Control of Winter Injury Caused by Ice Cover on Annual Bluegrass and Creeping Bentgrass.

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Summary

A lab study compared the effect of ice cover and ice encasement with a control treatment (no ice) on annual bluegrass (*Poa annua*) and creeping bentgrass (*Agrostis palustris*) plants. Generally, snow covered plants maintained cold hardiness much longer than plants that were ice encased. Cold hardiness levels for the ice covered plants were intermediate between the other two treatments. This effect was much more pronounced for annual bluegrass than for creeping bentgrass. For annual bluegrass, after 60 days, cold hardiness levels were: -18^0 C for snow covered plants, -10^0 C for ice covered plants and -2^0 C for ice encased plants. By 90 days, ice encased plants were dead. By 120 days, the ice covered plants were dead. For creeping bentgrass, the same trend occurred, but the loss of cold hardiness was greatly delayed. Therefore, at 150 days the snow covered plants had a cold hardiness level of -27^0 C compared to -18^0 C for the ice encased plants.

A related field study compared the effects of: snow cover, snow removed in February, ice cover and ice removed in February for annual bluegrass and creeping bentgrass plants. Annual bluegrass plants that had been ice covered had very little cold hardiness after 60 days and were dead by 75 days. Creeping bentgrass plants in all treatments could tolerate temperatures below -28^0 C after 90 days.

Overall Objectives

- Determine effect of ice cover and encasement on annual bluegrass and creeping bentgrass under controlled conditions.
- Compare different management strategies for preventing ice injury under field conditions for annual bluegrass and creeping bentgrass.
- Determine impact of thawing and flooding on LT_{50} levels.

Trial 1 - Effect of Ice Cover and Ice Encasement under Controlled Conditions

Methodology

Annual bluegrass and creeping bentgrass plants were cold hardened and then tested to determine the baseline LT_{50} value. These plants were stored in a freezer at -4^0 C and tested for hardiness levels at various periods of time: 15, 30, 45, 60, 75, 90, 120 and 150 days. Plants of each species were stored under three different conditions: control, ice cover and ice encasement. The control treatment plants were covered with snow to prevent desiccation, but were not covered with ice. Plants in the ice cover treatment were covered with 2.5 cm of ice. The ice was added gradually by misting. Plants in the ice encasement treatment were immersed in water and then frozen.

At each sampling period, the plants were subjected to a freeze test in a circulating bath (Model Lt_{50}, Neslab Instruments, Portsmouth, NH). In the circulating bath, plants were allowed to equilibrate for 8h at –2^0 C. The temperature was then decreased by 2^0 h^{-1} in a stepwise fashion. When the temperature was in the selected range, a test tube with plants from each treatment was removed and the temperature was decreased by a further 2^0 C. For example, plants may have been removed at –6, -8, -10, -12, -14 and -16^0 C. After the freeze test, the plants were transferred to the greenhouse for 4wk and plant regrowth was rated for survival to establish a LT_{50} value, which represents the lowest temperature at which 50% of the plants survived.

Results and Discussion

Baseline LT_{50} values were -21^0 C for annual bluegrass and -38^0 C for creeping bentgrass. There were dramatic differences in LT_{50} values between the two species (Table 1): creeping bentgrass plants maintained cold hardiness for longer periods of time.

The snow or ice cover treatments significantly influenced the LT_{50} levels at most sampling dates. Plants subjected to the snow cover treatment maintained cold hardiness for the longest period of time. In contrast, the ice encasement treatment produced the most rapid loss of cold hardiness.

Table 1. Effect of species, treatment and species x treatment interaction on LT_{50} values of plants stored under controlled conditions.

	Sampling Date (Days)							
Source of Variation	15[1]	30	45	60	75	90	120[3]	150[3]
Species								
Annual bluegrass	-14a	-17a	-16a	-10a	-13a	-7a	-	-
Creeping bentgrass	-40b	-39b	-38b	-36b	-35b	-34b	-27	-23
Treatment								
Snow cover	-28a	-28a	-28a	-28a	-27a	-27a	-	-
Ice cover	-26b	-28a	-27a	-23b	-24b	-19b	-	-
Ice encasement	-26b	-27a	-25b	-18c	-20c	-16c	-	-
Species x Treatment								
Blue/snow cover	-14	-18	-16	-18	-18	-18	-	-
Blue/ice cover	-14	-16	-16	-10	-13	-4	-	-
Blue/ice encasement	-13	-16	-15	-2	-7	dead	-	-
Bent/snow cover	-41	-39	-40	-38	-37	-36	-33	-27
Bent/ice cover	-39	-39	-38	-37	-36	-35	-27	N/A
Bent/ice encasement	-39	-38	-35	-34	-33	-32	-20	-18
S_y for Sp x Trt[2]	NS	0.9	0.8	1.4	NS	NS		

[1]Within a column and for each source of variation, means followed by the same letter are not significantly different at p=0.05 (LSD).
[2] S_y for interactions significant at p=0.05.
[3]Anova performed for creeping bentgrass only.

