Field evaluation of winterkill in annual bluegrass and creeping bentgrass

Creeping bentgrass is unaffected by ice cover, but annual bluegrass can suffer substantial injury.

Environmental Institute for Golf

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Every year, putting greens and fairways in Iowa and golf courses north of the transition zone suffer some level of winter injury. When turf loss is substantial, the superintendent is faced with explaining why the grass died and, in many cases, why it died on that particular course and not on other nearby courses. Superintendents who make it through the winter with no injury gain faith that their strategy is working, and those who lose grass wonder why they have lost grass this winter when they have not lost grass in the past.

Most of the research to date evaluates a single type of winter injury and tries to determine whether it contributes to the death of the turf. Our approach was to compare many scenarios for winter injury in a single year to help superintendents make strategic decisions about problems they face such as ice removal, trucking water, covers, etc.

A unique part of our research strategy was to collect and recover grass samples during winter to determine exactly when grass dies, and thereby provide the superintendent with a reasonable idea of which type of winter condition has the greatest potential for turf loss and, in turn, whether it is worth the expense or effort to take action to minimize the injury. Our main goal was to better prepare superintendents to explain local winter turf injury to their golfing and administrative clientele.

Objectives

The objectives of the research were to determine the specific cause of winter injury on greens (snow cover, ice formation, desiccation, crown hydration and rehydration and freeze/thaw cycles), and to determine whether superintendents should allow winter to take its natural course or whether they should actively manage to reduce winter injury by practices such as using protective covers and removing ice.

Materials and methods

Study site

The study was carried out simultaneously on two separate greens during three years. One green was Penncross creeping bentgrass (*Agrostis stolonifera* L.) growing on a native soil at the Iowa State University Veenker Memorial Golf Course and the other was 85% annual bluegrass (*Poa annua* L.) and 15% creeping bentgrass growing on a USGA-type green at the Iowa State University Horticulture Research Station. The Veenker Memorial green was mowed at 0.13 inch (3.3 millimeters), and the Horticulture Research green was mowed at 0.17 inch (4.3 millimeters).

Plot construction

The 10 winter scenarios used in the study are presented in Table 1. Plots were constructed with plastic barriers to contain snow and ice treatments. Artificial snow from a local ski resort was used when natural snow was not present.

Ice was made by placing 0.25 to 0.5 inch (6.35 to 12.7 millimeters) of water on the plot area and allowing it to freeze; after the first ice layer was made, ice was made at a rate of 0.125 inch

(3.2 millimeters) per day until the turf was completely covered, and then it was made at a rate of 1 inch (25 millimeters) per day. A jackhammer and a BlueBird vertical mower were used for ice-removal treatments.

Sampling and rating

Core samples were collected every 14 to 20 days and were allowed to regrow in a growth chamber for 28 days to determine when grass actually died during winter. Turf recovery (dry weight yield) was used to indicate the amount of winter injury. Soil temperature was measured in the crown area of the plant at 0.5 inch (13 millimeters) below the canopy surface. Turf was visually rated in the spring for percent living turf cover and quality on a scale of 1 to 10, where 10 = no injury and 1 = completely brown dead grass.

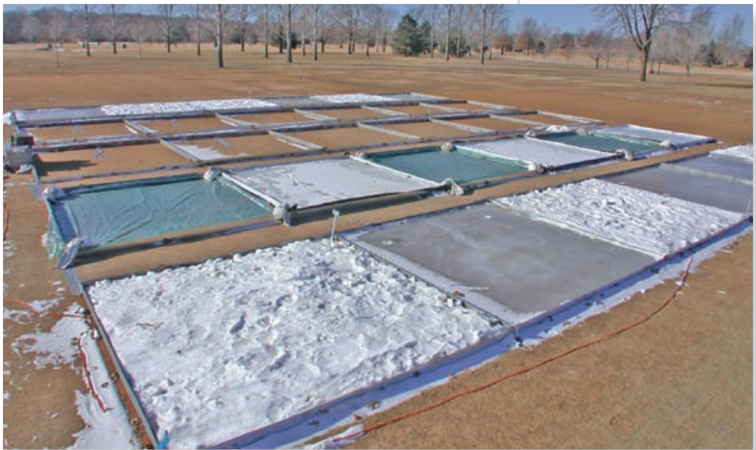
Results and discussion

Improving winter acclimation in October/November

We never know what type of winter conditions will prevail, so it is best to enter the winter season with plants that have been "hardened off" and acclimated for all types of winter conditions.

