Winterkill — Causes and Prevention

Severe winterkill during the past decade has stimulated an increase in turfgrass research that helps turf managers avoid winter injury.

BY BOB VAVREK

Most turf issues arrive more or less on schedule each year — undersized practice tees will become infested with crabgrass and goosegrass by the end of summer, dollar spot will eventually affect turf somewhere on the course, roughs will grow like crazy each spring, and the cumulative effect of heavy traffic will thin out turf in wet, shady areas. Granted some problems are more serious and difficult to control than others, but the fact that we can anticipate them makes it easier to develop effective management programs to minimize their impact on turf quality.

Unfortunately, winterkill is far more unpredictable. A bermudagrass practice tee or an annual bluegrass putting green might be devastated by frigid temperatures for two consecutive years but then survive the next ten winters unscathed. When golfers arrive in the spring and discover the presence of temporary greens, they can easily overreact to the situation. Recollections of past winter injury and the slow recovery that followed can leave golf facilities grasping at straws, sometimes quite expensive straws, to prevent similar episodes of inconvenience and lost revenue.

TABLE 1

Comparative low-temperature stress hardiness of the major turfgrass species

Relative Ranking	Common Name	Scientific Name
Superior	Rough bluegrass	*Poa trivialis*
	Creeping bentgrass	*Agrostis stolonifera var. stolonifera*
Good	Colonial bentgrass	*Agrostis capillaris*
	Kentucky bluegrass	*Poa pratensis*
Medium	Annual bluegrass	*Poa annua*
	Fine-leaf fescues	*Festuca* species
Fair	Perennial ryegrass	*Lolium perenne*
	Tall fescue	*Festuca arundinacea*
	Japanese zoysiagrass*	*Zoysia japonica*
Poor	Common bermudagrass*	*Cynodon dactylon*
	Seashore paspalum	*Paspalum vaginatum*
	Hybrid bermudagrass*	*C. dactylon x C. transvaalensis*
	Manila zoysiagrass	*Zoysia matrella*
Very Poor	Centipedegrass*	*Eremochloa ophiuroides*
	Bahiagrass	*Paspalum notatum*
	St. Augustinegrass*	*Stenotaphrum secundatum*
	Carpetgrass	*Axonopus* species

**Considerable genotype variation in low-temperature hardiness is found*

Table 1. Cold tolerance varies among turfgrass species (Beard, 1996).

CAUSES — RARELY ONE AND OFTEN MANY

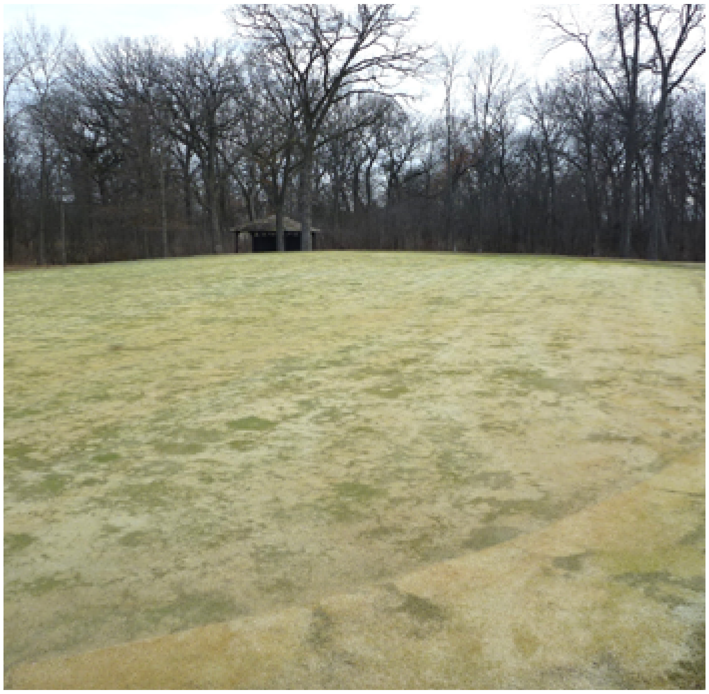
Cold-temperature tolerance varies among turfgrass species (Table 1). Winter injury to cool-season grasses can be caused by several factors, including ice suffocation, crown hydration, low-temperature injury, or desiccation. Winter injury also can be caused by various fungal pathogens. These stresses can occur alone, in combination, or multiple times throughout the winter, which makes preventing turf loss extremely challenging.

