**Strategies for Removing Ice from Annual Bluegrass Golf Greens**

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**Summary**

Ice cover on annual bluegrass (*Poa annua* L.) putting greens often causes damage in the cold climates of North America during long winters. The objective of this study is to evaluate various ice removal strategies for use on annual bluegrass putting greens. In addition, the various products were evaluated for their phytotoxicity (damage caused by the product) to the turf. An initial screening study was conducted in order to choose the best treatments for the field study. Selection of treatments was based on effectiveness (efficacy) and phytotoxitity of the products. Results of the field study that was conducted in March 2004, are preliminary in nature. The clear polyethylene and the no cover treatments appeared to be superior to the black polyethylene cover. As far as the individual treatments were concerned, the two ice melters, Landscape and Alaskan, appeared to soften the ice more rapidly than the other treatments.

**Introduction**

In a survey conducted by the PTRC in 1999 for the Prairie Provinces, 60% of golf course superintendents indicated that ice cover injury was sometimes or often a problem to their putting greens. Overwintering problems have always been a major concern but it seems that a weather change over the last few years has resulted in a higher incidence of ice cover injury.

Winter injury is a particular problem on annual bluegrass greens. In a study conducted at the PTRC, annual bluegrass and creeping bentgrass (*Agrostis palustris* Huds.) plots were flooded and cold hardiness levels were monitored at 15, 30, 45, 60, 75 and 90 day intervals (Tompkins, et al, 2001). In addition, cold hardiness levels were determined following ice removal at day 45. For creeping bentgrass, cold hardiness levels were –29$^{o}$C when covered for 90 days, while annual bluegrass plants had a cold hardiness level of only –12$^{o}$C on day 45, -6$^{o}$C on day 60 and were dead by day 75. Removing the ice cover on day 45 did not improve survival.

For golf course superintendents, ice removal from annual bluegrass greens is an important part of preventing winter injury. However, there is a lot of confusion about the best method and timing of the ice removal. The goal of this experiment is to examine different ice removal strategies that might be used by golf course superintendents. Air temperature may influence the technique that works best at a given time and timing of removal may also be a factor. In addition, this study will determine the effect of various ice removal treatments on phytotoxicity to the plants.

**Methodology**

**Screening Study of Radiant Heat Producing Products and Materials - 2003**

Radiant heat producing products and materials were tested in year one. Ice was initially established in 591ml Ziploc containers in the freezer. Treatments were then established in the field on March 25, 2003 in a split plot design with four replications. Main plots included the following four cover treatments: no cover, clear polyethylene, black polyethylene and a clear greens cover. Subplots included three heat attractant materials: control, Milorganite and activated charcoal. The heat attractant materials were placed on the ice in the frozen containers and then were arranged in snow under the winter covers. The experiment was established on a day of full sun and two replications were conducted at one time. Each group of two replications were established and then left for two hours. Individual treatments were rated for surface hardness, and the amount of ice melted after two hours. Surface hardness was determined using a Clegg Impact Tester. For this test, the higher the number, measured in Clegg Impact Units (CIU), the harder the surface. The amount of ice melted was determined by draining off the water into a graduated cylinder. The air temperature under the covers was also recorded.

**Screening of Ice Melters Based on Freezing Point Depression**

*Lab Study for Effectiveness of the Products*

The goal of this screening trial was to identify appropriate ice melter products and determine rates of application for a field study. One problem in comparing different products, some granular and some liquid, is to establish a rate for each product. In order to determine efficacy, each of the products was examined at a number of different rates so that products could be selected for the field trial which commenced in year two and will continue in year three of the study.

Ice was established in small disposable Ziplock square containers (591 ml) to a depth of 1" (2.5cm). Individual products were applied to the surface of the ice and allowed to stand in an incubator for one hour to determine their effects on melting. The individual products were tested at various rates of application and at two temperatures: $-4^0$ C and $-10^0$ C. Treatments that were not effective at $-4^0$ C were eliminated from the trial and not included in the $-10^0$ C trial. The treatments were replicated two times in a randomized complete block design. A statistical analysis was not conducted on this screening trial as the goal was simply to determine what products were effective.

