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 was to evaluate various ice removal strategies for use on annual bluegrass putting greens. In addition, the various products were evaluated for turf injury (damage caused by the product). An initial screening study was conducted in order to choose the best treatments for the field study. Selection of treatments was based on effectiveness and turf injury caused by the products.

Results of the five separate field tests showed that there was ice removal was not improved with the use of covering materials. As far as the individual treatments were concerned, the Landscape and Alaskan ice melters had the greatest effect on reducing ice hardness, increasing ice melt and reducing the ice bond. The methanol was not as effective as either of the granular ice melters in the three tested parameters. The radiant heat producing materials, black sand and Milorganite, appeared to be more effective when light intensities were greater in the late winter study. It also appeared that full sun improved their performance.

This field trial was conducted over a three year period to attempt to determine turf injury as a result of the various products. Turf injury was measured as percent area damage. There were no differences in turf injury when considering the covering materials. On one occasion Alaskan Ice Melter caused greater injury than any of the other treatments. Landscape Ice Melter also had significantly more injury than the other treatments. Methanol, Milorganite and black sand had injury that was similar to the untreated control.

Relative hardiness levels were measured in year three to determine whether the different ice melting strategies negatively impacted hardiness levels. The early winter test of year three showed that there were no differences in relative hardiness levels and the plant grew on normally after the freeze test, which might indicate that there was no damage from the 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

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

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.

Turf Injury Study
Treatments were applied to the turf in this field study at a rate where a reasonable level of efficacy was demonstrated to determine turf injury. Plugs were watered with the material and percent turf injury was 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. Ethylene glycol

Field Study – 2004-2006
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, Hutcheson Sand, Huntsville, Ont.). Treatments for this study were selected based on the results of the initial screening tests for effectiveness of the products (efficacy) and turf damage (phytotoxicity).

In order to develop the individual plots, twelve wooden frames with outside measurements of 120 cm X 120cm were constructed with 4 x 7 cm lumber. A plywood cover was constructed to fit over the frames. Within these frames, six individual 0.25 m^2 cells were constructed. Plots were oriented in a north to south fashion in order to provide maximum exposure to sunlight. The frames were then banked with composted soil to reduce the leakage of water from the frames during ice formation. Enough plots for two separate experiments were set out in late fall of each year prior to the onset of winter.

In all, five individual tests were completed over the duration of this trial. In year one, only one test was conducted in March, while in year two tests were conducted in January and March and in year three, December and March tests were undertaken. 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 25 by 25cm with a mesh size of 2 by 5 cm, was placed on the turf surface. A 1cm eyebolt was fastened in the centre of each of the plates.

In year one, difficulty developing the ice cover was encountered due to unseasonably warm temperatures. Several unsuccessful attempts were made to develop the ice and on each attempt, snow was packed around the frames and on top of each of the covers for insulation purposed. In a final attempt to create the ice, water was applied to the plots on an hourly basis throughout the night of 22 March and the testing was initiated the following morning.

In the year two and three of the study, ice development was initiated when temperatures were sufficiently cold and individual frames were then covered with the plywood and snow. In year two, the January test was conducted 35 days after ice initiation and the March test was conducted 20 days after initiation of the ice. In year three the test was conducted 16 days after initiation in December and 29 days after initiation in March.

Individual treatments were pre-measured and then applied at 30 minute intervals to each of the replications. This was done in order to allow sufficient time for data collection. Following application, the plots were covered with the corresponding polyethylene covers and then left for four hours, after which the covers were removed and the data were collected.

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

To determine the effectiveness of the various products and covers, data were collected for ice melting capabilities, surface hardness of the ice, strength of the bond of the ice to the turf surface, air temperatures under the covering materials, and turf damage.

The ice melting capability of the various treatments was subjectively rated for percent of ice melt and then values were converted to an adaptation of the Horsfall-Barratt grading scale where: 0 = 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., Lafayette, IN). Values were determined by lifting the weight to a pre-determined height and dropping it onto the ice, which yielded a value for surface hardness. For this test, the higher the registered value, measured in Clegg Impact Units (CIU), the harder the surface.