Winter covers are often used to protect greens. Placing tarps too early can disrupt the natural process of plant hardening (2), so tarps should be placed after the grass has stopped growing and no more grass clippings are collected during mowing.

Preconditioning was not evaluated in our study, and grass in all treatments was considered



The winter trial at Veenker Memorial GC, Jan. 23, 2003. Snow from a local ski resort was added to the plots because no snow had fallen at the golf course. **Photos by D. Minner**

Winter treatments

Simulated winter conditions	Winter	Spring	Treatment	Treatment dates (days with snow or ice coverage)†	Results/conclusions
1. Dry/open	dry	dry	no cover, no ice, no snow; turf subject to desiccation	2003 Jan. 10-Mar. 20 (68) 2004 Jan. 6-Mar. 23 (77) 2005 Jan. 1-Mar. 14 (73)	desiccating conditions not present during study
2. Wet	wet	wet	turf hydrated; no surface ice	2003 Jan. 10-Mar. 20 (68) 2004 Jan. 6-Mar. 23 (77) 2005 Jan. 1-Mar. 14 (73)	no benefit since desiccating conditions did not exist
3. Ice continuous	ice	ice	extended ice cover for 90 days	2003 Jan. 10-Mar. 18 (66) 2004 Jan. 6-Mar. 12 (67) 2005 Jan. 1-Feb. 20 (32)‡	tip burn on creeping bentgrass; severe loss of annual bluegrass suspected by ice-induced crown dehydration
4. Snow continuous	snow	snow	extended snow cover 90 days	2003 Jan. 10-Mar. 18 (66) 2004 Jan. 6-Mar. 16 (71) 2005 Jan. 1-Mar. 6 (65)	improved spring green-up and reduced winter turf loss of annual bluegrass
5. Impermeable + ice	ice	ice remove	white impermeable cover (Impermeable) designed to prevent plant hydration and ice encasement; 4 inches of ice over cover.	2003 Jan. 10-Feb. 18 (39) 2004 Jan. 6-Feb. 23 (48)§ 2005 Jan. 1-Jan. 25 (25) ‡,//	substantial increase in spring green-up and winter survival of annual bluegrass
6. Ice removal	ice	ice remove	ice removed after 60 days of ice formation	2003 Jan. 10-Feb. 18 (39) 2004 Jan. 6-Feb. 23 (48) 2005 Jan. 1-Jan. 25 (25)	no improvement of annual bluegrass survival
7. Ice melt/freeze	ice	melt/ freeze	natural melt/freeze cycle applied in spring	2003 Jan. 10-Feb. 18 (39) 2004 Jan. 6-Feb. 23 (48) 2005 Jan. 1-Jan. 25 (25)	same amount of annual bluegrass injury as continuous ice
8. Snow removal	snow	melt/ freeze	snow removed after 60 days of winter	2003 Jan. 10-Mar. 20 (68) 2004 Jan. 6-Feb. 23 (48) 2005 Jan. 1-Feb. 8 (39)	same as continuous snow
9. Permeable/dry	dry	dry	permeable turf cover; ice/snow removed	2003 Jan. 10-Mar. 20 (68) 2004 Jan. 6-Mar. 23 (77) 2005 Jan. 1-Mar. 14 (73)	cover improved spring green-up and winter survival of annual bluegrass
10. Permeable + snow	snow	snow	permeable turf cover; ice/snow present 90 days	2003 Jan. 10-Mar. 18 (66) 2004 Jan. 6-Mar. 16 (71)§ 2005 Jan. 1-Mar. 6 (65)//	cover improved spring green-up and winter survival of annual bluegrass

†On the start date for each winter treatment, snow or ice was applied. The last day of a treatment was the day tarps were removed or ice and snow had naturally melted from the plot area.
‡Warm temperatures prevented continuous ice on plots. Ice was not present Jan. 25-Feb. 8 and Feb. 14-19.
§Permeable or impermeable covers removed March 23, 2004.
//Covers removed March 14, 2005.

Table 1. Simulated winter conditions and dates of application for 10 different winter treatments applied on Penncross creeping bentgrass at Veenker Memorial GC and on a mixed annual bluegrass/creeping bentgrass green at the Iowa State University Horticulture Center from 2003 to 2005. Treatments were applied to a different area of the research green each year.

Ice was removed with a jackhammer **(left)** and with a verticutter **(right)**.

to have achieved maximum winter hardiness.