Winter injury to warm-season grasses is typically caused by low temperatures. However, dead bermudagrass is no less important than dead annual bluegrass when it comes to unhappy golfers or lost green fees and cart revenues.

RESEARCH — CHALLENGES AND PROGRESS

Many turf problems are relatively easy to study in the field because they occur on a consistent and predictable basis. However, studying the causes and prevention of winterkill is far more challenging and bears less fruit because the weather conditions that stress turf do not occur every year. For example, it is very difficult to perform field studies on the effects of extended ice cover or rapid drops in temperature. Often, these conditions can only be consistently created and studied in a laboratory. Fortunately, the latest generation of high-tech growth chambers can replicate a wide range of environmental conditions that cause winter injury, providing meaningful research data that is much easier to obtain than relying on the weather.

The foundation of cool-season turfgrass winterkill research was established by Dr. James Beard at Michigan State University during the mid-1960s. Beard's series of experiments provided the 60- to 75-day benchmark for annual bluegrass survival under ice. Many turf managers




Winter injury to annual bluegrass greens can occur across the entire putting surface or in localized areas where water puddles and freezes.

still refer to that standard today. Beard's research documented the relative tolerance of cool-season turf species to cold temperatures (Table 1) and clearly demonstrated that creeping bentgrass could tolerate cold temperatures and ice cover far longer than annual bluegrass (Beard, 1964). However, perhaps the most important lesson learned from Beard's work is that winter weather can injure or kill turf in a variety of ways. Understanding the primary causes of turf stress during winter is essential to prevent winterkill.

Dr. Beard recognized that the condition of turf going into winter had a great influence on its ability to survive frigid temperatures, ice cover, crown hydration, and desiccation. Factors such as low height of cut during fall hardening-off, shade, poor drainage, and excessive fall fertilization make turf more susceptible to winter stress. These concerns are even greater on today's golf courses because of the pressure to mow greens much lower and push the playing surfaces much harder every fall to meet player expectations. Let's review some of what we know, what we thought we knew, and what we have yet to learn regarding the complicated, interrelated processes that can cause winter injury.

DIRECT LOW-TEMPERATURE KILL AND CROWN HYDRATION

Subfreezing soil temperatures are the primary cause of winter injury to cool-season grasses. The mechanism for injury is either rapid ice formation within crown tissue cells or the irreversible loss of moisture from crown tissue as ice forms in the spaces between plant cells. Excess water in the upper soil profile or on playing surfaces is a wild card that can trigger severe turf injury when wide swings in temperature occur during winter.

Grasses differ with respect to cold tolerance. Species such as rough bluegrass and creeping bentgrass can tolerate much lower soil temperatures than annual bluegrass or perennial ryegrass. However, the genetic differences in cold tolerance between grass species are not fully expressed unless the turf has adequate time to acclimate to cold temperatures before winter.

Shorter day lengths and a steady decrease in temperatures to just above freezing cause physiological and biochemical changes to turf. Plant tissues lose moisture and harden, while crowns accumulate sugars, amino acids, and other metabolites. High concentrations of metabolites provide the "antifreeze" that helps turf survive cold temperatures for extended periods of time. Metabolites also provide the energy that dormant plants need for respiration throughout the winter and to fuel spring green-up.