In order to measure the strength of the bond between the ice and the turf surface, a 50 kg spring scale (Pesola Macro Line, Switzerland) was attached to the expanded metal 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 on one replication was recorded following the initiation of the ice using a data logger (CR10X, Campbell Scientific, Edmonton, Alberta) running 12 thermocouples through a multi-plexer (AM25T, Campbell Scientific). 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 polyethylene covers. This was intended to measure the amount of heat generated under the covers.

In the spring of each year, the plots were evaluated for percent turf injury. This factor was determined by assessing the percentage of the plot that displayed symptoms of injury. In addition, injury recovery ratings were assessed in a similar fashion throughout the spring period. This assessment was used as an indication of turf injury, a particular concern for the salt and alcohol based products.

In year three of the field study relative hardiness levels were determined to assess if there were treatment differences. Once again, this was intended to assess any specific injury as a result of the application of the salt and alcohol based products. Samples were collected the day after the ice melting test from the clear polyethylene treatment only. In December, samples were collected from each of the six sub-plots in one replication, while, in March, samples were collected from all four replications. A 10cm by 10cm plug was removed from each plot to an approximate depth of 2.5cm. Individual plugs were then sub-sampled using a 1.8cm soil probe and placed in trays with a piece of moistened paper placed underneath. Trays were refrigerated overnight at 4^oC and then were transferred to a programmable freezer set to a temperature of -5^oC. Plants were held at this temperature for a period of two hours and then temperatures were lowered in a step-wise fashion at 2^oC per hour. Plugs were removed at temperatures that were thought to be in the range of the relative hardiness level and then were placed back in the refrigerator and maintained at 4^oC overnight. Plugs were then transplanted into potting soil, watered and placed in a growth chamber at $20/10^oC$ day-night temperatures with 14 hours of artificial light. Plugs were allowed to grow on for a period of four weeks.

Initially, eight plugs were destructively sampled and it was determined that there was an average of 20 individual plants per plug. Following this, plugs that had been subjected to the freeze test were destructively sampled and live plants that did not come from seed were counted. An LT_{50} value (the lethal temperature to kill 50% of the plants) was determined when there were 10 living plants in the plug.

Golf Course Study

A study to determine the effect of three ice melting treatments at the Olds Central Highlands Golf Course was undertaken on December 21, 2004. A number of *Poa annua* greens developed an ice layer that was 1-2 cm thick during a snow melt that occurred in November. Alaskan Ice Melter and Absolute Zero Ice Melter at rates of 50 kg/100m^2 were compared with methanol at 50 litres/100m^2 and an untreated control for their effects on ice melting and removal. Products were applied evenly on plots which measured 0.5 by 0.5 metres and were replicated four times in a randomized complete block design. Products were applied at 10:30 AM and then were evaluated two hours later.

Surface hardness was measured prior to the treatment application and then after two hours after application. One value was recorded for each plot using the Clegg impact tester. In addition, subjective ice melt ratings were conducted using the same methodology as in the field study.

Results and Discussion

Screening Study of Radiant Heat Producing Products and Materials

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 no cover and Milorganite was used together.

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 possibly not long enough to produce a melting effect from the covers, but was long enough for materials in the treatments (i.e. salts) to cause some melting.

