases during the hardening process, and cell walls and membranes undergo changes that improve their ability to tolerate ice crystals. The hardening process begins in late summer with the onset of cooler temperatures and shorter days and can continue through early winter. Maximum cold-temperature hardiness is obtained after the turf has been exposed to sub-freezing temperatures. Other factors that impact the hardening process include soil moisture, growing environment, and fertility.

The level of hardiness varies among plant species and even among cultivars or biotypes within a species. It is no surprise that maximum cold-temperature hardiness levels for annual bluegrass and perennial ryegrass are considerably lower than those for creeping bentgrass, rough bluegrass, and Kentucky bluegrass. Maximum cold-temperature hardiness is measured as the lethal temperature (surface temperature) at which 50 percent of the population survives (LT_{50}). The LT_{50} for most annual bluegrass in the field is approximately 14°F as compared to -38°F for creeping bentgrass. Rough bluegrass has nearly the same low LT_{50} as creeping bentgrass, and

Kentucky bluegrass is greater but still much lower than annual bluegrass.

The level of cold-temperature hardiness obtained by the plant in fall is dependent on weather conditions. Maximum cold-temperature tolerance is usually obtained in early winter. It declines throughout the winter as the grass is exposed to warmer temperatures, freeze-thaw cycles, anoxic conditions, and hydration. It is conceivable that an annual bluegrass plant will survive a 15°F temperature in January but will be killed by that same temperature in early March. Late winter and early spring are probably the most critical periods in regard to winter injury, as the grass plants lose carbohydrate reserves and hardiness and usually become hydrated and begin to break winter dormancy. A rapid and severe temperature drop at that time often spells disaster.

MAXIMIZING COLD-TEMPERATURE HARDINESS

Practices that aid the plant in maximizing cold-temperature hardiness are the basis for programs to combat freeze injury. Plants that gain maximum cold-temperature hardiness stand the greatest chance to survive winter. Obviously, weather has the greatest impact on the process, and a cool, dry fall with some frost on the ground is ideal for preparing the plants for the winter ahead. However, management programs can also be manipulated to improve the hardening process. The following practices are implemented for that purpose.

- Raise the height of cut in late summer to improve the plant's ability to photosynthesize and produce carbohydrates more efficiently.
- Eliminate shade to maximize the turfgrasses' ability to photosynthesize and produce the carbohydrates that provide cold-temperature hardiness. Turf growing in sunny environments also will have a lower tissue moisure content and increased cell wall thickness.
- Supplement the fertility program with potassium to eliminate deficiencies. Potassium is an important nutrient used by the plant during the hardening process. Initiate the applications in early September when the hardening-off process begins.
- Avoid heavy early fall (late September to mid-October) nitrogen applications that can promote excessive shoot growth at the expense of carbohydrate storage and root development. Late fall dormant nitrogen applications made with a controlled-release nitrogen source should not impact the hardening-off process.
- Take steps to alleviate soil compaction in late summer to promote stronger growth that will aid the plant in fall. Many turf managers also hand-fork low areas or cultivate the greens with the VertiDrain machine equipped with solid tines in late fall to provide some winter drainage and perhaps help diffuse toxic gases during the winter months.
- Irrigate sparingly in fall to reduce plant hydration. Predisposing the turfgrass to moderate drought stress will lead to greater hardiness and improve the cells' ability to tolerate dehydration in winter.

A rapid and severe temperature drop could spell disaster for hydrated turf.

DEALING WITH SNOW AND ICE

Perhaps the most difficult management decision for turf managers involves snow and ice removal. The management decision and ultimate success of the actions taken depend on many variables, including the calendar date, weather conditions, and ice cover duration. The insulation provided by the snow cover is beneficial for helping the plants retain their hardiness. Snow removal is not usually initiated until later winter or early spring, unless an ice layer is present below. Paths are sometimes cleared through deep snow to allow water to flow off the greens more rapidly during periods of thaw. The goal is to prevent standing water that hydrates the turfgrass, leaving it more susceptible to freeze injury.

Snow may be removed earlier in winter if it becomes necessary to expose an ice layer. Remov-

Covering systems consisting of a permeable geotextile fabric, an insulating layer of straw, and a non-permeable cover offer protection against freeze injury.

ing a large snowpack can be a daunting task that requires a large staff and special equipment. Hours can be spent just clearing paths to access the green sites. Tractor-mounted snow blowers, snow grooming equipment, truck plows, payloaders, small bulldozers, snow shovels, and darkening agents are all used to remove snow from frozen greens. Heavier snow removal equipment is preferred for the task when a substantial ice layer is present and there is less fear of damaging the playing surface. It is critical that the snow be deposited far enough from the greens so that water will not flow back onto the greens as the snow melts.

