WINTER INJURY OF TURFGRASSES*

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SUMMARY

The winter injury discussions in this paper are limited to the effects of direct low temperature kill. The other two major causes of winter injury are low temperature fungi and winter desiccation. Two distinct types of symptoms are associated with low temperature kill of turfgrasses. One type involves the immediate kill of the entire plant which is completely dead at the time of spring thaw. The second type involves a differential low temperature kill of the root crown tissue and subsequent desiccation of the shoots. Relative low temperature hardiness of turfgrasses varies through the season, with late winter and early spring being most critical in terms of minimum hardiness to low temperature. Cultural factors which stimulate growth and cause a reduction in hardiness will result in increased low temperature kill: the most important of such factors are excessive nitrogen, a deficiency of potassium, a close cutting height, or inadequate surface and internal soil drainage. Winter injury of turfgrasses is frequently associated with ice and snow accumulations. However, research to date indicates that the commonly used perennial turfgrass species can tolerate up to sixty days of ice coverage without damage. Under Michigan conditions direct low temperature kill of turfs which are in a high state of hydration is a more significant cause of winter injury than the effects of toxic accumulations under an ice cover. The relative low temperature hardiness of fourteen hardened cool season turfgrass species is presented.

INTRODUCTION

The actual temperature of a turfgrass plant or its individual parts is determined by the surrounding environment. Temperatures of the below-ground portions of the plant are usually identical with the adjacent soil temperatures, while the above-ground parts tend to follow the air temperature. The greatest temperature extremes usually occur at the surface of the turf and are moderated with increasing distance above and below the turfgrass surface (4). The actual soil-air temperatures will vary with latitude, altitude, topography, season of the year and time of day.

The temperature at which a particular process occurs at the highest rate is referred to as the optimum temperature. The optimum temperature will vary depending on (a) the age of the plant, (b) the stage of development, (c) the specific plant organ involved, (d) the physiological condition of the plant, (e) the duration of the temperature exposure and (f) the variation in other environmental factors. Because so many factors influence the optimum temperature it should be considered as a range rather than a specific fixed temperature.

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Turfgrasses having a temperature optimum for growth in the range of 15 to 24°C are commonly referred to as cool-season turfgrasses while species with an optimum temperature range of from 27 to 35°C are called warm-season turfgrasses. The optimum temperature for maximum growth is not necessarily synonymous with the optimum temperature for turfgrass quality. The optimum temperature for growth is usually higher than that for turfgrass quality. Also, the optimum temperature for shoot growth is generally higher than the optimum temperature for root growth. In general, it is more important to have optimum temperatures for root growth of turfgrasses than for shoot growth.

Turfgrasses growing in the optimum temperature range will have increased nutrient and water-holding requirements as well as requiring more frequent mowing. As temperatures are increased or decreased from the optimum range the various metabolic processes within the plant are slowed. The net result is a general reduction in the growth which continues until, at a certain point, growth actually ceases.

LOW TEMPERATURE STRESS

Direct low temperature kill is a problem in both warm-season and cool-season turfgrass species. Low temperature stress is a major factor affecting the northern limits of adaptation of warm-season turfgrass species. Low temperature kill, winter desiccation and low temperature fungi are the three major causes of winter injury to turfgrasses. The following sections will be devoted to a discussion of low temperature kill and related phenomena.

At temperatures below the minimum for growth the turfgrass plant becomes semi-dormant. However, respiration and photosynthesis continue in cool-season turfgrasses even at temperatures below 5°C.

If temperatures become sufficiently low, direct low temperature kill occurs. The low temperature injury may involve ice crystal formation of an intracellular or extracellular nature.

Intracellular freezing is usually a non-equilibrium process which results in the explosive growth of ice crystals in tissues having a high hydration level. These large ice crystals cause mechanical disruption of the tissue of the protoplasm and the eventual death of the tissue.

Equilibrium freezing processes involve extracellular ice formation in which the living protoplasts may or may not be injured. During equilibrium freezing there is a redistribution of water from within the cells to the extracellular regions because of the lower vapour pressure of the extracellular ice. If this extracellular ice formation continues for a sufficient length of time actual frost desiccation of the protoplasm may occur. Associated with the phenomena is a contraction of the protoplasm. With extreme dehydration the protoplasm becomes brittle and is subjected to extreme tensions during contraction which can result in actual mechanical damage of the protoplasm.