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

Covers	Final Ice Hardness	Ice Melting Effectiveness	Liquid Extracted
	Clegg impact units	0 -11 scale	mls
Covers			
Clear polyethylene	11a	4a	17b
Black polyethylene	13a	3a	18b
Clear greens cover	12a	4a	22ab
No cover	10a	4a	28a
$LSD_{0.05}$ =	*n/s*	*n/s*	*0.6*
Products			
Milorganite	12a	5a	36a
Activated charcoal	10a	5a	18b
Untreated control	14b	2b	8c
$LSD_{0.05}$ =	*1*	*0.4*	*4*
Cover x Product Interaction			
Clear poly. x Control	14	5	6f
Clear poly. x Milorganite	10	2	29c
Clear poly. x Activated Charcoal	9	5	16e
Black poly. x Control	14	2	18de
Black poly. x Milorganite	13	4	18de
Black poly. x Activated Charcoal	12	4	17e
Clear greens x Control	14	2	6f
Clear greens x Milorganite	13	6	44b
Clear greens x Activated Charcoal	10	5	16e
No cover x Control	11	2	4f
No cover x Milorganite	10	5	53a
No cover x Activated Charcoal	10	5	26cd
$LSD_{0.05}$ =	*n/s*	*n/s*	*9*

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

Table 2 - Air temperature recorded under the greens covers.

	No Cover	Clear Polyethylene	Black Polyethylene	Clear Greens Cover
	Air Temperature C^o			
Starting Temperature	0	0	0	0
Final Temperature	2.3	4.0	5.9	3.2

Screening of Ice Melters for Effectiveness of the Products

Based on the information in Tables 3 to 5, 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 of application for the field trial were selected based on results from this study.

Table 3 - Amount of ice melt (ml) after one hour at –4°C.

	Application Rate (kg/100 m^2)										
	6	12	31	62	93	124	155	186	217	248	279
Granular Product											
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

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

Turf Injury Study

Turf injury ratings were influenced by treatment at each of the 3 rating periods: 3, 7 and 14 days after treatment (Table 5). 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.

Table 5 - Turf injury 3, 7 and 14 days after treatment (DAT).

Ice Melting Product	3 DAT	7 DAT	14 DAT
	% Damage		
Calcium chloride	79fg	39f	5a
Urea	83g	73g	73c
Great white ice melter	73efg	29def	0a
Landscape ice melter	0a	0a	0a
Alaskan ice melter	54de	21cde	0a
Sodium chloride	58ef	31ef	0a
Isopropol alcohol	0a	0a	0a
Magnesium chloride	33cd	13abc	0a
Methanol	5ab	3ab	0a
Ethylene glycol	25bc	15bcd	0a
Glycol	33cd	18cde	0a
Liquid ice melter	78fg	31ef	18b
Untreated control	0a	0a	0a
$LSD_{0.05}$ =	*23*	*14*	*10*

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

Field Studies

Late Winter Test March 23, 2004

Products and covering materials were selected for the field study based on the results of the screening study and the turf injury study. Black sand was substituted for activated charcoal due to its availability and success in other studies.

Initially, 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.

Although there were no significant differences between the covers due to high variability from replication to replication, there was a trend. Generally, there was less ice melt on the plots that had no cover in comparison to the covered treatments (Table 6). There was no clearly superior product for the sub-treatments.

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 (Table 6). The Alaskan Ice Melter softened the ice the most.

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 (Table 6). There were no clear trends for the individual products.

Turf injury ratings showed that the two ice melters had significantly more injury that the other treatments. This would indicate that there was some toxicity to the turf as a result of the application of the ice melters. The Alaskan Ice Melter had significantly higher turf injury than did the Landscape Ice Melter.

Table 6 – Results of ice melter trial conducted on March 23, 2004.

	Air Temperature	Initial Ice Hardness	Final Ice Hardness	Ice Melting Effectiveness	Ice Bond	Turf Injury May 6/04
	C°	– Clegg impact units –		0-11 scale	g/cm^2	%
Covers						
Clear polyethylene	23.3ab	n/r*	18a**	7.4a	3a	
Black polyethylene	31.7a	n/r	39a	5.7a	29a	
No cover	12.7b	n/r	16a	8.2a	2a	
$LSD_{0.05}$ =	*11.5*		*n/s*	*n/s*	*n/s*	
Products						
Alaskan ice melter	50 kg/100m²	n/r	11a	7.3a	15a	37.6c
Landscape ice melter	50 kg/100m²	n/r	22a	7.2a	8a	20.9b
Methanol	50 litres/100m²	n/r	28a	7.1a	6a	3.5a
Milorganite	15 kg/100m²	n/r	34a	6.9a	18a	0.4a
Black sand	15 kg/100m²	n/r	29a	6.9a	13a	1.0a
Untreated control		n/r	21a	7.2a	6a	0.0 a
	$LSD_{0.05}$ =		*n/s****	*n/s*	*ns*	*12.7*