Monitor the condition of annual bluegrass that has been under ice cover for 40 days.

A decision to remove ice is a more difficult one that can result in both good and bad consequences. The primary purpose for removing ice is to prevent damage from anoxia. The decision is usually based on the duration of ice cover. A standard rule of thumb often used is to begin monitoring the condition of annual bluegrass that has been under ice cover for 40 days, and begin removal work after 60 days or immediately if anoxic conditions are evident. Creeping bentgrass generally tolerates longer periods of ice cover, and action can be taken at the 60-day mark or longer if there are no signs of anoxic conditions. The type of ice cover can impact the decision as well. It is also important to monitor the green's surface for standing water after ice begins to melt. Take steps to remove ice dams and slush to move water off the greens.

Ice removal can be completed mechanically, with specialized geotextile fabrics, or with darkening agents. Natural organic fertilizers, topdressing sand, inorganic soil amendments, marking paints, sunflower seeds, charcoal dust, and many other substances are used as darkening agents to hasten ice removal when weather conditions are conducive to do so. The agents honeycomb the ice layer, making it porous and easier to remove from the greens.

Ice is also removed mechanically using core cultivation equipment equipped with solid tines. Larger VertiDrain and Aerway machines, vertical mowers, jackhammers, and sledgehammers have also been used when an ice layer has to go fast. Mechanical ice removal is usually made easier when a geotextile fabric is in place over the green. The cover provides some protection to the surface during the removal work, and the exposed ice seems to detach from the covers more easily. Geotextile mats are also installed on greens in late fall with the hope that they will expedite ice melt. One such mat is a black, open-weave material (Enkamat). The ice forms through the mat but is melted more rapidly from the heat absorbed by the exposed dark plastic material.

The actions taken to remove snow and ice covers expose the turf to wider temperature fluctuations, and this can lead to freeze injury. Concerns are greatest with grasses that have begun to break dormancy prematurely or are hydrated. A permeable cover may be reapplied to the exposed greens to offer some protection for the vulnerable plants until they regain some degree of hardiness.

THE USE OF PROTECTIVE COVERS

Permeable geotextile covers have long been used to protect turfgrass from winter wind desiccation and to promote earlier spring growth. The covers are sometimes used as protection against freeze injury as well. Unfortunately, they are usually far less effective for that purpose, as they provide only minimal insulation and do not prevent tissue hydration. More extensive covering systems are being utilized for the winter protection of greens. The covering systems utilize impermeable covers alone or consist of both permeable and impermeable covers and an insulating material. The covering systems are designed to prevent plant hydration and ice encasement and are used as insulation to help maintain plant hardiness.

The covering systems used specifically against freeze injury are not always effective; however, they certainly improve the odds for success in northern regions where injury is most common. More extensive cover systems using an insulating material are preferred where snow cover is not dependable or temperatures are especially cold.

The systems are usually composed of a permeable cover placed over the ground, followed by a 6- to 8-inch layer of clean straw, and finally an impermeable cover. The impermeable cover keeps the insulating material dry and also prevents water from hydrating the turf. The impermeable cover is installed so that water cannot move under the fabric from surrounding areas. This may involve draping the cover over surrounding mounds or inserting the cover edge under the sod.

A curled wood fiber mat (American Excelsior Company) is also used successfully to prevent freeze injury damage. It is applied alone over the surface or with an impermeable cover to provide insulation. Researchers and superintendents are continually experimenting with other insulating materials to simplify, improve, and reduce the costs associated with winter protection.

An impermeable cover alone is sometimes used to prevent plant hydration and associated freeze injury. The cover is usually installed over a permeable cover in the same ways discussed above, but without the insulating material. The use of the single non-permeable cover alone will not offer any insulation, so it is probably most effective in regions where there is a more dependable snowpack.

The cover systems are installed as late as possible in fall after the plants are hardened. The surfaces are first treated with fungicides and rodent repellent to protect against snow mold diseases and animal activity, respectively. Once in place, there is little to be done except to periodically monitor soil temperatures under the covers and to make sure the covers remain secure. The insulating covers should keep soil temperatures cold even as air temperatures climb. So, efforts to remove those cover systems is initiated in early spring, as the greens become accessible. Removing the non-insulated cover systems is more difficult and depends on air and soil temperatures and the condition of the turf. The non-permeable cover is removed when air and soil temperatures rise. The permeable cover is left in place to protect the turf from desiccation and temperature extremes until the plants have acclimated to the cooler weather.

