Low-temperature kill and ice sheets

"Winterkill" is a broad term that includes many types of turf injury. But to truly understand it, superintendents should focus on its specific causes.

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Any injury to turf during the winter is included under the nonspecific term "winterkill" (4). It encompasses major winter injury problems such as direct low-temperature kill, winter desiccation, low-temperature pathogens and traffic on thawing snow. Other less common injuries can result from ice coverage and frost heaving. To develop a definitive understanding of the specific symptoms, injury mechanisms, causes and cultural methods to prevent turf loss during the winter, it is important to think in terms of the specific individual components rather than the general term winterkill.

Low-temperature kill

Direct low-temperature kill occurs as a result of ice formation in the plant tissue at temperatures below 32 F (4). Death may occur during either the freezing or thawing phase.

Extensive kill by this mechanism is most likely to occur on golf courses with the following closely mowed turf:

- Annual bluegrass *(Poa annua)* in the cooler cool-humid regions.
- Perennial ryegrass *(Lolium perenne)* in the cool and intermediate cool-humid regions.
- Bermudagrass *(Cynodon* species and hybrids) in the cooler warm-humid regions.

However, even the extraordinarily cold-hardy creeping bentgrass can be killed by low-temperature stress in the following situation: In early February, the turf-soil thaws, subsequent temperatures above 60 F stimulate leaf growth, rain continues for three days late in the second week, and then there is a very rapid 24-hour drop in temperature to below 20 F.

Direct low-temperature kill occurs at temperatures below 32 F, though low-temperature leaf discoloration (or chill stress injury) occurs only on warm-season grasses at tissue temperatures between 55 and 60 F with a loss of chlorophyll and associated green color (4, 11, 17). These two types of suboptimal temperature injury should not be confused.

- *Injury symptoms.* Typical symptoms of direct low-temperature kill are turfgrass leaves that initially

Very dense, "black ice" can form on poorly drained areas of the golf course in northern regions. Low-temperature injury is most likely to occur in poorly drained sites during late winter and early spring with repeated freeze/thaw cycles.

appear water-soaked, then turn whitish-brown and progress to a dark-brown color. The leaves are limp and tend to lie as a mat over the soil. A distinct putrid odor is frequently evident, especially in poorly drained low areas. Turf damage may also appear in large irregular patches.

- *Plant hardening.* Before the first permanent freeze, the grass plant undergoes a series of key physiological adjustments. Known as cold hardening, these adjustments include plant growth slow down, increased carbohydrate reserve and reduced tissue hydration. All these adjustments maximize the potential for turfgrass to survive low-temperature stress (4, 8, 9, 10, 12, 19, 22, 23). When a grass plant reaches peak cold hardiness, it is characterized by a substantial increase in carbohydrate reserves and a reduced tissue water level. During cold hardening, the crown tissue water content may be lowered from 85 percent to between 65 and 70 percent, depending on the species and cultivar (5).

The relative hardiness level and inversely related susceptibility to direct low-temperature kill varies in a distinct pattern over the winter period. Following the hardening phase at temperatures between 35 and 45 F, the turf and associated soil freezes about the same time the peak low-temperature hardiness and associated low meristematic tissue hydration levels occur.

Depending on the location, this peak cold hardiness typically occurs between early December and early January. Following this peak there is a gradual decline in low-temperature

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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.**

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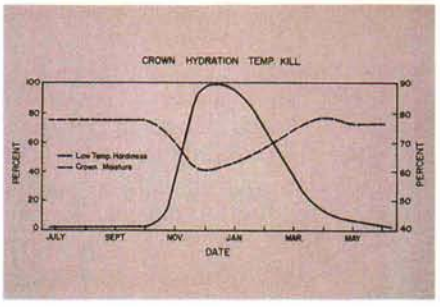
hardiness, an increase in the meristem hydration, and a decrease in the carbohydrate reserve level during late January and early February, which is accelerated during late February through March. Turfgrasses are least cold hardy during spring green-up.