*n/r not rated
** Within a column, numbers followed by the same letter are not significantly different at p=0.05.
*** not significant at p=0.05

The temperatures collected under the covers were difficult to explain (Table 7). Temperatures as high as 31.6°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 7 – Temperatures under various covering materials.

	Average Temperature
Ambient air temperature	11.0
No Cover	12.6
Clear Polyethylene	17.3
Black Polyethylene	31.6

Early Winter Test January 18, 2005

The first of two winter tests was conducted on January 18, 2005. This test was initiated at 10 AM when the air temperature was -5°C. The sky was overcast and the winds were calm. The skies remained overcast and one half hour after data collection began fog moved in and remained for the balance of the testing period. Air temperatures remained constant throughout the test period.

The uncovered treatments were observed every thirty minutes over the four hour period and information was recorded. Following application of the products an immediate reaction between the ice and the Alaskan Ice Melter, the Landscape ice melter and the methanol resulted in an audible crackling. Granules in both of the ice melters were observed to be drilling through the upper surface of the ice and thirty minutes after application the ice surfaces were rough and pitted and channels in the ice were observed. The Alaskan Ice Melter produced a bluish coloration as it dissolved into the ice and after one hour it appeared to have melted the ice more than the Landscape Ice Melter. The top 0.5cm of ice on the plots treated with methanol was transformed into water which remained on top of the still frozen ice. The amount of iced melted did not change after the first 30 minutes.

After four hours, the covers were removed and the hardness of the ice, the melting effect and ice bond were evaluated. A noticeable film of water was present on the plots at this time.

Table 8 – Results of ice melter trial conducted on January 18, 2005.

Temperature		Air	Initial Ice Hardness	Final Ice Hardness	Ice Melting Effectiveness	Ice Bond
		C°	– Clegg impact units	–	0-11 scale	g/cm²
Covers						
Clear polyethylene		-2.3	116a*	69a	2.6a	145a
Black polyethylene		-4.8	105a	66a	2.8a	141a
No cover		-4.5	98a	55a	2.5a	149a
	$LSD_{0.05}$ =	*n/s*	*n/s*	*n/s*	*n/s*	*n/s*
Products						
Alaskan ice melter	50 kg/100m²		101	40a	4.6a	98a
Landscape ice melter	50 kg/100m²		116	53a	4.1ab	126a
Methanol	50 litres/100m²		109	44a	3.8b	157a
Milorganite	15 kg/100m²		102	83b	1.0c	170a
Black sand	15 kg/100m²		108	77b	1.5c	170a
Untreated control			101	83b	1.0c	148a
		$LSD_{0.05}$ =	n/s**	*14.5*	*0.7*	*n/s*

* Within a column, numbers followed by the same letter are not significantly different at p=0.05
** not significant at p=0.05

There were no differences between the covering materials and the uncovered plots. This would indicate that there was no benefit to covering the turf following the application of the products (Table 8).

The three ice melting products, Alaskan Ice Melter, Landscape Ice Melter and methanol all reduced the hardness of the ice. The Milorganite and the black sand did not significantly reduce the hardness of the ice when compared to the untreated control (Table 8).

The two granular ice melters, Alaskan and Landscape, were more effective in melting the ice than all of the other products. The methanol was significantly better at melting the ice than the either of the heat attractants materials, Milorganite and black sand. These two products were no different than the untreated control (Table 8).