Direct low-temperature injury

The LT_{50} (low temperature that kills 50% of the test population) in laboratory research studies for annual bluegrass ranges from 14 F to -4 F (-10 C to -20 C) and -40 F (-40 C) for creeping bentgrass (3,6). It is important to note that LT_{50} is a valuable research tool for estimating tolerance to freeze injury, but it is not an absolute value that indicates when injury will occur under field conditions.

Because we recorded temperatures of 7.7 F (-13.5 C) without any injury to annual bluegrass in our study (treatment 10; Table 2), we believe there was no direct low-temperature injury to annual bluegrass. In fact, the only treatments that injured annual bluegrass were those involving ice cover (treatments 3, 6, and 7; Tables 3, 4).

Should ice be removed?

An important part of our study was to answer the questions about ice removal (treatment 6, Table 1). Studies in Canada have shown that injury may occur when turf is covered with ice for an extended period. Microbial activity continues under ice cover, causing a depletion of oxygen and a buildup of toxic gases that is often referred to as *anoxia*. Annual bluegrass is more susceptible to anoxic conditions under ice cover than creeping bentgrass.

Previous research has found that hardiness decreases in annual bluegrass after 30 days of ice encasement, and plants are dead after 70 days, yet creeping bentgrass maintains hardiness levels after 90 days of continuous ice cover (5). Earlier reports in the U.S. indicate that annual bluegrass was injured after 75 days of ice cover, and creeping bentgrass was not injured even after 150 days

Minimum winter temperatures

	2003				2004				2005			
	Days 10-48		Days 49-76		Days 6-52		Days 53-77		Days 1-38		Days 39-73	
Winter treatment	Minimum temperature†											
	F	C	F	C	F	C	F	C	F	C	F	C
1. Dry/open	14.0	-10.0	12.9	-10.6	11.5	-11.3	22.8	-5.1	10.8	-11.8	21.4	-5.9
2. Wet	8.4	-13.1	11.5	-11.4	13.1	-10.5	23.0	-5.0	8.1	-13.3	21.4	-5.9
3. Ice continuous	10.6	-11.9	14.0	-12.7	10.9	-11.7	21.6	-5.8	12.4	-10.9	21.2	-6.0
4. Snow continuous	9.9	-12.3	7.7	-13.5	14.4	-9.8	15.1	-9.4	22.1	-5.5	18.5	-7.5
5. Impermeable + ice	10.2	-12.1	9.7	-12.4	14.2	-9.9	21.7	-5.7	20.5	-6.4	20.8	-6.2
6. Ice removed	8.4	-13.1	12.0	-11.1	9.1	-12.7	19.9	-6.7	12.7	-10.7	20.8	-6.2
7. Ice melt/freeze	9.3	-12.6	12.0	-11.1	10.4	-12.0	19.6	-6.9	16.7	-8.5	21.0	-6.1
8. Snow removed	10.6	-11.9	12.9	-10.6	16.1	-8.8	18.5	-7.5	21.7	-5.7	20.8	-6.2
9. Permeable/dry	13.3	-10.4	13.8	-10.1	12.6	-10.8	23.2	-4.9	12.9	-10.6	21.6	-5.8
10. Permeable + snow	7.7	-13.5	12.4	-10.9	17.2	-8.2	18.7	-7.4	17.8	-7.9	18.7	-7.4

†Minimum temperatures are not necessarily recorded during the same day or at the same time. F, Fahrenheit; C, centigrade.

Table 2. Treatment temperature readings observed at the creeping bentgrass green (Veenker Memorial GC).

Grass core samples were placed in the greenhouse for recovery and determination of winter injury.

of ice cover (1). Recent studies from Canada indicate that annual bluegrass damage occurred after 90 days of ice cover, and creeping bentgrass was still alive on day 150 (6).

These results leave superintendents guessing as to when ice should be removed or if it should be removed at all. Based on the conditions in our Iowa study, there was no winterkill of creeping bentgrass when ice cover lasted for 67 consecutive days, the maximum amount of time that ice could be maintained on the study area (treatment 3, Table 1). A slight bleaching or tip burn was the only injury that occurred, and this was noticed for all treatments exposed to ice cover.

Ice cover and annual bluegrass

In contrast, ice cover treatments on annual bluegrass did result in winterkill, but it was not caused by anoxia. We first suspected this because the treatments receiving continuous ice for 67 days (treatment 3) had the same amount of annual bluegrass survival (35%) as the treatments where ice was removed after 39 days (treatment 6, Table 4). Had anoxia been the cause for annual bluegrass injury, then we should have observed a benefit from ice removal, but that did not happen.