The temperature during the acclimation period is an important factor in the ultimate level of turf cold tolerance. Consequently, cold hardiness varies from year to year. Cold hardiness is at its peak during early winter and steadily decreases throughout winter. As soil temperatures increase during spring, the dehardening process begins and the moisture in crown tissue increases (Tompkins, et al., 2000). Dehardening can occur before any visible signs of green-up.

Recent research shows that brief periods of mild weather during late winter or early spring can make annual bluegrass more susceptible to cold-temperature stress than creeping bentgrass (Hoffman, et al., 2014). Both species required a lengthy six-week period to fully acclimate to winter temperatures in the lab. Immediately after acclimation, creeping bentgrass had higher tolerance to cold temperature than annual bluegrass. Cold tolerance was measured by determining the temperature that killed 50 percent of plants (LT50) exposed to the cold-temperature treatment. After exposing fully hardened plants to 39.0°F temperatures for 24 hours, the LT50 increased from 0°F to 7.7°F and from -4.4°F to -1.3°F for annual bluegrass and creeping bentgrass, respectively (Figure 1).

The rapid loss in cold tolerance of annual bluegrass versus creeping bentgrass after a brief increase in temperature suggests that an extended thaw or short period of mild winter weather could increase the susceptibility of annual bluegrass playing surfaces to low-temperature injury or crown hydration. In essence, annual bluegrass never achieves the same level of winter hardiness as creeping bentgrass. Furthermore, the tolerance of annual bluegrass to cold temperatures quickly decreases after a short period of mild weather, potentially leading to severe turf loss during periods of frigid late winter or spring weather, especially when playing surfaces are wet. Perhaps we should be more worried about the weather in March than in December.

ICE SUFFOCATION

The potential for severe turf loss caused by dense ice cover on annual bluegrass putting greens is a frightening thought for turf managers. The cause of the problem is visible — you can see when ice forms, you can walk across it, you can even touch it — and each day it remains is one day closer to the time grass could die from lack of oxygen or the buildup of toxic gases. Some consultants recommend removing ice after 45 days, 60 days, or 75 days, fearing severe turf loss if the putting greens remain ice covered for much longer. Unfortunately, removing ice layers requires a great deal of effort and there is risk of damage to playing surfaces. Is all this stress and anxiety justified? Is a time bomb actually ticking?

Much of what we know about turf injury following long periods of ice cover is derived from laboratory experiments using freezers or growth chambers. Field experiments related to ice cover have always been challenging to design and replicate because weather conditions vary. Despite the challenges, a considerable amount research has been done in Canada, where conditions make it easier to maintain ice on turf for extended periods of time.

Dr. Beard's research at Michigan State University found that annual bluegrass and creeping bentgrass encased in ice could survive for 75 days and 150 days, respectively (Beard, 1964). Recent laboratory and field research from Canada studied the effects of ice encasement (turf that is saturated with water, frozen, and covered with ice), ice cover (turf that is covered by 1 inch of ice), and snow cover on annual bluegrass and creeping bentgrass. In the lab, annual bluegrass died after 90 days of ice encasement but was able to survive 90 days of ice cover and snow cover. However, ice cover increased annual bluegrass LT50 from -6°F to 25°F, whereas snow cover increased annual bluegrass LT50 from -6°F to 0°F (Tompkins, et al., 2004). In the field, annual bluegrass that was flooded and frozen died after 75 days. A rapid loss of annual bluegrass cold hardiness occurred between 60 and 75 days in the lab and between 45 and 60 days in the field. However, removing ice or snow after 45 days did not improve the ability of annual bluegrass to survive cold temperatures in this study.