LOW TEMPERATURE HARDINESS

The ability of a turfgrass plant to survive an unfavourable internal low temperature stress is referred to as low temperature hardiness. With the advent of cooler temperatures during the late fall period, certain morphological and physiological changes occur in the turfgrass plant which result in low temperature hardening prior to the occurrence of low temperatures. The growth rate of the turfgrass plant is slowed and eventually ceases, the plant becomes darker green, smaller in size, reduced in leaf area, and more prostrate in growth habit with a lower tissue hydration level (19). During this hardening period there is an accumulation of carbohydrates. Enzymes are activated which convert the insoluble carbohydrates to soluble sugars which accumulate in the vacuole and cause an increase in the osmotic potential (13, 16). There are also changes which occur in the protoplasmic proteins which result in an increased capability to bind water (12, 15). As a result of these physiological changes there is a significant reduction in the water content of the protoplasm which enables the plant tissues to achieve a maximum level of low temperature hardiness (8, 13). A period of approximately three to four weeks at temperatures below 7°C are required for cool-season turfgrasses to achieve maximum low temperature hardiness (13).

A reduced cell size is correlated with increased low temperature hardiness. Studies have shown that, in the crown meristematic area of annual bluegrass (Poa annua L.) the larger cells in the lower portion which are responsible for initiating new roots are injured much more readily than the small cells in the upper portion of the crown which are responsible for initiating shoot growth (9). In addition, young tissues are more low temperature hardy than old tissues (3). Leaf or root kill by low temperatures is not critical as long as the meristematic area of the crown is not injured. These root and leaf tissues can be readily replaced by the initiation of new growth from the crown meristem area. However, should injury occur to the crown meristem area serious loss of turf will occur (9).

Environmental influences

The relative low temperature hardiness achieved by a turfgrass plant is influenced by the environment. The first prerequisite for introducing hardiness is low average daily air and soil temperatures. Actively growing plants generally have a minimum level of low temperature hardiness (8).

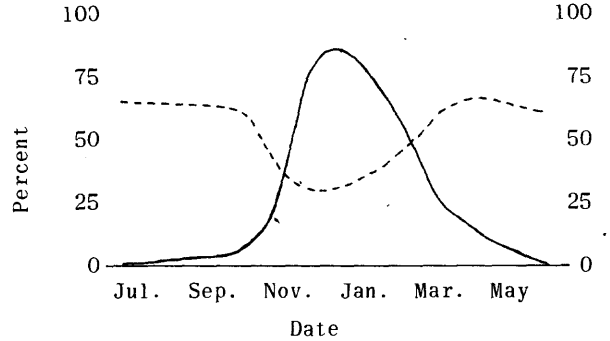

Figure 1: variation in the low temperature hardiness (——) and crown tissue hydration level (- - -) of Toronto creeping bentgrass (Agrostis palustris Huds.) during a typical winter season at East Lansing, Michigan

The hardiness level varies over the winter period (Figure 1). Maximum low temperature hardiness generally occurs during December or early January. There is a slight reduction in hardiness in February followed by a very drastic reduction in March and April. This decline in hardiness over the winter period is also associated with an increase in the crown hydration level (8). The minimum level of low temperature hardiness occurs in late winter and early spring. Thus, low temperature injury of turfgrasses is most likely to occur during this period, especially if the crown tissues contain a high water content. Thawing winter snows and the associated standing water, especially if the soil is frozen, will accentuate the increase in crown hydration level at this time and increase the likelihood of low temperature injury should temperatures decline to below - 6°C.

Cultural factors

Any cultural practice which stimulates growth will cause a reduction in hardiness and an increase in the susceptibility to kill by low temperature. Thus, excessive nitrogen fertilization, irrigation or any similar cultural practice which tends to stimulate growth in late fall will result in a reduction in low temperature hardiness (1, 3, 10, 12, 13, 14, 17, 21). In contrast to the nitrogen response, higher potassium levels result in improved low temperature hardiness (1, 10). Actually, itis not just a low nitrogen level or a high potassium level that is critical in maximum low temperature hardiness but the interrelationship or balance between the two nutrients (10). A fertilization ratio of 2 to 1 or 3 to 1 nitrogen to potassium has resulted in maximum low temperature hardiness of Kentucky bluegrass (*Poa pratensis* L.) under Michigan conditions.