Although we did not measure gas exchange and anoxic conditions under the ice, we did collect grass samples every two weeks for recovery in the growth chamber in order to determine when plants were actually killed during the winter season. To our surprise, annual bluegrass was injured sometime during the two-week period after ice cover was initiated. If anoxia was not the cause of winter injury and removal of ice accumulation was not the solution, then what type of injury occurred? One might expect direct low-temperature injury because the crown region under the ice was colder than 14 F (-10 C) and below the LT_{50} reported for injury of annual bluegrass. Again, the range of study treatments helps us answer this question. Direct low-temperature injury alone was not the cause of winterkill under the ice because several other treatments, including the open/dry control plot with no ice cover, also had temperatures near the crown that were below 14 F (-10 C) (treatment 1, Table 2).

An impact hammer drill was used to sample greens during the winter to determine when the grass actually dies.

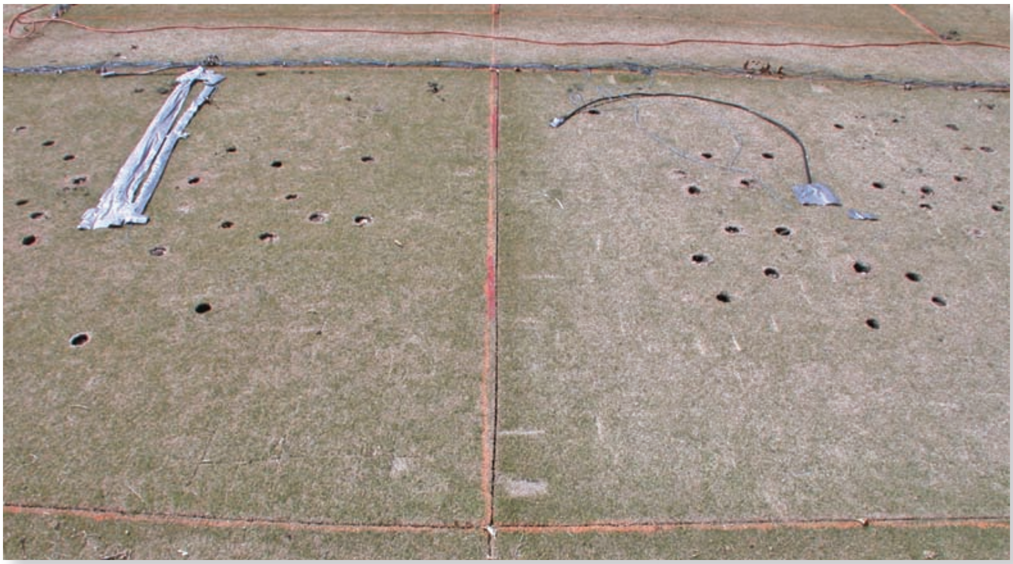
Crown rehydration was also not expected because injury occurred in mid-January, and conditions for breaking dormancy were not prevalent. There was very little chance that water was accumulating in the crown and causing cells to rupture. Likewise, the conditions for desiccation did not exist because it was unlikely that the plants under ice were exposed to drying conditions.

Annual bluegrass survival

Winter treatments	Jan. 15	Feb. 26	April 8
	Weight (grams)†		
1. Dry/open	0.60	1.22	0.79
2. Wet	0.70	1.12	1.00
3. Ice continuous	0.26	0.81	0.30
4. Snow continuous	0.70	1.02	0.80
5. Impermeable + ice	—	—	0.95
6. Ice removal	0.32	0.31	0.22
7. Ice melt/freeze	0.33	0.32	0.34
8. Snow removal	0.60	1.23	1.22
9. Permeable/dry	0.54	1.44	1.09
10. Permeable + snow	0.71	1.27	0.89

†Weight recovered from grass clippings above crown level in a 3.14-square-inch (20.25-square-centimeter) core after 28 days of growth at 71.6 F (22 C).

Table 3. Annual bluegrass survival during winter 2004 as indicated by weight recovered from grass clippings. Higher dry weight indicates less winter injury.



This photo taken Jan. 4, 2003, during spring green-up shows the difference between the creeping bentgrass protected by snow cover **(left)** and the creeping bentgrass showing tip burn from ice cover **(right)**. The creeping bentgrass completely recovered.

