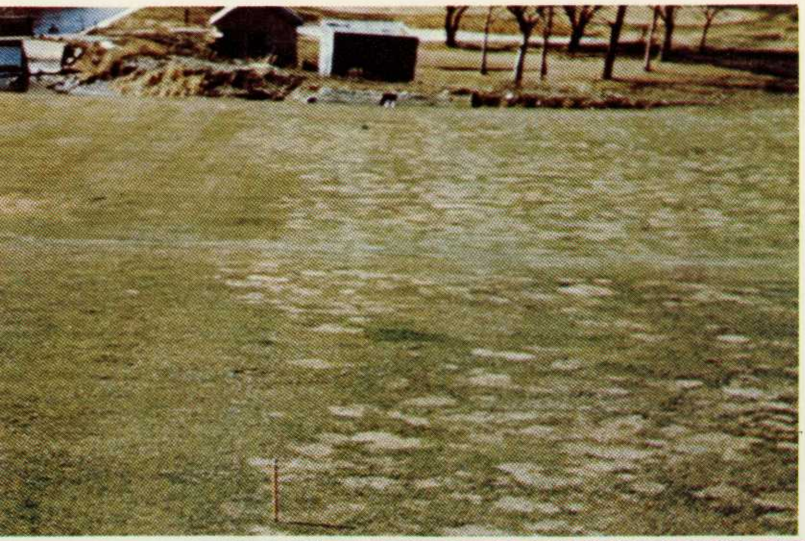
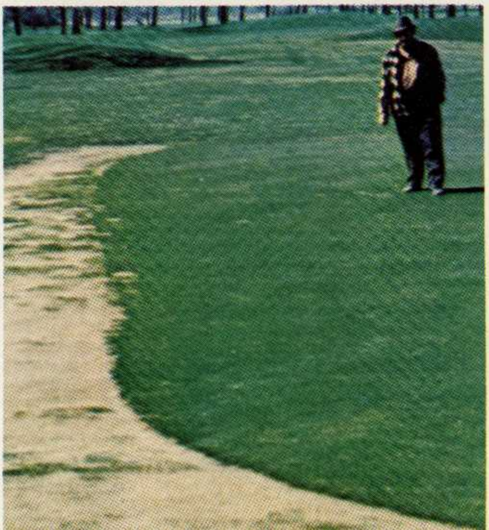


Mercury compounds are very useful in the prevention of the snowmold diseases. Without preventive treatment, turf is frequently ruined completely.

Poorly drained areas seem particularly susceptible to the ravages of winterkill. Here a low area in bentgrass-Poa annua turf has been killed because of inadequate drainage.



This putting green is constructed of a permeable soil mixture; the collar, of native soil. It appears the better drained areas can better survive winterkill conditions.

Study winterkill, then fight it!

Understanding this unpredictable foe is essential to any success in preventing damage.

By DR. MARVIN H. FERGUSON
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Winterkill is one of the foremost dreads of the turfgrass grower. The damage can be deadly and it is largely unpredictable. Winterkill occurs on Bermudagrass in the upper South, on *Poa annua* and sometimes on bentgrass in New England and the Midwest. In the Great Plains states where cold drying winds are prevalent, desiccation can ruin almost any kind of turf.

If we ever are to achieve any degree of success in the control of winter injury, we must first seek to understand *why* turf is killed some years and escapes in other years when the weather seems to be just as cold. An examination of some of the physiological principles involved may point the way to more successful methods of management.

As a starting point, we may ask, "When is the plant killed? At the time it freezes? At the time of thaw? At some point of time between the first freeze and the final thaw? After thawing has occurred and growth has begun?" It appears that winterkill can occur at any of these times, depending upon environment and the condition of the plant.

A study of so technical and complicated a subject without the use of scientific jargon (meaningless to all but plant physiologists) is quite difficult. Therefore, the reader is warned that many statements in this article are greatly oversimplified. At the 1964 annual meetings of the American Society of Agronomy, the subject was treated at considerable length and detail by Dr. James Beard of Michigan State University, Dr. Jack LeBeau of the Lethbridge Experiment Station of Alberta, Dr. J. R. Watson of the Toro Manufacturing Company of Minneapolis, and by this writer. Readers interested in the more technical aspects of the subject can be directed to sources of literature by any of these men.

Killed at time of freezing—Reverting to the question of *when* the actual killing takes place, we may first examine the case where killing occurs at the time of freezing. Usually, if plants are killed by initial freezing, it happens when the onset of freezing temperatures is very rapid and when plants have not had time to become "hardened."

A rapidly growing plant has a high proportion of water. This water is present in the sap solution and may occur within the cells and, in some cases, the intercellular spaces. The protoplasm, the vital part of the cell, may under these conditions contain a relatively small proportion of the total water. When a plant has time to "harden," the tissues lose much of the free water in the sap, the sap solution becomes more concentrated, and biochemical and biophysical changes cause the protoplasm to become hydrated with water in a "bound," that is, unfreezable form.