Although there were no significant differences between the force required to break the ice bond, the Alaskan Ice Melter had the lowest value (Table 8).

Table 9 - Turf injury early winter study May 17, 2005.

Ice Melting Product		Turf Injury
		% Damage
Covers		
Clear polyethylene		100a*
Black polyethylene		100a
No cover		100a
	$LSD_{0.05}$ =	n/s
Products		
Alaskan ice melter	50 kg/100m^2	100a
Landscape ice melter	50 kg/100m^2	100a
Methanol	50 litres/100m^2	100a
Milorganite	15 kg/100m^2	100a
Black sand	15 kg/100m^2	100a
Untreated control		100a
	$LSD_{0.05}$ =	*n/s*

*Within a column, numbers followed by the same letter are not significantly different at p=0.05
** not significant at p=0.05

Late Winter Test March 8, 2005

Products for the first replication were applied and the covers were spread over the wooden frames and stapled down at 9:40 AM. Each subsequent replication was initiated one half hour after the previous replication. Air temperature was -2^{0}C and the sky was clear and calm for the duration of the trial.

Once again, there was an immediate reaction where there was an audible crackling between the ice and the granular ice melters and the methanol. Four hours after the initiation of the study, the covers were removed from the first replication and data was collected. Pools of water up to 1.25cm deep were observed on top of still frozen ice. Air temperatures were: 2^{0}C for the uncovered plot, 4^{0}C for the clear polyethylene plot, and 15^{0}C for the black polyethylene.

When products were applied on replication two the air temperature had risen to 0^{0}C. When covers were removed the air temperatures were: 3^{0}C for the uncovered plot, 6^{0}C for the clear polyethylene plot, and 8^{0}C for the black polyethylene. When replication three was initiated temperatures had risen to 3^{0}C. Air temperatures for the uncovered plot were

3^0C, 6^0C for the clear polyethylene plot, and 9^0C for the black polyethylene. When replication four was initiated temperatures had risen to 4^0C. Air temperatures for the uncovered plot were 7^0C, 7^0C for the clear polyethylene, and 10^0C for the black polyethylene.

Table 10 – Results of ice melter trial conducted on March 8, 2005.

Temperature	Air	Initial Ice Hardness	Final Ice Hardness	Ice Melting Effectiveness	Ice Bond
	C°	– Clegg impact units –		0-11 scale	g/cm^2
Covers					
Clear polyethylene	4.5b	137a*	28a	7.0a	13a
Black polyethylene	5.5b	137a	36ab	6.9a	24a
No cover	10.7a	141a	50b	6.7a	66b
$SD_{0.05}$ =	*4.5*	*n/s*	*18*	*n/s*	*30*
Products					
Alaskan ice melter	50 kg/100m^2	138a	24a	7.7a	49abc
Landscape ice melter	50 kg/100m^2	138a	34ab	7.3ab	36ab
Methanol	50 litres/100m^2	132a	39abc	6.8bc	35a
Milorganite	15 kg/100m^2	139a	45bc	6.6cd	58c
Black sand	15 kg/100m^2	144a	35ab	6.8bc	56c
Untreated control		139a	53c	6.1d	50bc
	$LSD_{0.05}$ =	*n/s***	*16*	*0.6*	*16****

* Within a column, numbers followed by the same letter are not significantly different at p=0.05
** Not significant at p=0.05
*** Within this column numbers followed by the same letter are not significantly different at p=0.10

Although the temperature was significantly higher under the black polyethylene cover, it did not impact the melting or the force to break the ice bond. In fact, those two values were significantly lower than the other covering materials. As with the previous studies, there was no benefit to covering the turf as the uncovered treatment was the best for surface hardness and breaking the ice bond (Table 10).

The granular ice melters, Alaskan and Landscape, were the best treatments for reducing ice hardness, melting effectiveness and for reducing the force to break the ice bond. When considering the ice hardness the methanol and black sand were equal to the two granular ice melters (Table 10).