• *Lethal temperature.* A frequently asked question is, The weather service reports the temperature dropped to _ F, has my turf been killed? First, the actual meristematic tissue temperature, which is allied to the surface soil temperature, is much more important in low-temperature kill than the air temperature, which is measured by the weather service at a standard 5-foot height. The specific lethal temperature can vary greatly, depending on the turfgrass species and cultivar, and the level of plant meristematic tissue hydration. Also, the actual killing temperature is elevated under conditions of a faster rate of freezing, a faster rate of thawing, a longer length of time the turf remains frozen, and/or increased number of freeze-thaw cycles (4). Consequently, it is difficult to accurately predict the specific lethal temperature.

• *Assessing turfgrass injury.* Spring green-up is the appearance of green shoots as spring temperature and moisture conditions become favorable, thus breaking winter dormancy. Prior to spring green-up, the extent of turf kill can be determined by two approaches. One way is to examine the crown-node meristematic tissues (7) by cutting a longitudinal cross-section through the crown or node meristem and examining it under a 10x, low-power, hand-magnifying glass. Tissues that are white and firm generally can be considered healthy, while brown and mushy tissues are a sign of death. Remember, all leaves and roots on a grass plant can be killed, but the turf will survive as long as the meristematic areas in the crowns and nodes of lateral shoots, such as rhizomes and stolons, are not damaged.



Seasonal representation of the relative crown meristem hydration level and the associated relative turfgrass low-temperature stress hardiness.

A second approach, if the turf is sufficiently thawed, is to collect a set of replicated turf plugs from representative areas on the course that historically have been prone to low-temperature kill. They should be placed in optimum growing conditions of light, temperature and water, and monitored to determine whether normal turfgrass green-up and recovery occur.

Selecting low-temperature hardy turfgrass species and cultivars. One of the more important preventive steps against low-temperature stress is selecting low-temperature hardy grasses. Great variations in hardiness occur among turfgrass species (6, 14). Those species with better hardiness rankings typically have the capability of accumulating higher carbohydrate levels and developing low crown-node meristematic tissue water levels (5). Also, note that warm-season turfgrasses not only experience loss of chlorophyll by chill injury at temperatures above 32 F, but some are also quite susceptible to direct low-temperature kill at temperatures below 32 F. The northernmost adaptation boundaries of most warm-season turfgrasses are limited principally by their susceptibility to direct low-temperature kill. In this regard, the loss of turf by low-temperature stress does not occur annually in many transitional areas, but cyclically, with peak kill frequencies of six to 10 years.

It also should be noted that there are substantial variations in direct low-temperature kill among cultivars within many species. This is especially true for St. Augustinegrasses, bermudagrasses, zoysiagrasses and centipedegrasses among the warm-season species, and perennial ryegrass among the cool-season turfgrasses (5, 6, 16, 18).

It is difficult to compare turfgrass cultivars in terms of their hardiness to low-temperature kill. These comparisons normally relate to low-temperature stress that occurs during the winter and are certainly valid among cultivars within the bermudagrasses and St. Augustinegrasses. However, confusion arises when low

Direct low-temperature kill to a creeping bentgrass putting green.

temperatures occur after spring green-up has already begun. In this case, the cultivars most susceptible to low-temperature kill would be those that initiate spring green-up the earliest. The warm-season turfgrass cultivars that remain dormant the longest in the spring exhibit the least susceptibility to this late low-temperature kill. In other words, the relative ranking of susceptibility to low-temperature kill among turfgrass cultivars is different during the normal dormant winter period compared with the spring green-up period. During spring green-up, the low-temperature hardening mechanism ceases to be operative, and the comparisons among cultivars depend strictly on whether new spring shoot growth has been initiated or whether the shoots of a cultivar remain dormant.

• *Preventive cultural practices.* A number of preventive cultural approaches can be used to minimize the potential for low-temperature injury. By far the most important aspect is maximizing surface and subsurface drainage to avoid crown hydration. The other cultural practices will only have a significant contributing effect if the maximum possible drainage is provided (4, 13, 15, 19, 20, 21). Any cultural practice that stimulates leaf growth also causes an increase in tissue hydration and a reduction in the carbohydrate reserve, with the net result being a loss of cold hardiness.

Ice sheets

Sleet storms and surface-freezing conditions can lead to ice sheets, and high-density ice sheets can result in "black ice." Ice covers also can form from thawing snow that refreezes rapidly. In the past four decades, numerous turfgrass writers have included ice cover damage caused by oxygen suffocation or toxic gas accumulation under the ice layer as a major cause of winterkill. A survey of the turfgrass research literature on this subject, however, reveals little valid scientific data concerning extended ice coverage, which causes impaired gas exchange and turfgrass death.