Crown dehydration

This study showed that exposing annual bluegrass to ice caused substantial winter injury. A comparison of several winter scenarios, combined with temperature measurements near the crown and grass samples taken during the winter season, leads us to believe that annual bluegrass in our study was substantially injured by crown dehydration caused by freezing. Because plants were injured within two weeks of ice cover, we believe that ice forming could have caused an efflux of water that resulted in dehydration at the cellular level or desiccation at the whole-plant level. If samples had not been collected during the growing season, the specific type of injury could not have been determined; instead, we would have been left with observations of dead annual bluegrass in the spring and the assumption that it was caused by 4 inches (10.2 centimeters) of ice cover. In our case, it was not necessarily the thickness of ice cover or the duration of ice cover that determined annual bluegrass injury, instead it was the fact that plants were killed in the short period after initial encasement by ice. This could have occurred even as the first 0.5 inch (1.3 centimeters) of ice formed.

Other researchers have observed a significant decrease in survival when annual bluegrass plants are in direct contact with water or slush that freezes, causing ice encasement. Damage can occur at the time of initial freezing and may not depend on the duration of ice coverage (4). Thus, a critical factor to annual bluegrass injury in our study involved the freezing of liquid water as it touched the plant. Under these circumstances, the mechanisms involved could have been crown dehydration (water extraction following ice formation) or direct low temperature associated with ice formation causing cell-membrane rupture.

Spring annual bluegrass survival

Winter treatments	2003	2004	2005
	Annual bluegrass cover (%)		
1. Dry/open	28	53	7
2. Wet	38	65	2
3. Ice continuous	12	36	12
4. Snow continuous	68	37	22
5. Impermeable + ice	—	69	23
6. Ice removal	11	36	13
7. Ice melt/freeze	8	10	18
8. Snow removal	52	46	18
9. Permeable/dry	66	82	18
10. Permeable + snow	—	92	27

Table 4. Annual bluegrass survival as shown by % annual bluegrass cover in the spring following winter.

Ice + covers

This type of ice injury is further supported by observing treatments where ice formed in direct contact with the grass compared with treatments where an impermeable cover was placed between the grass and the ice layer. Ice over the impermeable cover had 69% annual bluegrass cover, whereas the same amount and duration of ice cover placed directly on the grass in the continuous ice treatment had 35% annual bluegrass cover.

Ice nucleation, the origination point of ice crystals, is greater when plants are wet. Impermeable tarps reduced plant wetness and seemed to provide good protection from winter injury because ice forming on top of the cover could not induce ice nucleation on the plant. Impermeable covers need to be evaluated under other noninsulating condi-

Left: Annual bluegrass survived when it was protected from ice formation by an impermeable cover. **Right:** However, annual bluegrass exposed to the continuous ice treatment did not survive. The photo was taken March 19, 2004.

After the ice had melted and the protective turf covers were removed, creeping bentgrass showed rapid spring green-up. **Lower left:** Treatment with an impermeable cover + ice. **Lower right:** Treatment with a permeable cover. The photo was taken March 20, 2004.

tions that could occur during winter. In our study, when ice finally melted in the spring and covers were removed, the creeping bentgrass that had been protected with an impermeable cover was dramatically greener than the creeping bentgrass protected by a permeable cover.

Conclusions

Superintendents who can afford permeable winter covers use them every year to prevent turf loss that frequently occurs from winter desiccation. Those who cannot afford covers often use a heavy application of topdressing sand and call it the "poor man's turf blanket." In our trials and on most golf courses, permeable turf covers seldom damage turf; they generally reduce winter injury or speed growth in the spring. The permeable covers in our study nearly doubled the amount of surviving annual bluegrass compared to the open/dry control treatments (Table 4). Covering greens with permeable covers is an important strategy when managing annual bluegrass greens.

We know a great deal about the separate components of winter injury, but there is much to discover before we can understand and explain how winter selectively injures grass on a specific golf course.

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GCM

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The research says

→ Continuous ice cover of 66 days caused bleaching of creeping bentgrass, but never resulted in turf kill or decline in turf cover.

→ Annual bluegrass was injured under ice cover, possibly because of ice-induced crown dehydration.

→ The formation of ice may be more important than the duration of ice cover in predicting annual bluegrass winter injury when ice is present.

→ Annual bluegrass is far more likely than creeping bentgrass to be injured during winter.

→ There was no advantage in removing ice cover once it had formed. A better strategy might be to prevent any amount of ice formation on annual bluegrass.

→ Synthetic covers and the natural cover of snow and ice raise the minimum temperature near the plant crown compared to exposed situations with no cover.