It is clear that physiological changes occur in turf under dense ice cover. Of these, the most concerning is that ice cover causes annual bluegrass to lose winter hardiness and die faster than creeping bentgrass. The explanation may have to do with oxygen levels under the ice. Recent studies indicate that annual bluegrass is more sensitive to low oxygen levels than creeping bentgrass, and that low oxygen levels cause greater turf stress than high CO_2 levels (Castonguay, et al., 2009). Another study monitored changes in O_2 and CO_2 levels under several types of impermeable covers commonly used to protect putting greens. Greens that experienced the greatest turf injury also had high rates of oxygen consumption, believed to be associated with high levels of organic matter in the soil (Rochette, et al., 2006). Research suggests that thatchy conditions may

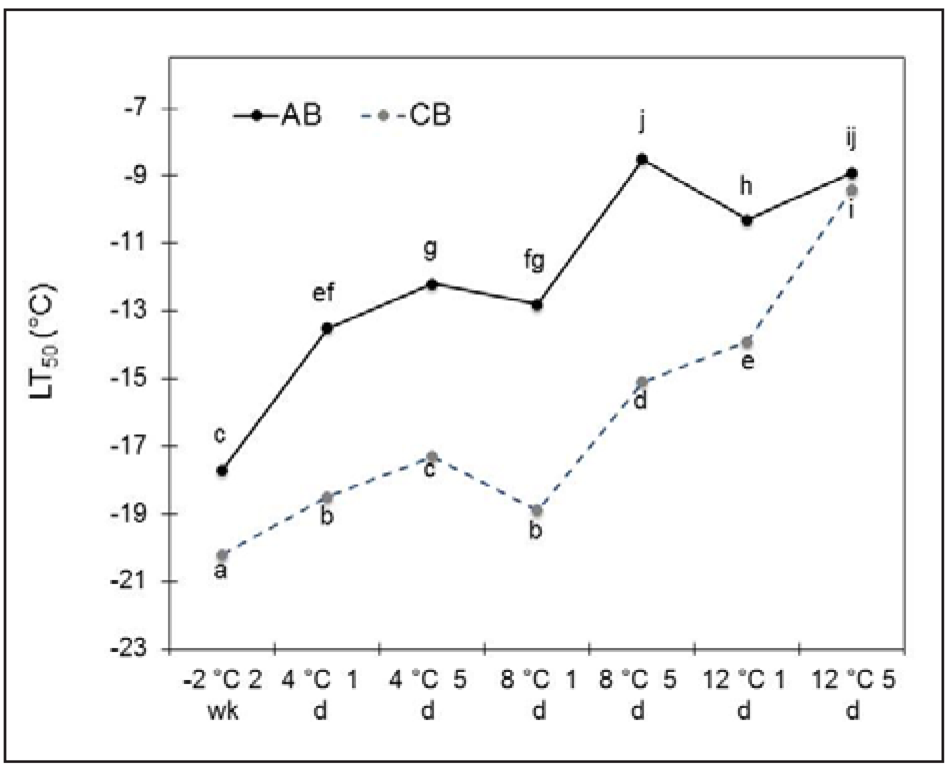


Figure 1. Change in freezing tolerance — i.e., LT50 — in annual bluegrass (AB) and creeping bentgrass (CB) during deacclimation following acclimation at -2°C for two weeks. Different lowercase letters indicate statistically significant differences ($p < 0.05$) across species and temperature regimes (Hoffman, et. al., 2014).

predispose turf to ice-related injury because soil microbes deplete the limited supply of oxygen available under dense layers of ice.

Even when ice is present, it is not always the cause of winter injury. Anyone who has managed annual bluegrass greens in a northern climate for an extended period has experienced turf loss in low-lying areas where ice cover was present for no more than a few weeks. It may be tempting to blame ice for the injury, but this is not enough time for ice suffocation to occur. The injury was more likely caused by crown hydration or direct low-temperature kill that may have occurred when ice first developed or during freeze-and-thaw cycles throughout the winter. Winterkill on greens is usually some combination of crown hydration, ice suffocation, and low-temperature injury.

