When *slow freezing* occurs, water is slowly drawn out of the cells and all freezable water is crystallized in the intercellular spaces. If such a condition is not prolonged, the plant may escape injury.

*Turf Killed at Time of Thaw*

When freezing occurs, water is pulled from the cells and the cell wall is pulled inward. The protoplasm in the cell becomes plasmolized, or balled up. Unless the protoplasm is well supplied with bound or unfreezable water, it becomes brittle. Upon thawing, water rushes back into the cell through the highly permeable cell wall, and the protoplasm may be stretched and subjected to shear forces sufficient to destroy it. Under these conditions, turf is killed at time of thaw.

*Turf Killed While Frozen*

The work done by Dr. Jack Le Bean, of Lethbridge Experiment Station in Alberta, Canada, indicates that fungi in plants produce gases while the plant is frozen. These gases may cause death. This production of toxic gas and traffic on frozen turf are the two main causes of turf death while still in a frozen state.

*Turf Killed After Thawing*

Many of the common pathogens associated with winter injury are apparently very active, and their destruction may be most pronounced just after thawing begins and when the plant is striving to re-initiate growth.

When frozen soil begins to thaw, heaving may also occur. Heaving may cause a large portion of the root system to be pulled off. If crown tissue has also been damaged, little of the plant is left to support continued growth, and death occurs when the immediate energy supply is exhausted.

*Desiccation*

Desiccation is the drying out of soil and plant tissues. It may cause severe damage in winter if adequate moisture is not maintained. In the absence of snow cover, moisture may be lost from frozen soil by sublimation. This means that the moisture may pass directly from solid to gas without becoming a liquid which is of course the only form available to the plant. When this happens, plants simply die from drought.

*Ice Sheets*

The most comprehensive work on ice sheet damage has been done by Dr. James Beard of Michigan State University. Some of the mechanisms of ice sheet damage suggested by Dr. Beard are the depletion of oxygen, the accumulation of carbon dioxide and the leaching of cellular constituents. Although Dr. Beard has thus far reached no definite conclusions on the matter, his work indicates that direct effects of low temperature may be more important than any of the mechanisms of ice sheet damage.

*What to Do When Winterkill Occurs*

1. Water lightly and regularly until the plant can re-establish its root system.

2. Where no plant is left, replant following whatever renovation is possible with spiker and perhaps some vertical mowing or vertical slicing.

3. Gentle treatment of the turf as if the entire damaged portion were all new seedlings, which in effect it is, is called for.

Winter injury has been so widespread and severe recently that numerous experiment stations have begun to study the matter more critically. There has been a renewed interest in soil warming by the use of electric heating cables and in the use of various types of coverings.

# *Winterkill: Learn The Cause, Improve The Cure*

by **JAMES W. TIMMERMAN,** Agronomist, USGA Green Section

Within the last five years, golf courses in the Northern United States have experienced winter injury as severe as any in history.

What are the causes of winterkill and what is known of their destructive action?

The ravages of winter are easily classed into six categories:

**ASSOCIATED ICE SHEET DAMAGE**

The extensive damage suffered from ice sheets during the 1961-62 winter season prompted considerable research. Investigated causes of ice sheet damage include:

1. Oxygen suffocation under the ice sheet.

2. Toxic accumulation of carbon dioxide and other breakdown products under the ice sheet.
3. Outward leaching of vital cellular constituents while submerged in water during thawing.
4. Outward diffusion of water from leaves encased in ice.
5. Direct low temperature injury.

The work of Dr. James Beard at Michigan State University, however, suggests that injury from the first four causes above normally does not happen until after 75 days. Ice sheets of this duration rarely occur in the United States. Injury, therefore, is apparently caused by direct low temperature kill.

Observations by Green Section agronomists conclude the following:

1. *Poa annua* is more severely injured than any other turfgrass found on northern golf courses.
2. A solid ice sheet must be in place 20 to 25 days before *Poa* is damaged.
3. Bentgrasses will subsist considerably longer.
4. Damage is always more severe on poorly drained soil which compacts readily.
5. Succulent turf experiences the greatest injury.

*Severe damage to this green was caused by traffic allowed during a thaw period.*

### DIRECT LOW TEMPERATURE INJURY

Injury of this type is associated with freezing and thawing of water in the plant. Death results because of the harmful effects of ice crystals either within the cell or in intercellular spaces.

In the case of intracellular (inside the cell) freezing, injury is caused by a mechanical disruption of the protoplasm by the ice crystals. Generally, intracellular freezing always kills the cell. However, this apparently happens in nature only to unhardened plant tissue frozen rapidly. Hardened tissue undergo changes which resist intracellular freezing. These changes include:

1. A reduction of water within the tissue.
2. An increase in soluble carbohydrates.
3. A change in the type of proteins present.
4. An increase of bound water within the cell.

When intercellular (outside the cell) freezing occurs, death may or may not result, depending on the degree the protoplasm of the cell is affected. Injury to the protoplasm from intercellular freezing is different from injury from intracellular freezing. When the plant freezes slowly, water is drawn from the cell into the intercellular spaces where it freezes. If enough water is drawn out of the cell, the protoplasmic consistency is increased until with extreme dehydration it becomes brittle. Due to the water removal, the cell wall contracts and subjects the brittle protoplasm to tensions. Upon severe contraction the tension produced results in mechanical damage to the protoplasm. Further injury can result if the plant thaws rapidly. When this happens, water rushes back into the cell and the protoplasm may be stretched and subjected to shear forces sufficient to destroy it.

Hardened tissue, because of an increase in the bound (unfreezable) water, can resist this type of injury. Bound water permits the protoplasm to remain ductile when subjected to dehydration that would otherwise render it brittle. However, the extent of kill from intercellular freezing is governed by a number of factors. These are:

1. The degree of plant hardiness. Damage is more severe on less hardy plants than in hardened plants.
2. Plants frozen rapidly may show more injury than those frozen slowly.