It was expected that the late winter test would have an effect on the radiant heat attractants, Milorganite and black sand. As light intensities increase from early to late winter, the heat attractants should work more effectively. However, this did not clearly happen.

Table 11 - Turf injury late winter study May 17, 2005.

Ice Melting Product		Turf Injury
		% Damage
Covers		
Clear polyethylene		37a
Black polyethylene		36a
No cover		44a
	$LSD_{0.05}$ =	n/s
Products		
Alaskan ice melter	50 kg/100m^2	36a
Landscape ice melter	50 kg/100m^2	35a
Methanol	50 litres/100m^2	32a
Milorganite	15 kg/100m^2	37a
Black sand	15 kg/100m^2	45a
Untreated control		47a
	$LSD_{0.05}$ =	*n/s*

* Within a column, numbers followed by the same letter are not significantly different at p=0.05
** Not significant at p=0.05

Early Winter Test December 14, 2005
The trial was conducted on December 14 and the treatments applied to the first replication at 10 AM. Each successive replication was conducted one-half hour later than the previous. The highest temperatures recorded under the various covering materials were 1.2^{o}C for the uncovered plots, 6.9^{o}C for the plots covered with clear polyethylene and 3.4^{o}C for the black polyethylene. There were no differences between the various covering materials for any of the criteria measured.

The granular ice melters significantly reduced the surface hardness of the ice when compared with the black sand or untreated control. Values for the methanol and the Milorganite were intermediate between the ice melters and the black sand and the untreated control.

Once again, the two granular ice melters Alaskan and Landscape Ice Melter were significantly better than any of the other melting strategies when considering the level of ice melting. The methanol was better than either the Milorganite or the black sand. Both of these were significantly better than the untreated control (Table 12).

When considering the bond between the ice and the turf surface, the Alaskan Ice Melter was better than any of the other treatments(Table 12).

Table 12- Table 10 – Results of ice melter trial conducted on December 14, 2005.

Temperature		Air	Initial Ice Hardness	Final Ice Hardness	Ice Melting Effectiveness	Ice Bond
		C^o	– Clegg impact units –		0-11 scale	g/cm^2
Covers						
Clear polyethylene		6.9	132a	97a	3.9a	205a
Black polyethylene		3.4	132a	86a	3.8a	209a
No cover		1.2	140a	97a	3.6a	222a
		$LSD_{0.05}$ =	*n/s*	*n/s*	*n/s*	*n/s*
Products						
Alaskan ice melter	50 kg/100m^2		135a	78a	6.0a	157a
Landscape ice melter	50 kg/100m^2		138a	79a	5.7a	226bc
Methanol	50 litres/100m^2		133a	91ab	4.2b	192ab
Milorganite	15 kg/100m^2		131a	97ab	2.8c	230bc
Black sand	15 kg/100m^2		140a	109b	3.0c	210abc
Untreated control			132a	106b	1.0d	255c
		$LSD_{0.05}$ =	*n/s*	*19*	*0.4*	*60*

* Within a column, numbers followed by the same letter are not significantly different at p=0.05
** Not significant at p=0.05

Late Winter Test March 28, 2006

Turf samples were collected from within the frames for each replication prior to the initiation of ice development in order to determine the relative hardiness levels. Samples were also collected from outside the frames for comparison purposes.

Ice formation began on February 28 and was complete on March 3, 2006. A 2.5 cm thick layer of clear ice was successfully created in each of the 0.25 m^2 plots. Testing was conducted 29 days after ice formation. The trial was initiated at 10:15 AM and was conducted similar to the other tests where successive replications commenced one-half hour after the previous replication. The sky was partially overcast at the start of the trial, mostly sunny at mid-day and then overcast again towards the end of the test period. The ambient air temperature ranged from 2^{o}C at the start of the period to a high of 5^{0}C at 1:00 PM. Temperatures under the covers reached 4.9^{o}C for the uncovered plots, 14.7^{o}C for the clear polyethylene and 26.8^{o}C for the black polyethylene at 1 PM.