The difference between snow cover and ice cover or ice encasement was more pronounced for the annual bluegrass plants than for the creeping bentgrass plants. By 90 days, the annual bluegrass plants that had been encased in ice were dead. By 120 days annual bluegrass plants that had been covered with ice were also dead. In contrast, creeping bentgrass plants maintained adequate cold hardiness levels for at least 120 days. However, by the 120 day and 150 day sampling dates, the differences in cold hardiness levels for creeping bentgrass plants that were snow covered compared to ice encased were very pronounced.

After 90 days, annual bluegrass plants that were snow covered still had LT_{50} levels of –18^{0} C. This was only a slight reduction in cold hardiness from the initial baseline level of –21^{0} C.

Therefore, ice cover produces a more rapid loss of cold hardiness than snow cover. Ice encasement causes an even more rapid loss of cold hardiness than ice cover. The relative impact of the snow and ice cover is much more pronounced for annual bluegrass than for creeping bentgrass. The loss of cold hardiness under ice, is probably a major contributor to winter injury to annual bluegrass turf. This impact of the ice cover or encasement is much greater than the impact caused by the presence or absence of snow cover that was identified in previous studies.

Effect of Desiccation on Cold Hardiness Levels

The ice encasement study was actually conducted twice: winter of 1998 and 1999. However, in 1998, there was a problem with plant desiccation in the freezer. This caused a reduction in the LT_{50} levels particularly for the annual bluegrass plants. Consequently, the study was repeated in 1999.

When the data from the combined years are analyzed, the effect of desiccation (1998) compared to control (1999) can be seen (Table 2). The LT_{50} values were much lower in 1998 than in 1999.

Table 2. Effect of year and species on LT_{50} values (average of three ice or snow cover treatments) for plants grown under controlled conditions.

	Sampling Date (Days)		
Source of Variation	30[1]	60	90
Year			
1998 (desiccation)	-18a	-18a	-14a
1999 (control)	-28b	-23b	-21b
Species			
Annual bluegrass	-8a	-5a	-4a
Creeping bentgrass	-37b	-36b	-31b
Year x Species			
1998/Annual bluegrass	0	0	0
1998/Creeping bentgrass	-35	-35	–28
1999/Annual bluegrass	-17	-10	-7
1999/Creeping bentgrass	-39	-36	-34
S_y for Y x Sp[2]	0.7	1.1	NS

[1]Within a column and for each source of variation, means followed by the same letter are not significantly different at p=0.05 (LSD).
[2] S_y for interactions significant at p=0.05.

The differences between species were more pronounced with this data from combined years. This is largely due to the fact that the dry conditions in 1998 promoted earlier mortality of annual bluegrass than creeping bentgrass. In 1998, LT_{50} values were only slightly lower for creeping bentgrass compared to 1999.

Unfortunately, since the amount of desiccation was not quantified, these results can only be used as illustrating another type of winter stress that is particularly a problem for annual bluegrass.

Trial 2 - Effect of Snow and Ice Cover Under Field Conditions

A field study was conducted over a three year period to compare the relative effects of snow cover and ice cover. The impact of removing the snow and ice after 45 days was also assessed. In the first year of the study, 1998, data collection began at 45 days. Unfortunately, by this time, the ice covered annual bluegrass plants were all dead. In the following two years, data collection began at 15 days. Consequently, results are reported for the combined years of 1999 and 2000. The results for 1998 are reported separately.

Methodology
Plots were established in a split plot design with four replicates. Main plots were species: annual bluegrass and creeping bentgrass. Subplots were snow and ice cover treatments:

- snow cover maintained as long as possible
- snow removed in February
- ice cover maintained as long as possible and
- ice cover removed in February.

Snow and ice were removed from the appropriate plots in mid-February. This would correspond to the 45 day sampling date in the lab study. Plants were sampled to determine LT_{50} values at 15, 30, 45, 60, 75 and 90 day intervals.

Results and Discussion - 1999 and 2000
It was only possible to maintain snow and ice cover on the plots for a 90 day period due to warm weather in the early spring. Creeping bentgrass plants maintained adequate levels of cold hardiness throughout this period (Table 3). Annual bluegrass plants had lost considerable hardiness by 60 days and by 75 days, those plants maintained under ice cover were dead.

There were significant differences between the snow and ice treatments at all sampling dates, but the removal of the snow or ice had no significant effect. Of course, the snow and ice weren't removed until the 45 day sampling period, so no effect would be expected during the 15, 30 and 45 day sampling periods.