*Phytotoxicity Study - Field Study*

Treatments were applied to the turf in this field study at a rate where a reasonable level of efficacy was demonstrated to determine phytotoxicity. Plugs were watered with the material and phytotoxicity ratings were determined using the ECW Western Canada Section methodology for crop tolerance.

The following treatments were randomized and replicated four times:

1. Sodium chloride
2. Potassium chloride
3. Magnesium chloride
4. Calcium chloride
5. Sodium acetate
6. Calcium magnesium acetate
7. Alaska Ice Melter
8. Great White Ice Melter

9. Urea
10. Ammonium sulphate
11. Methanol
12. Ethanol
13. Ethylene glycol
14. Isopropol alcohol
15. Glycol

**Field Study- 2004-05**
Treatments for this study were chosen based on the results of the initial screening tests for efficacy and phytotoxicity. Treatments for this experiment were initiated on 01 March 04. Twelve wooden frames with outside measurements of 120 cm X 120cm were constructed with 4 x 7 cm lumber. Within these frames, six individual 0.25 $m^2$ cells were constructed. The trial was oriented in a north to south fashion in order to provide maximum exposure to sunlight.

The trial was set up in a split plot design where the main plots were no cover, cover with clear polyethylene and cover with black polyethylene. Sub plots were no treatment, Alaskan Ice Melter, Landscape Ice Melter, methanol, Milorganite and black sand (Early Green Pre-winter Topdressing, Hutcheon Sand, Huntsville, Ont.).

In order to create the ice within each individual frame, plots were watered in a manner to simulate the effect of a freezing rain, with a final goal of 2.5 cm of ice. Prior to the initiation of the ice, an expanded metal plate 25x25cm with a mesh size of 2cm x 5 cm, was placed on the turf surface. A 3/8" eyebolt was fastened in the centre of each of the plates.

During the month of March several attempts were made in creating an acceptable ice cover to conduct the trial. However, unseasonably warm temperatures significantly impaired the ice making. In order to retain ice cover, snow was packed around the outside and on top of each of the frames, which was cover with plywood. This task was performed many times only to have warm temperatures melt the snow and ice. In a final attempt, water was applied to the plots on an hourly basis throughout the night of 22 March and the testing was initiated the following morning. Individual treatments were applied to the plots and then were covered with the corresponding covers. A replication was initiated every hour and kept in place for four hours. After the four hours the covers were removed and the data measurements were collected.

In order to measure the strength of the bond between the ice and the turf surface, a 50 kg spring scale (Pesola Macro Line with drag pointer) was attached to the mesh plate and an upward force was exerted. Once the bond between the ice and the turf surface broke, the spring scale reading was recorded. If the surface bond did not break, a chain hoist with a 4:1 mechanical advantage was attached to the eyebolt and an aluminum sawhorse. The spring scale was attached after the gear assembly and force was applied to the spring scale. Once again values were recorded when the bond between the ice and the turf surface was broken.

Air temperature and soil temperature for each plot was recorded following the initiation of the ice using a Campbell Scientific CR10X data logger running 12 thermocouples through a multi-plexer (Campbell AM25T). Data was collected from each of the main plots and each of the four replications. The thermocouples were attached to the wooden frame so that they were not in contact with the ice or with the covers. This was intended to measure the amount of heat generated under the covers.

Later in the spring of 2004, the plots will be evaluated for three quality factors, colour, density and area cover. These ratings will be based on the National Turfgrass Evaluation Program (NTEP) protocols where numeric values are assigned to individual plots where 9 is best and 1 is poorest, and 6 is considered acceptable. Colour will be evaluated by 1 is a brown dormant turf and 9 is a very uniform dark green colour. Turf density, a measure of the number of shoots per unit area, will be rated based on 1 is a thin, weak turf stand and 9 is a very dense tight-knit stand. The third factor rated will be area cover and values ranged from a 1 for a complete absence of turf to a 9 for complete cover with the desired turf. The presence of weeds or voids in the turf reduced this rating. Phytotoxicity will be determined using the ECW Western Canada Section methodology for crop tolerance.