The cover systems are not a guarantee that winter injury will be prevented. There are major concerns about snow mold disease under the covers. Anoxic conditions can also occur under more extensive covering systems, just as they do under ice. A strip of live turfgrass under a cover seam or tear is a telltale sign of cover-induced damage via suffocation. A grid system of perforated 2- to 4-inch drainage pipe is often installed under the cover systems in an attempt to provide some passive air exchange. The pipe is daylighted above the snowpack. Superintendents are installing chimney vents and are using other creative means to improve passive and forced airflow as concerns with anoxia become realized.

LONG-RANGE CONSIDERATIONS

What long-range strategies are available to reduce the likelihood of winter damage? One of the surest and most economical steps to prevent winter damage is to correct poor growing environments. Shaded turf is always more vulnerable to freeze injury for reasons discussed earlier and because annual bluegrass thrives in such environments. Ice cover will last the longest in the dense shade as well. Look at shade patterns in late summer and fall when determining what trees impact the turf most. Conifers tend to be the worst culprits, as they create very dense shade. Do not overlook dense afternoon shade patterns when reviewing green and fairway sites!

Poor surface drainage on greens and in fairways is a prerequisite for prolonged ice cover and freeze injury. Sure, the covering systems discussed above will offer some protection, but a better strategy is to correct the surface drainage problems. Correcting poor drainage may be as simple as lowering a collar lip that impedes water flow, or it may entail more extensive grading work to raise

Annual Cost for the Covering System Used to Cover 18 Greens at Hillsdale Golf and Country Club in Marebel, Quebec*

Fungicide protection	$3,100*
Covers	
3 Evergreen permeable	4,500
3 Ice Shield non-permeable	4,600
(replacement covers purchased annually)	
Straw, 1,000 bales @ $3	3,000
Vent system	700
Labor, 5-7 staff	11,000
(to apply fungicides, covers, straw, and spring removal)	
Total	$28,000

*Costs in Canadian dollars (Canadian $ × $0.66 = U.S. $)

water-holding depressions or low-lying areas. Complete reconstruction may be considered to totally redesign a poorly drained green and gain internal drainage. Both reconstruction and surface grading work provide the added benefit of regrassing the putting surfaces with more winter-tolerant bentgrass. The work is disruptive and can be expensive, but the costs and inconvenience are minimal when compared to the costs of winter injury protection and potential damage year after year.

Establishing and maintaining more winter-tolerant grasses will also reduce the occurrence and severity of winter injury. Creeping bentgrass is probably the most tolerant and practical grass for greens, tees, and fairways in the northern regions. However, rough bluegrass, with its extreme cold-temperature tolerance, is now being utilized for greens and fairways in the far north. Kentucky bluegrass is also being considered more and more for fairway plantings because of its relatively good tolerance of cold-temperature threats and disease.

WHERE DO WE GO FROM HERE?

Our knowledge base of winter injury is growing, but much yet needs to be learned. A better understanding of the physiological mechanisms and genes involved with cold-temperature hardiness will provide new tools for breeding more winter-tolerant turf species and cultivars, and provide managers with new strategies to maximize plant hardiness in fall. New and field-practical methods to monitor gases under ice and covering systems will soon be available to help with decisions involving snow and ice removal or a need for venting. Ongoing fieldwork at universities and golf courses will also refine the use of winter protection covering strategies and examine new products and ideas to aid in snow and ice removal.

Our ability to prevent or reduce the severity of damage continues to improve, but it is important to realize that winter injury remains a natural phenomenon whose effects are dictated mostly by weather. Even the most arduous fall preparations and the use of extensive covering systems will never completely prevent winter damage when unique weather conditions favor its occurrence. Experienced turf managers also realize the importance and the greatest challenge of obtaining a dose of good luck when it comes to surviving a northern winter.

Snow blowers have become invaluable tools for accessing greens and removing snow during the winter months.

LITERATURE CITED

Dionne, J. 2000. Winter Protection of Annual Bluegrass Golf Greens. *USGA Green Section Record*. 38(5):11-13.

Gusta, L.V. 1980. Freezing Resistance of Perennial Turfgrasses. *HortScience*. 15(4):494-496.

Roberets, J. M. 1993. Understanding Crown Hydration Injury. *Golf Course Management*. 52-54.

Rossi, F. S. 1998. The Science and Management of Turfgrass Winter Injury. *Cornell University Turfgrass Times*. 9(3):1,4,5,8.

Tompkins, D. K., C. J. Bubar, J. B. Ross. 1996. Physiology of Low Temperature Injury with an Emphasis on Crown Hydration in *Poa annua* L. and *Agrostis palustris*. *Prairie Turfgrass Research Center Annual Report*. 40-49.

Vavrek, R. C. 1994. Have an Ice Day. *USGA Green Section Record*. 33(9):17-18.

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