Mowing height also affects low temperature hardiness (21, 23). Low temperature kill of Kentucky bluegrass was substantially increased at cutting heights below 3.8 cm (10).

Low temperature kill of turfgrasses is frequently associated with standing water. Proper surface and internal drainage are important factors influencing the crown hydration level of the turfgrass plant and the resulting susceptibility to low temperature kill. Proper surface contouring will ensure rapid removal of excess water. Adequate non-capillary pore space in the soil and a well-designed tile system will ensure the most effective and rapid removal of excess water from within the soil.

Turfgrass species influenced

The low temperature hardiness of turfgrass species varies greatly (Table 1). The warm-season species are usually more susceptible to low temperature kill than the cool-season species. There is also a great range of variability among the cool-season varieties (2, 3, 8, 11, 12, 16, 18, 20, 21, 22).

Controlled climate chamber studies at Michigan State University showed creeping bentgrass (*Agrostis palustris* Huds.) and rough bluegrass (*Poa trivialis* L.) had superior low temperature hardiness (8). Other cool-season turfgrasses possessing an acceptable level of low temperature hardiness included Kentucky bluegrass (*Poa pratensis* L.), colonial bentgrass (*Agrostis tenuis* Sibth.), and timothy (*Phleum pratense* L.).Intermediate in hardiness were annual bluegrass (*Poa annua* L.) and red fescue (*Festuca rubra* L.), while tall fescue (*Festuca arundinacea* Schreb.), perennial ryegrass (*Lolium perenne* L.) and Italian ryegrass (*Lolium multiflorum* Lam.) had inferior hardiness levels along with the warm-season turfgrass species.

Table 1: the relative low temperature hardiness of fourteen hardened turfgrasses

Relative low temperature hardiness	Turfgrass species
Excellent	Rough bluegrass Creeping bentgrass
Good	Timothy Kentucky bluegrass Canada bluegrass Crested wheatgrass Colonial bentgrass Redtop
Intermediate	Annual bluegrass Red fescue Tall fescue Meadow fescue
Poor	Perennial ryegrass
Very poor	Annual ryegrass

Varietal differences in low temperature hardiness are also evident (8, 22). The relative low temperature hardiness of several commonly used creeping bentgrass cultivars and one colonial bentgrass are shown in Table 2. Similar varietal differences have been evident in the Kentucky bluegrasses and ryegrasses.

LOW TEMPERATURE KILL SYMPTOMS

Two distinct types of symptoms are associated with low temperature kill of turfgrasses. The first type involves immediate kill of the entire turfgrass plant including the meristematic tissues. In this situation, the turf is completely dead at the time of spring thaw.

The second type involves a differential low temperature kill of the crown tissue. Basically, the temperature becomes low enough to kill the lower portion of the crown tissue but not the upper portion (9, 21). As a result the root system and meristematic tissues capable of initiating new roots are killed whereas the above-ground portion of the plant is uninjured at the time of spring thaw. As warmer temperatures occur, growth and transpiration are stimulated and death of the turfgrass plant usually occurs immediately. The shoot tissues die of desiccation because there is no root system present to absorb moisture for replacement of the water lost through transpiration. Atmospheric desiccation is the secondary cause of death with the original cause being differential low temperature kill of the turfgrass crowns which probably occurred during the late winter or early spring period.

ICE AND SNOW COVERS

Ice and snow accumulations sometimes persist for an extended period during the winter. The possibility exists under these conditions that a dense ice cover could impair gaseous diffusion processes to the extent that the turfgrass plant is injured due to either (a) suffocation caused by a lack of oxygen necessary for respiration or (b) direct kill caused by toxic gases which accumulate under the ice cover. Evidence to date suggests that the latter is the more likely cause of injury attributed to ice sheets. However, extensive field and controlled climate chamber studies at Michigan State University have failed to confirm that ice covers themselves are a major cause of turfgrass winter injury (5, 6, 7). Most turfgrass species are relatively tolerant to extended periods of ice cover of up to sixty days (Figure 2). Species differences in tolerance are evident, with annual bluegrass being more susceptible than Kentucky bluegrass or bentgrass. Bentgrass has survived continuous ice cover for as long as 150 days at -3°C.