Ice melt was subjectively rated for percent of melt and then values were converted to an adaptation of the Horsfall-Barratt grading scale where:

0 is no melt
1 = 0% to 3%melt
2 = 3% to 6%melt
3 = 6% to 12%melt
4 = 12% to 25%melt
5 = 25% to 50%melt
6 = 50% to 75%melt
7 = 75% to 88%melt
8 = 88% to 94%melt
9 = 94% to 97%melt
10 = 97% to 100%melt
11 = 100%melt

Surface hardness was determined for each plot using a Clegg Impact Tester (Model 95048 Layfayette Instrument Co.). Values were determined by lifting the weight to a pre-determined height and dropping it onto the ice, which yield a value for surface hardness. For this test, the higher the registered value, measured in Clegg Impact Units (CIU), the harder the surface.

Originally, ice was to be removed from each plot after 7, 21 and 35 days in order to evaluate turf quality and relative cold hardiness levels. However, due to warm temperatures in the month of March this part of the test was not conducted.

Treatments in the field study included:
Main Plots
1. No cover
2. Clear polyethylene
3. Black polyethylene

Sub-plots
1. Untreated control
2. Alaskan Ice Melter 50 kg/100m$^2$
3. Landscape Ice Melter 50 kg/100m$^2$
4. Methanol 50 l/100m$^2$
5. Milorganite 15 kg/100m$^2$
6. Black Sand 15 kg/100m$^2$

**Results and Discussion**

**Screening Study of Radiant Heat Producing Products and Materials - 2003**

The type of cover did not significantly influence ice hardness (Table 1), but the use of the amendments Milorganite or activated charcoal did reduce ice hardness. The greatest amount of liquid was extracted when the combination of no cover and Milorganite was used.

Table 1. Effect of cover and amendment on ice hardness and liquid extracted after 2 hours.

| Treatment | Ice Melted After 2 Hours (1-9 Scale) | Ice Hardness (CIU)[1] | Liquid Extracted After 2 hours (mls) |
|---|---|---|---|
| Type of Cover | | | |
| No cover | 4a | 10a | 28a |
| Clear polyethylene | 4a | 11a | 17 b |
| Black polyethylene | 3a | 13a | 18 b |
| Clear greens cover | 4a | 12a | 22ab |
| | | | |
| Amendment | | | |
| Control | 2a | 14 b | 8 c |
| Milorganite | 5 b | 12a | 36a |
| Activated Charcoal | 5 b | 10a | 18 b |
| | | | |
| Cover x Amend. | | | |
| No cover x Control | 2a | 11a | 4 f |
| No cover x Mil. | 5a | 10a | 53a |
| No cover x AC | 5a | 10a | 26 cd |
| Clear poly. x Control | 5a | 14a | 6 f |

| | | | |
|---|---|---|---|
| Clear poly. x Mil. | 2a | 10a | 29 c |
| Clear poly. x AC | 5a | 9a | 16 e |
| Black poly. x Control | 2a | 14a | 18 de |
| Black poly. x Mil. | 4a | 13a | 18 de |
| Black poly. x AC | 4a | 12a | 17 e |
| Clear greens x Control | 2a | 14a | 6 f |
| Clear greens x Mil. | 6a | 13a | 44 b |
| Clear greens x AC | 5a | 10a | 16 e |

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

However, the greatest increase in air temperature under the cover was associated with the black polyethylene cover (Table 2). Therefore, the 2 hour period was probably not long enough to produce a melting effect from the covers, but was long enough for materials in the amendments (i.e. salts) to cause some melting. In the coming year, a longer period of time will be tested as the temperature differences would indicate that the cover type should produce an effect.

Table 2. Air temperature recorded under the greens covers.

| | Air Temperature ($^0$C) | | | |
|---|---|---|---|---|
| | No Cover | Clear Polyethylene | Black Polyethylene | Clear Greens Cover |
| Starting Temperature | 0 | 0 | 0 | 0 |
| Final Temperature | 2.3 | 4.0 | 5.9 | 3.2 |

**Screening of Ice Melters Based on Freezing Point Depression**

*Lab Study for Effectiveness of the Products*

Based on the information in Tables 3 to 6, a number of products were eliminated from further study due to a lack of efficacy. These included: KCl, ammonium sulphate, sucrose and calcium magnesium acetate. Rates for the upcoming field trial were selected based on results from this study.