When slow freezing occurs, the first ice crystals form in the spaces between cells, and more and more water is drawn out of the cells into these intercellular spaces until all the freezable water has been crystallized. If such a condition prevails for a short while and then thaws occur, the plant may escape being damaged.

When rapid freezing occurs in un-

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hardened plants, ice crystals may form within the cell and the protoplasm may be disorganized. It is generally believed that such intracellular ice induces fatal injury at the time it is formed.

Killed at time of thaw—When freezing occurs in plant tissues, water is withdrawn from cells and ice crystals are formed in the spaces between cells. The withdrawal of water causes cell walls to be pulled inward. The protoplasm within the cell becomes balled up or "plasmolyzed." Unless the protoplasm is well supplied with "bound water" it becomes brittle. Upon thawing, water rushes back into the cell through the highly permeable cell wall. Rapid "deplasmolysis" occurs and the protoplasm may be stretched and subjected to shear forces sufficient to destroy it.

It is reasonable to assume that prolonged cold which contributes to the brittleness of the protoplasm would be conductive to greater injury. It is also likely that repeated freezing and thawing would become increasingly harmful.

Killed at some period between freezing and thawing—One of the older theories about ice damage held that the ice crystals ruptured the cell walls. This theory has been discredited. It appears not to be the case in most plants. In turfgrasses, however, where traffic is a factor, it appears very likely that physical damage by ice crystals is a serious cause of injury.

Dr. LeBeau's work in Alberta indicates that fungi in the plants produce gases that kill the plants. This production of gases apparently occurs while the plant is frozen. Here, then, are two situations wherein the plant succumbs at sometime between freezing and thawing.

Killed after thaw and growth has apparently begun—Many of the more common pathogens (the causal agents of disease) associated with the winter injury of turf grasses appear most active when snow goes off and temperatures are beginning to rise. It seems likely that these plants are killed after thaw or at the time of thawing.

Heaving of the ground often results in plants being left almost out of the soil and it sometimes causes a considerable portion of the root system to be pulled off. It also has been noted that a considerable portion of the crown tissue may have been destroyed, leaving relatively little vascular tissue to transport moisture and nutrients. In these cases, plants may be alive and they may begin growth, but die because moisture and nutrients are completely exhausted.

Desiccation—Desiccation, the drying out of the soil and of the plant tissues, is a commonly blamed condition for winterkill. In the absence of a snow cover, moisture may be lost from a frozen soil through the process of sublimation. This is a process whereby water passes directly from the solid to the vapor phase—from ice to moisture vapor without passing through the liquid phase.

It is difficult to determine whether turf killed under these conditions dies sometime during the winter or in spring when growth functions begin. Such plants simply die from drouth.

Ice Sheets—One of the puzzling conditions associated with winterkill is the effect of ice sheets. It has been demonstrated that *Poa annua* dies relatively soon under an ice sheet, but that bent and bluegrass are quite hard to kill. Dr. James Beard of Michigan State University has investigated this matter but has not reached definite conclusions.

Some of the mechanisms suggested are the depletion of oxygen, the accumulation of carbon dioxide, and the leaching out of cellular constituents. Dr. Beard's work appears to indicate that the direct effects of low temperatures may be the most important.

How to prevent it—Having examined briefly the several mechanisms which operate to produce winterkill, let us consider steps which may reduce the effects of cold.

1. Don't fertilize and water turf so generously that it approaches cold weather in a soft and succulent condition.

2. Use ample phosphorus and potash in the periods before winter. Abundant nitrogen appears to be less detrimental if it is balanced by the use of phosphorus and potash.

3. Apply a protective fungicide. There

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are numerous good fungicides available. The mercury materials have been especially effective over a long period of years. If midwinter thaws occur, a repeat application may be in order.

4. Protect against drying out. The placing of brush to hold snow is one practice that appears useful. Following experiments by Dr. J. R. Watson in Minnesota, several superintendents have used polyethylene covers on greens. Such a cover is effective in eliminating desiccation injury and ice-sheet damage. Timing of the placement and removal of the cover appears to be critical. Watering from tank trucks during "open" spells in the winter has helped some superintendents to save turf on exposed areas.

5. Assure good drainage. Soils that are well-drained and well-aerated have been shown repeatedly to support a turf less susceptible to winterkill.

6. Remove ice sheets or at least break them up.

7. When thaws occur, begin watering lightly and regularly until the plant can reestablish its root system.

8. Try to keep traffic off frozen greens or even those covered with an early season frost. Traffic physically damages the grass plant. More important, keep traffic off when the soil on top has thawed and that underneath is still frozen. At this time soil structure is damaged, roots are severed and the weakened plant tissue is particularly liable to injury.

9. Choose varieties that have demonstrated cold hardiness. There appears to be substantial difference within species relative to the ability to withstand cold.

Cold injury has been so widespread and so serious in recent years 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.

As we learn to know more of the "why's" of winterkill, it is certain that we shall come to be able to invoke the "how's" of controlling it. •