Faced with an unpredictable combination of winter stresses, here are some ways to minimize the risk of winter injury from cold temperatures or ice coverage:

- Avoid excessive inputs of nitrogen or irrigation during fall to prevent lush growth as turf begins the hardening process.
- Address surface and subsurface drainage problems. Eliminate raised collars that prevent water from flowing off greens.
- Raise the mowing height on greens before turf begins to harden off. This provides ample time for turf to produce and store carbohydrates before winter.
- Address shade problems that limit turf growth. Shaded playing surfaces tend to experience the most severe winter injury due to weak turf conditions entering winter dormancy. Shaded areas also are vulnerable because they typically have higher populations of annual bluegrass. Furthermore, shaded sites usually accumulate more ice and snow, and retain ice longer, than turf in full sun.
- Monitor organic matter (thatch) content and employ the necessary cultivation and topdressing practices to prevent excessive accumulation.
- Insulated impermeable covers may be helpful on greens that experience chronic winterkill from ice or crown hydration. The articles Winter Protection of Annual Bluegrass Golf Greens and Working Undercover: Minimizing Winter Damage to Greens provide more information about using covers.
- Replace annual bluegrass with creeping bentgrass for more sustainable playing surfaces.

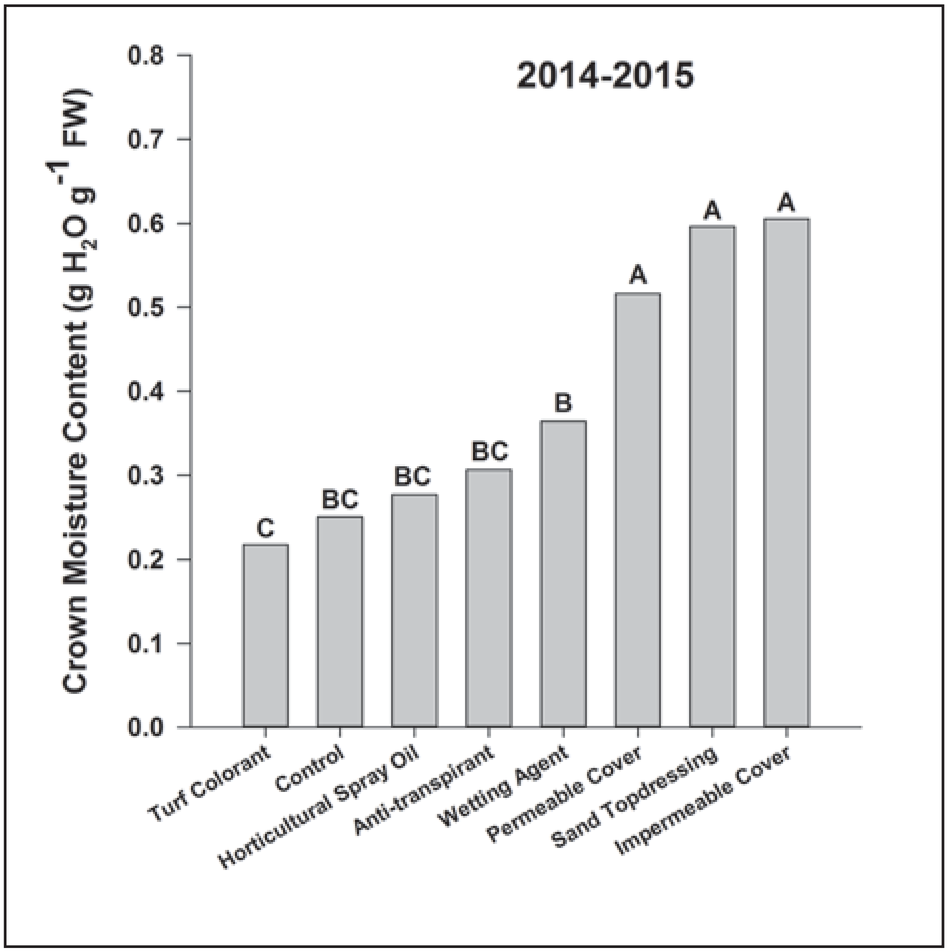


Figure 2. The ability of protective measures to preserve crown moisture through winter (courtesy of William Kreuser, Ph.D., University of Nebraska).