Table 2: percentage low temperature survival of turfgrasses sampled 5 Dec., 1963

Grass	Percent crown moisture	Temperature treatment (°F. and °C.)							
		25	20	15	10	5	0	-5	-10
		-4	-6.7	-9.4	-12.2	-15	-17.8	-20.4	-23.2
Creeping bentgrass									
Toronto	61.3	100	100	100	100	100	99	98	97
Cohansey	64.5	100	100	100	100	100	100	99	98
Washington	61.0	100	100	100	100	100	100	98	94
Seaside	62.2	100	100	100	100	100	99	97	67
Penncross	55.5	100	100	100	100	97	93	90	75
Congressional ..	54.0	100	100	100	99	97	93	87	67
Colonial bentgrass									
Astoria	66.1	100	100	100	99	94	71	30	7
Redtop	55.0	100	97	90	78	70	60	47	27
Rough bluegrass ..	72.1	100	100	100	100	100	99	96	76
Kentucky bluegrass									
Merion	76.6	100	100	100	100	96	79	50	32
Kenblue	77.9	100	100	100	100	91	65	15	2
Newport	73.2	100	100	100	98	85	65	4	1
Annual bluegrass .	79.8	100	100	100	100	95	31	8	3
Creeping red fescue									
Pennlawn	78.0	100	100	97	90	63	17	4	0
Tall fescue									
Kentucky 31	74.1	100	100	100	83	40	27	5	3
Alta	77.4	100	100	98	72	33	22	4	0
Perennial ryegrass									
Norlea	79.3	100	100	100	100	71	4	1	0
Common	81.1	100	100	98	78	13	0	0	0
Italian ryegrass .	85.5	83	68	17	3	0	0	0	0

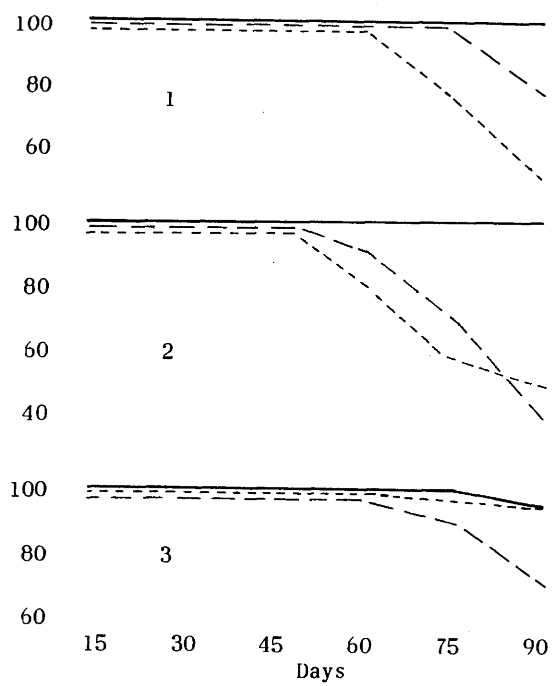

Figure 2: percent survival of hardened Toronto creeping bentgrass, common Kentucky bluegrass, and annual bluegrass:

1. After being flooded, then frozen and held at -4°C for intervals up to 90 days.
2. After being frozen, then layered with ice and held at -4°C for intervals up to 90 days.
3. After being frozen, then layered with ice over snow and held at -4°C for intervals up to 90 days.

—— Bentgrass
— — Kent. Bluegrass
- - - - Annual Bluegrass

Ice removal

A question frequently arises as to whether the ice and snow covers should be removed, particularly from greens and tees of golf courses. Basically, this is a sound practice in the United States although the reason for removal may be different from what most turfgrass laymen think. Complete removal of an ice or snow cover may subject the turf to winter desiccation injury. Actually, there is no urgency in the removal of an ice and snow cover during the initial sixty days unless a thaw is imminent. Probably more injury to turfgrasses is caused by the increased crown hydration effect associated with standing water when the ice and snow thaws than by the direct effect of the ice cover causing an accumulation of toxic gases and kill of the grass plant. Kill of the plant is highly likely if the hydrated crowns which have stood in water during the thaw period are subjected to low temperature stress of below -6°C. Thus the removal of an ice or snow cover is essentially a means of "mechanical draining" of water from the green. If and when an ice and snow cover is removed, approximately one-half to one-quarter inch of cover should be left on the green in order to avoid winter atmospheric desiccation problems. Research to date at Michigan State University indicates that, under the climatic conditions found in Michigan, direct low temperature kill of turfgrass plants which are in a high state of hydration is a much more significant cause of winter injury than the direct effects of toxic accumulation.

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