Table 3: Amount of ice melt (ml) after one hour at –4$^o$C following application of granular ice melters.

| | Application Rate (kg/100 m$^2$) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ice Melting Product | 6 | 12 | 31 | 62 | 93 | 124 | 155 | 186 | 217 | 248 | 279 |
| NaCl | 5 | 13 | 15 | 20 | 29 | 50 | 38 | 42 | 46 | 51 | 72 |
| $CaCl_2$ | 2 | 5 | 19 | 31 | 50 | 73 | 79 | 87 | 93 | 117 | 136 |
| KCl | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Ammonium Sulfate | 0 | 0 | 2 | 9 | 9 | 4 | 2 | 3 | 0 | 0 | 0 |
| Urea | 0 | 1 | 3 | 14 | 14 | 12 | 16 | 18 | 14 | 3 | 5 |
| Sucrose | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Alaskan Ice Melter | 2 | 8 | 12 | 34 | 38 | 39 | 40 | 62 | 56 | 50 | 56 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Great White Ice M. | 4 | 5 | 10 | 31 | 32 | 33 | 33 | 55 | 38 | 39 | 44 |
| Landscape Ice M. | 2 | 2 | 12 | 23 | 39 | 59 | 66 | 78 | 88 | 101 | 130 |
| Ca Mg Acetate | 1 | 0 | 1 | 9 | 7 | 9 | 8 | 14 | 2 | 2 | 4 |

Table 4: Amount of ice melt (ml) after one hour at –4°C following application of liquid ice melters.

| | Application Rate (L/100 $m^2$) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ice Melting Product | 19 | 37 | 56 | 74 | 93 | 112 | 130 | 149 | 167 | 186 | 205 |
| $MgCl_2$ | 6 | 9 | 14 | 24 | 27 | 30 | 32 | 37 | 37 | 47 | 42 |
| Liquid Ice Melter | 3 | 6 | 19 | 25 | 27 | 37 | 43 | 43 | 48 | 61 | 62 |
| Ethylene Glycol | 13 | 17 | 25 | 39 | 37 | 42 | 40 | 52 | 51 | 50 | 56 |
| Glycol | 4 | 2 | 9 | 15 | 15 | 16 | 17 | 21 | 22 | 15 | 27 |
| Isopropol Alcohol | 12 | 16 | 18 | 29 | 23 | 20 | 19 | 26 | 19 | 25 | 17 |
| Methanol | 14 | 21 | 30 | 37 | 35 | 38 | 40 | 42 | 36 | 33 | 31 |

Table 5: Amount of ice melt (ml) after one hour at –10°C following application of granular ice melters.

| | Application Rate (kg/100 $m^2$) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ice Melting Product | 6 | 12 | 31 | 62 | 93 | 124 | 155 | 186 | 217 | 248 | 279 |
| NaCl | 1 | 2 | 9 | 21 | 22 | 27 | 37 | 42 | 37 | 36 | 45 |
| $CaCl_2$ | 0 | 1 | 11 | 28 | 42 | 53 | 63 | 80 | 88 | 98 | 113 |
| Alaskan Ice Melter | 0 | 1 | 6 | 24 | 27 | 34 | 36 | 52 | 44 | 42 | 45 |
| Great White Ice M. | 1 | 1 | 5 | 15 | 22 | 21 | 24 | 32 | 26 | 23 | 28 |
| Landscape Ice M. | 1 | 2 | 6 | 24 | 31 | 43 | 57 | 77 | 83 | 93 | 99 |

Table 6: Amount of ice melt (ml) after one hour at –10°C following application of liquid ice melters.

| | Application Rate (L/100 $m^2$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ice Melting Product | 19 | 37 | 56 | 74 | 93 | 112 | 130 | 149 | 167 | 186 |
| Liquid Ice Melter | 8 | 8 | 16 | 19 | 26 | 29 | 31 | 38 | 39 | 43 |

*Phytotoxicity Study*

Phytotoxicity ratings were influenced by treatment at each of the 3 rating periods: 3, 7 and 14 days after treatment (Table 7). In comparing the different products, different rates were used based on results from the efficacy study. Consequently, a product like urea which was applied at a very high rate caused more damage than some of the other products which were applied at lower rates. As with the efficacy study, these results are intended only as a screening tool to reduce the number of treatments in the field study which commenced in March 2004.