The methanol, Alaskan and Landscape ice melters all caused an immediate crackling after the treatments were applied to the ice. The Milorganite and black sand, and the Alaskan and Landscape ice melters, drilled holes through the ice. By 12:00 PM the upper ice surfaces were very wet, and condensation was observed on the clear polyethylene covers. By 2:00 PM pools of water were present in the frames with no cover and the clear polyethylene cover. The ice under the black polyethylene was noticeably less melted than the other two.

When considering the effectiveness of the covering materials the no cover and the clear polyethylene were significantly better than the black polyethylene for ice hardness. The two granular ice melters reduced the surface hardness the most (Table 13).

The black polyethylene was not as effective at melting the ice as were the no cover and the clear polyethylene cover (Table 13). The two granular ice melters and the Milorganite were the best ice melting strategies when considering the level of ice melt. The black sand and the methanol were not as effective.

There were no differences in the ice bond measurements (Table 13).

In this test considerable melting had occurred after four hours which affected the results. It would seem when light intensities are greater at the end of March that four hours between initiation of the treatments and data collection was too long a period of time. It would appear that ice removal strategies could be initiated well before the four hour period.

A final rating on the relative hardiness levels and turf injury was not yet completed when this report was written.

Table 13 – Results of ice melter trial March 28, 2006.

Temperature		Air	Initial Ice Hardness	Final Ice Hardness	Ice Melting Effectiveness	Ice Bond
		C^o	— Clegg impact units —		0-11 scale	g/cm^2
Covers						
Clear polyethylene		14.7	133a	14a	6.3a	16a
Black polyethylene		26.8	134a	41b	4.3b	77b
No cover		4.9	135a	12a	6.3a	12a
		$LSD_{0.05}$ =	*n/s*	*10*	*1.6*	*16*
Products						
Alaskan ice melter	50 $kg/100m^2$		138a	13a	6.5a	29a
Landscape ice melter	50 $kg/100m^2$		130a	20ab	6.3ab	36a
Methanol	50 $litres/100m^2$		136a	29c	5.4b	34a
Milorganite	15 $kg/100m^2$		133a	24bc	6.2ab	34a
Black sand	15 $kg/100m^2$		135a	21b	5.0b	34a
Untreated control			133a	27bc	4.5b	36a
		$LSD_{0.05}$ =	*n/s*	*7*	*1.2*	*n/s*

* Within a column, numbers followed by the same letter are not significantly different at p=0.05
** Not significant at p=0.05

Golf Course Study
The trial was initiated at 10:30 AM when the air temperature was -2^{o}C. Data collection followed two hours later when the air temperature was 0^{o}C.

Both granular ice melting products, Alaskan and Absolute Zero, significantly reduced the ice hardness after two hours. However, there was no difference between the methanol and the untreated control. As far as ice melting effectiveness, the two ice melting products and the methanol almost completely melted the surface ice and there were no differences between the three melters. All were significantly better than the untreated plots. An evaluation of turf injury and turf quality will be conducted in the spring time after green up to determine if there were any negative affects of the products.

Turf injury was complete in the area of this test and there were no differences between treatments. Recovery in this area was not complete until July 1.

Table 12 – Affect of ice melting products, golf course test 2004.

		Initial Ice Hardness	Final Ice Hardness	Ice Melting Effectiveness
		– Clegg impact units –		0-11 scale
Products				
Alaskan ice melter	50 kg/100m^2	100a*	36a	8.3a
Absolute ice melter	50 kg/100m^2	110a	49a	8.5a
Methanol	50 litres/100m^2	120a	90b	8.3a
Untreated control		114a	88b	3.5b
	$LSD_{0.05}$ =	*n/s***	*29*	*1.3*

* Within a column, numbers followed by the same letter are not significantly different at p=0.05
** Not significant at p=0.05

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