DESICCATION

Desiccation can be a simple but serious threat to turf health during winter. Cold, dry wind blowing across exposed playing surfaces can literally freeze-dry turf to death. Golf courses typically experience the most issues with desiccation when located in areas prone to high winds, frigid temperatures, low annual rainfall, and inconsistent snow cover.

The good news is that turf can be protected from desiccation. Applying sand topdressing or installing protective covers can help maintain healthy moisture levels in crown tissue during winter (Figure 2). Wind breaks or snow fences are other options commonly used for preventing desiccation. Some courses also utilize portable water tanks or sprayers to irrigate greens when winter temperatures are above freezing and the soil can accept moisture.

The bad news is that desiccation can kill creeping bentgrass just as easily as annual bluegrass. Furthermore, the windy conditions that contribute to desiccation injury make it challenging to install and maintain covers.

BERMUDAGRASS WINTER INJURY

Traffic tolerance and rapid recovery from injury make bermudagrass an excellent choice for golf courses in warm climates. However, poor tolerance of freezing temperatures limits bermudagrass use in northern states and the northern portion of the transition zone. Ultradwarf bermudagrass greens are even more susceptible to injury from freezing temperatures.

The USGA has funded a considerable amount of research at several universities to develop high-quality, cold-tolerant cultivars of bermudagrass. This research has contributed to an increased use of cold-tolerant bermudagrasses in more northern locations. However, the term "cold tolerant" is relative. Establishing bermudagrass in locations where soil temperatures are likely to fall below 25°F, even for short periods of time, is foolhardy unless steps are taken to insulate and protect the turf. However, the following practices can help prevent bermudagrass winterkill:

- Follow the "25-degree rule" and cover bermudagrass greens with a lightweight, geotextile fabric whenever forecasts predict temperatures of 25°F or lower. Covers can help maintain safe soil temperatures for bermudagrass during cold weather. Research indicates that many different covers can provide an acceptable level of protection (Goatley, et al., 2007). Additional insulation, such as double covers or pine straw, may be needed if temperatures fall below 5°F. The Regional Update Covering Guidelines for Ultradwarf Bermudagrass Putting Greens provides additional information about using covers.
- Aggressively manage organic matter accumulation with topdressing and cultivation.
- Maintain consistent moisture levels throughout winter months. This is especially important for sand-based greens and tees because dry, sandy soils do not effectively buffer the effects of cold air temperatures.
- Use cold-tolerant bermudagrass cultivars, such as Riviera, Yukon, Patriot, NorthBridge, and Latitude 36, when trying to establish bermudagrass playing surfaces in the central and northern portions of the transition zone.

CONCLUSION

Beginning the golf season with temporary greens or a delayed opening due to winterkill is a serious setback for any golf facility. The more we learn about the complex processes that occur beneath a seemingly harmless blanket of ice and snow, the better our chances of protecting turf from winter injury.

An annual bluegrass green covered by a dense layer of ice will be increasingly susceptible to turf loss as winter progresses.

The most effective way to protect an ultradwarf bermudagrass green from cold temperature injury is to cover the turf when temperatures are predicted to drop below 25°F.

Turf managers would love a set of simple recommendations that completely eliminate the potential for winterkill — e.g., remove ice from greens after X days, raise the mowing height to XYZ inches in mid-September, and stop watering November 1 and winterize the irrigation system the following day. Preventing winterkill would be simple if the weather was the same each year, but we know that is not possible. Unfortunately, as turf research unravels the mysteries of winter stress, we find very few black-and-white explanations, rather mostly shades of gray.

Perhaps the most important message is that maintaining healthy turf throughout the summer and fall gives turf the best opportunity to survive winter. More than 50 years ago, Dr. Beard recommended establishing cold-tolerant grasses and addressing problems with shade, low mowing heights, thatch, and drainage to limit winter injury. Those recommendations remain sound to this day, but sometimes we forget.

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