Table 3. Effect of year, species, year x species, snow/ice treatment, year x snow/ice treatment, and species x snow/ice treatment on LT_{50} (^{0}C).

Source of Variation	Baseline	15 Day[1]	30 Day	45 Day	60 Day	75 Day[3]	90 Day[3]
	Sampling Time						
Year							
1998/99		-29a	-27a	-26a	-22a	-	-
1999/00		-29a	-29a	-27a	-23a	-	-
Species							
Annual Bluegrass	-22	-17a	-15a	-15a	-9a	-	-
Creeping Bentgrass	-42	-40b	-40b	-39b	-36b	-33	-29
Year x Species							
1998/bluegrass		-19	-14	-15	-8	-	-
1998/bentgrass		-39	-40	-38	-35	-32	-31
1999/bluegrass		-16	-17	-14	-9	-	-
1999/bentgrass		-42	-40	-40	-37	-34	-27
S_y for Y x Sp[2]		0.6	NS	NS	NS	NS	NS
Snow/Ice Treatment							
Snow cover		-30b	-29c	-28c	-24c	-	-
Snow removed		-30b	-29c	-29c	-27d	-	-
Ice cover		-28a	-27b	-25b	-21b	-	-
Ice removed		-27a	-26a	-24a	-18a	-	-
Year x Treatment							
1998/snow cover		-30	-28	-28	-25	-	-
1998/snow removed		-30	-28	-28	-26	-	-
1998/ice cover		-28	-26	-26	-20	-	-
1998/ice removed		-27	-26	-25	-16	-	-
1999/ snow cover		-30	-30	-29	-24	-	-
1999/ snow removed		-30	-30	-31	-27	-	-
1999/ ice cover		-27	-28	-25	-22	-	-
1999/ ice removed		-27	-26	-24	-20	-	-
S_y for Y x Tr		NS	NS	0.8	NS		
Species x Treatment							
Blue/snow cover		-20	-18	-17	-12	(-16)	(-14)
Blue/snow removed		-20	-18	-19	-15	(-15)	(-12)
Blue/ice cover		-15	-13	-12	-6	(dead)	(dead)
Blue/ice removed		-14	-13	-10	-2	(dead)	(dead)
Bent/ snow cover		-41	-40	-39	-37	-34	-30
Bent/snow removed		-40	-40	-39	-39	-35	-30
Bent/ice cover		-40	-41	-39	-36	-32	-29
Bent/ice removed		-40	-39	-39	-34	-32	-29
S_y for Sp x Tr		0.7	0.9	0.8	NS	2.1	NS

[1]Within a column and for each source of variation, means followed by the same letter are not significantly different at p=0.05.
[2]S_y for interactions significant at p=0.05.
[3]Anova performed on creeping bentgrass only.

Ice cover had a much more dramatic impact on the loss of cold hardiness (and eventual plant mortality) for annual bluegrass than for creeping bentgrass. By 60 days, the annual bluegrass plants that had been subjected to ice cover had lost almost all their cold hardiness, or were dead. At this same date, creeping bentgrass plants with ice cover had cold hardiness levels of -36^0 C. By 90 days, creeping bentgrass plants under ice cover, still had LT_{50} levels of –29^0 C.

Surprisingly, in this study, there was no benefit to the annual bluegrass plants from removing the ice cover. It is possible that removing the ice at 45 days was not early enough. Removing the ice at 30 days or earlier might have produced a better result. This is an area that should be explored further as it is a common practice in the golf course industry to remove ice on annual bluegrass greens.

In general, the results of the field study and the lab study were fairly similar although there was a slightly more rapid loss of cold hardiness in the field. It is not surprising that there would be an earlier loss of cold hardiness in the field study as temperatures are more variable than in the freezer. The ice cover treatment in the field study was probably most comparable to the ice encasement treatment in the lab study.

Annual bluegrass plants experienced a more rapid loss of cold hardiness in the field than in the lab. For example, in the lab study, the ice encased plants had little cold hardiness at 60 and 75 days and were dead by 90 days. In the field study, the ice covered plants had little cold hardiness at 60 days and were dead by 75 days.

Creeping bentgrass plants also experienced a more rapid loss of cold hardiness in the field. For example, in the lab study, at 90 days, ice encased creeping bentgrass plants had a LT_{50} level of-32^0 C compared to -29^0 C for the ice cover treatment in the field study.

Winter conditions may have contributed to these differences as an unusually warm period preceded the initiation of the ice cover treatments in both years.