Several specific studies and numerous field observations demonstrate

Studies at Michigan State University have shown direct low-temperature injury to annual bluegrass occurs somewhere between 75 days (left) *and 90 days* (right) *when frozen in dense, clear ice.*

that most C_3 cool-season perennial turfgrasses can survive more than 60 days under dense ice coverage with no injury (1, 2, 3). A commonly published guideline has advised removing an ice cover before it has been in place for 20 days. There is no validity to this guideline as related to the small meristematic crowns and nodes of perennial grasses. The 1960s origin of this 20-day maximum was based on a University of Wisconsin study with the very fleshy, high-carbohydrate, tap-rooted alfalfa *(Medicago saliva).* Physiologically, the root-crown system of this legume and that of a turfgrass are very different.

An interesting ice coverage study was conducted at Michigan State University. Three mature turfs - creeping bentgrass *(Agrostis stolonifera var. stolonifera),* Kentucky bluegrass *(Poa pratensis)* and annual bluegrass *(Poa annua var. annua)* - were allowed to fully harden well into December in East Lansing, Mich., and then 4-inch-diameter turf plugs were drawn. The plugs were placed in glass jars filled with water, which was slowly frozen to form dense clear ice. Then the top was capped off with a small amount of water, the cover plate was sealed with a rubber gasket and the jar sleeve was screwed tight, and the ice encasement system was slowly frozen. Four replications were involved. The turf plugs encased in ice were held at 25 F in a freezer for up to five months. A set of four replications was removed at 15-day intervals,

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Low-temperature kill is increased by:

Environmental conditions	Unfavorable cultural conditions/practices
Wet, saturated surface soil	Poor surface and subsurface drainage
Shaded site	Close cutting height
Rapid rate of freezing or thawing	Low potassium (K) level
Repeated freezing and thawing	Excessive nitrogen (N) level
Extended time frozen	Thatch accumulation

Low-temperature kill with a resultant differential browning to the lower crown meristem tissue of a grass plant. This is a view of an injured whole plant that subsequently would have died.

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thawed slowly and evaluated for turf survival in a glass house.

The results revealed creeping bentgrass and Kentucky bluegrass survived five months or 150 days of dense ice encasement without significant injury. Annual bluegrass was killed between 75 and 90 days. These results show that ice coverage for up to 150 days should not be a concern when low-temperature-hardened creeping bentgrass and Kentucky bluegrass turfs are involved. However, an ice cover exceeding 75 days is a concern with annual bluegrass. After 60 to 75 days of ice coverage, efforts should be taken to remove the ice sheet down to about 1 inch of the turf surface by mechanical means.

A common occurrence associated with ice sheets is turfgrass kill in areas where ice cover existed the previous winter. Typically, the ice cover would have been in place for a much shorter time than 150 days. The mechanism for this type of kill usually is direct low-temperature kill. It typically occurs during the following circumstances: before a freeze-up of the ice cover, following a period of extensive water accumulation that increases the grass meristematic crown hydration levels, which is followed by a subsequent very rapid freeze to below 20 F. Turf kill also may occur during the thawing period when the resultant standing water where the ice cover existed causes increased crown hydration and is then followed by a rapid freeze to below at least 20 F. This crown hydration followed by a rapid freeze typically occurs in locations where ice covers were observed during the winter. Thus, it is often assumed that ice covers directly cause the turf injury, when in fact that may not be the case.

There are also preventive activities that can be misinterpreted. For example, in the early 1960s the Midwest had extensive kill of greens, which at that time was attributed to ice covers. Only one golf course superintendent had removed the ice from his greens, and those were the only ones that were not severely injured. It was assumed that removing the ice sheet prevented the accumulation of toxic gas around the grass, therefore avoiding kill. Another more appropriate interpretation of that situation, however, would be that the removal of the ice sheets was a means of mechanically removing the water, which upon thaw would have created a high crown hydration situation. Essentially, the water was being physically hauled off the greens prior to thaw. Accordingly, deep snow-ice covers on key turf areas are usually removed before a major thaw to minimize meristem hydration. □

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