3. Greater injury may occur with longer freezing periods than after short freezing periods at the same temperature.
4. Greater injury may occur if thawing is rapid than if it is gradual.
5. Repeated freezing and thawing may increase an injury from which the plant could have recovered after a single freezing.
6. Injury may increase after thawing if the plant is exposed to unfavorable conditions.

Based on the above findings, it appears that the chance for low temperature kill is greatest when the plant is in a reduced state of hardiness. Dr. Beard warns that the two most critical times for kill occur during late winter thaws and just after the spring thaw. Three or four days of warm temperatures result in a premature loss of hardiness due to an increase in hydration levels within the plant. Injury can occur if this is followed by a severe drop in temperatures to below freezing. He suggests other factors which also lead to increased hydration levels and thus to loss of hardiness.

1. Poor surface drainage.
2. Inadequate internal drainage of soil (compacted soil).
3. Ice or snow accumulations which impair surface drainage and cause ponding and submergence of grass crowns.
4. Melting from beneath the ice and snow layer with no means of draining the water away from the grass crowns.

## TRAFFIC

Traffic damage is becoming more of a concern because of increased winter play and use of the course for snowmobiling, skiing, and sledding. Injury is by two means: Mechanical injury to the grass plant, and injury due to soil compaction and displacement.

Mechanical injury from traffic includes, first, the attrition or wearing away of semi-dormant or dormant turf. Because the turf is not growing actively, above ground parts are not replaced. Damage of this type is particularly severe on partially or completely frozen soil which has no resiliency. Second, when the soil thaws to a depth of one-half inch or more and remains frozen below, traffic at this time can shear-off plant roots, resulting in death when growth resumes. Finally, traffic on frosted turf results in cellular rupture within the plant. This is especially injurious when the grass is in a reduced state of hardiness during late fall and early spring.

Injury of a less direct nature occurs when traffic is allowed on partially frozen or saturated soil. Obvious damage is footprinting and vehicular rutting. Less obvious damage is the soil compaction which results. This usually manifests itself as problem areas during the growing season and increased *Poa annua* invasion.

## DISEASE

The two major diseases of concern in winter injury are *Typhula itoana* (grey snow mold) and *Fusarium nivale* (pink snow mold). These diseases initiate growth in the fall when the weather cools and humidity is high. Activity continues under a snow blanket, particularly if the ground remains unfrozen, and during cool, wet periods of spring when the incidence of kill is greatest. The optimum air temperature for development ranges between 32 and 45 degrees Fahrenheit, although *Fusarium* can remain active up to 65 degrees.

Injury in the spring from both diseases is noticed as small, roughly circular patches of pale-yellow turf. As the diseases progress, the patches enlarge and coelesce, resulting in rather large areas of blighted turf. *Typhula* will usually exhibit a characteristic halo of grayish-white mycelial growth at the margin of the patches, whereas *Fusarium* produces a pink mycelium. *Typhula* is further distinguished from *Fusarium* by the presence of small, reddish-brown fruiting bodies called sclerotia, roughly the size of a pinhead, embedded in the leaf and crown tissue of infected turf.

Recent research in Canada suggests that certain other fungi in plants can produce gases that can kill turf, apparently while the plants are frozen.

## DESICCATION

Kill from desiccation is usually a problem in the Plains States, but the severity of injury suffered in the Northeast during the 1967-68 winter was the worst in 20 years. It brought out clearly the need for understanding its destructive power so that injury in the future can be avoided.

Death due to desiccation is actually a wilting process. Even though the plant is dormant, a low level of transpiration occurs. If the plant loses more water than the roots can supply, the plant wilts or "desiccates." This happens when the water in the soil is frozen or when the soil is dry or saturated. Injury is most severe on high, windswept areas, free from snow.

## HEAVING

Heaving damage is caused by alternate freezing and thawing of the soil, which raises the plant above the soil level. Injury can be severe if the roots are severed. However, established sod is seldom injured. Heaving is most damaging to poorly anchored plants and on late fall- and early spring-planted grasses.

We can easily see, therefore, that winterkill occurs in a variety of ways. The key to avoiding extensive damage obviously lies in adequate preparation before winter strikes. Only by understanding the causes and methods of kill can the best available means of prevention be more effectively employed.

# *Winter Drainage Problems*

**by G. DUANE ORULLIAN,** Agronomist, USGA Green Section

Winter damage to turfgrass poses a challenge to the management practices of any turfgrass specialist. A carefully planned program is essential for winter maintenance in most northern latitudes.

Winter injury is due to many causes, and we should prepare for the worst in order to achieve success. Control measures must vary according to cause or injury. Is it best to "act" to prevent winter problems, or wait until they occur and then "react" to them? Good preventative maintenance prior to winter will help avoid problems.

Unfortunately, many of our turf problems are a constant source of trouble throughout the year. Poor soil drainage is one of these and affects turf during both summer and winter.

## ICE, WATER AND SUFFOCATION

Before going further, the following quote from Dr. John Monteith in the 1932 issue of the USGA Bulletin, Vol. 12, No. 4 might be considered:

> "A disease recognized on turf in 1914 was given the descriptive name—Brown Patch which led to much confusion. Another disease was later recognized and designated as 'Small Brown Patch.' Any casual student of turf knows that when turfgrasses are killed by any means, they usually turn to some shade of brown, therefore, if a sufficient percentage of grass is killed in an area, it is likely to form a browned patch!

*Breaking up snow and ice sheet to allow for surface drainage of water on frozen soil. Ice sheets should be removed if they persist longer than three weeks.*