Results and Discussion - 1998

The weather conditions in 1998 were much milder than in the other two years, with a prolonged warm period in January and February that would have influenced cold hardiness levels. Consequently, by 45 days, the cold hardiness levels for all treatments were lower than the levels present in the other two years of the study (Table 4). For example, ice covered annual bluegrass plants were already dead at 45 days. In contrast, in the other two years, these plants still had hardiness levels of -12^0 C at 45 days.

The snow cover was better protection for the annual bluegrass plants than the ice cover. Plants under ice cover were dead by 45 days, while plants under snow cover were still alive at 75 days.

For the creeping bentgrass plants, there were no relevant treatment differences until 75 days. By this time, all plants were starting to lose cold hardiness due to the warming temperatures. In the plots where a cover was maintained, whether snow or ice, better levels of cold hardiness were retained into the dehardening period.

Table 4. Effect of snow and ice cover treatment on LT_{50} values (^{0}C) for two species of grass grown in the field during the winter of 1997-98.

Treatment	Baseline	45 Days[1]	60 Days	75 Days
Annual bluegrass	-19			
snow cover		-13b	-10b	-7b
snow removed		-10b	-14b	-15c
ice cover		0a	0a	0a
ice removed		0a	-2a	0a
Creeping bentgrass	-39			
snow cover		-35cd	-39c	-32e
snow removed		-40d	-38c	-26d
ice cover		-34c	-39c	-31e
ice removed		-37cd	-38c	-22d

[1]Within a column, means followed by the same letter are not significantly different at p=0.05 (LSD).

Trial 3 - Effect of Temperature and Flooding on Loss of Cold Hardiness for Plants Maintained under Snow or Ice

This pilot study was undertaken to determine the relative effect of temperature and flooding on the loss of cold hardiness for annual bluegrass plants. These dehardening treatments were applied to plants that had been stored under snow cover and plants that had been ice encased.

Methodology

Cold hardened annual bluegrass plants were stored at $–4^0$ C in a freezer. Plants were stored for 60 days either with a snow cover or encased in ice. At this time, plants were sampled to determine the baseline LT_{50} level. Plants were then removed and thawed at room temperature for six hours and then subjected to different dehardening conditions:

- 8^0 C and flooded,
- 1^0 C and flooded,
- 8^0 C.

Results and Discussion

This was intended to be a pilot study to screen possible treatments for a larger study. There are a few changes that should be made to a larger study. For example, 60 days in the freezer was too long. By 60 days, the baseline hardiness levels were only $–8^0$ C for the ice encased plants, compared to –22 for the snow covered plants (Table 5). With a starting baseline of $–8^0$ C for these plants, it was not possible to demonstrate any meaningful impact on cold hardiness by temperature and flooding.

At 8^0 C, flooding did not produce an increased loss of cold hardiness. In fact, any time there were significant treatment differences (i.e. 2 days and 4 days), better cold hardiness was associated with the flooded plants. This may have been due to the fact that the higher water content may have slowed the dehardening process as air warms more rapidly than water.

Table 5. Effect of storage conditions and dehardening treatments on LT_{50} levels (^{0}C).

	Time Exposed to Dehardening Conditions				
Source of Variation	Baseline	2 Days[1]	4 Days	6 Days	8 Days
Storage Conditions					
Snow cover	-22	-12a	-10a	-11a	-6a
Ice encasement	-8	-2b	-4b	-2b	-2a
Dehardening Treatments					
8^0 C + Flooded		-9a	-9a	-6a	-4a
1^0 C + Flooded		-7ab	-9a	-7a	-3a
8^0 C		-5b	-5b	-7a	-5a
Storage x Dehardening					
Snow/8^0 C + Flood		-15	-8	-12	-4
Snow/1^0 C + Flood		-12	-15	-11	-5
Snow/8^0 C		-9	-8	-11	-8
Ice/8^0 C + Flood		-3	-9	-1	-3
Ice/1^0 C + Flood		-1	-2	-2	-1
Ice/8^0 C		-2	-2	-3	-2
S_y Storage x Dehard[2]		NS	1.4	NS	NS

[1]Within a column and for each source of variation, means followed by the same letter are not significantly different at p=0.05.
[2]S_y for interactions significant at p=0.05.

Surprisingly, the increase in temperature from 1^0 C to 8^0 C did not produce a more rapid loss of cold hardiness. The only time there was a significant treatment difference was at 4 days where the snow covered plants that were flooded at 1^0 C had a LT_{50} level of –15^0 C compared to –8^0 C for the snow covered plants exposed to 8^0 C. The general low impact of temperature on dehardening, may be partly related to the fact that water takes longer to heat up than air.

While preliminary, these results may suggest some implication for low-lying areas on annual bluegrass greens. Perhaps the loss of cold hardiness is more related to freezing and thawing, with the associated ice injury, than it is to flooding only.

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