Table 7: Effect of treatment on phytotoxicity 3, 7 and 14 days after treatment (DAT).

| Treatment | 3 DAT[1] | 7 DAT | 14 DAT |
|---|---|---|---|
| Control | 0a | 0a | 0a |
| Calcium chloride | 79 fg | 39 f | 5a |
| Urea | 83 g | 73 g | 73 c |
| Great white ice melter | 73 efg | 29 def | 0a |
| Landscape ice melter | 0a | 0a | 0a |
| Alaskan ice melter | 54 de | 21 cde | 0a |
| Sodium chloride | 58 ef | 31 ef | 0a |
| Isopropol alcohol | 0a | 0a | 0a |
| Magnesium chloride | 33 cd | 13abc | 0a |
| Methanol | 5ab | 3ab | 0a |
| Ethylene glycol | 25 bc | 15 bcd | 0a |
| Glycol | 33 cd | 18 cde | 0a |
| Liquid ice melter | 78 fg | 31 ef | 18 b |

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

**Results of Field Study - 2004**

It was felt that multiple tests could be performed over a short period of time in a single season with the developed methodologies. However, with the unseasonably warm temperatures in the month of March only one test was conducted and conditions were not ideal for the formation of ice or the collection of the data. As a result, the results are preliminary in nature.

The temperatures collected under the covers were questionable (table 8). Temperatures as high as 31.6$^{o}$C should have melted the ice but did not. However, the no cover treatment, which had the lowest temperature, showed less ice than the two covered treatments.

Table 8 – Temperatures under various covering materials.

| Main Treatments | Average Temperature |
|---|---|
| Ambient air temperature | 11.0 |
| No Cover | 12.6 |
| Clear Polyethylene | 17.3 |
| Black Polyethylene | 31.6 |

Although there were no significant differences between the sub treatments due to high variability from replication to replication, there was a trend. Generally, there was more ice melt on the plots that had no cover than either of the covered treatments. There was no clearly superior product for the sub-treatments.

Table 9 – Ice melt rating. Horsfall-Barratt rating scale where 0 = no melt and 11 = complete melt.

| Treatments | Untreated | Alaskan | Landscape | Methanol | Milorganite | Black Sand |
|---|---|---|---|---|---|---|
| No Cover | 8.0 | 9.0 | 8.3 | 8.0 | 7.7 | 8.0 |
| Clear Poly | 7.7 | 7.7 | 8.3 | 6.7 | 7.3 | 7.0 |
| Black Poly | 6.0 | 5.3 | 5.0 | 6.7 | 5.7 | 5.7 |

Surface hardness displayed some clear trends. Ice under the black cover was much harder than the no cover treatment, while the clear polyethylene was between the two. The Landsape and Alaskan Ice Melters softened the ice the most.

Table 10 – Surface hardness test. Higher values equal harder ice surface measured in Clegg Impact Units.

| Treatment | Untreated | Alaskan | Landscape | Methanol | Milorganite | Black Sand |
|---|---|---|---|---|---|---|
| No Cover | 9.5 | 12.9 | 10.2 | 14.8 | 25.0 | 23.3 |
| Clear Poly | 23.3 | 10.1 | 8.9 | 28.2 | 14.1 | 20.2 |
| Black Poly | 44.2 | 9.9 | 26.3 | 55.7 | 56.4 | 41.7 |

The ice bond was the least for the no cover treatments while the black polyethylene had the highest bonding between the ice and the turf surface. There were no clear trends for the individual products.

Table 11 – Ice bond test. Force (kg) to break bond between ice and turf surface.

| Treatment | Untreated | Alaskan | Landscape | Methanol | Milorganite | Black Sand |
|---|---|---|---|---|---|---|
| No Cover | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Clear Poly | 2.3 | 1.0 | 1.0 | 3.3 | 1.7 | 2.3 |
| Black Poly | 7.6 | 26.0 | 12.3 | 6.7 | 31.3 | 21.0 |

*This trial was supported by the Canadian Turfgrass Research Foundation and the Alberta Turfgrass Research Foundation.*