

# **Evaluation of Ventilation Systems under Winter Covers to Prevent Injury from Anoxia on Annual Bluegrass Greens**

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## **Summary**

Winter damage to annual bluegrass (*Poa annua* L.) golf course putting greens often occurs in the cold climates of North America. To prevent direct low-temperature damage and ice encasement impermeable tarps with an insulating material underneath are used on putting greens. The Glendale Golf and Country Club is a well established club in Edmonton, Alberta that has had a history of winter injury on their putting greens while using an impermeable tarping system. The extreme injury event from the 2006-2007 winter was presumably associated with conditions of anoxia under impermeable protective winter covers. The objective of this study was to evaluate various ventilation systems under impermeable winter covers that would prevent the development of gas concentrations that would result in injury due to anoxia. The study was conducted onsite at the Glendale Golf and Country Club on their annual bluegrass putting greens over a three year period beginning in the winter of 2011-2012. Four ventilation systems were installed in early November of each year prior to permanent snow cover and their efficacy in preventing damage under the covers was compared. The four systems included: a simple supplementary ventilation system, the supplemental ventilation system with exhaust vents, the supplemental ventilation system with the addition of a passive ventilation system using two 'roof turbines' and a system comprised of the supplemental ventilation system with a complex matrix of pipes attached to exhaust vents were installed under the covers. During the three years of this study no damage occurred while these systems were installed under the tarps. Both carbon dioxide and oxygen levels were maintained within an acceptable range. Consequently, the cover system used prevented damage from low temperature injury and the ventilation systems, whether simple or complex, prevented damage from conditions associated with anoxia.

## **Introduction**

Winter damage to golf course putting greens can be caused by a number of different factors, but injury from low temperature and injury from prolonged ice cover are particularly pertinent problems here in Canada. Injury can be more serious if the predominant grass species is annual bluegrass (*Poa annua* L.), which typically dominates older greens in the cold climates of the northern hemisphere.

Freezing injury can occur when ice crystals form within the cell and damage the cell membrane due to expansion. Typically in the fall, plants accumulate food within the cells in the form of simple sugars, a process known as hardening. These accumulated foods serve to depress the freezing point and the greater amount of food stored the lower the freezing point. When plants break dormancy in the spring following warm temperatures, they will rapidly utilize these stored foods and the plant's ability to resist freezing is reduced. At this time, temperatures just below freezing may be sufficient to cause damage particularly if plants are submersed in water.

Ice cover injury occurs as a result of either oxygen depletion (anoxia) or toxic gas build-up under the ice (Rochette et al., 2006). When ice forms as a result of a mid-winter thaw or rainfall event, it seals the surface and can disrupt the normal flow of gases to and away from the plant. Previous research showed that a rapid loss of relative hardiness of annual bluegrass plants began

to occur somewhere between 45 and 60 days of continual ice cover while plants under non-iced conditions lost hardiness very slowly (Tompkins, Ross and Moroz, 2004). In contrast, creeping bentgrass was still alive after 120 days of continual ice cover. In an earlier study, Beard (1964) found that injury to annual bluegrass occurred 75 days after continual ice cover.

Similarly, anoxia can occur when impermeable covers are used to protect the green from freezing temperatures. Rochette et al. (2006) found that under impermeable covers anoxic conditions occur over time based on the soil organic matter content of the putting green. Once anoxia occurs, plants undergo anaerobic respiration which is inefficient in the breakdown of stored sugars and can produce potentially phytotoxic metabolites such as ethanol and carbon dioxide (Rochette et al., 2006). Therefore, factors that lead to injury are the result of a depletion of food reserves, oxygen depletion, and/or a build-up of toxic metabolites. Sensitivity to conditions of anoxia has been reported as being common amongst various plant species (Bertrand et al., 2001).

#### *History of Winter Injury at The Glendale Golf and Country Club*

The Glendale Golf and Country Club is a well established club in Edmonton, Alberta that has putting greens that are predominantly annual bluegrass. There has been a history of winter injury at the club and many strategies have been tried over the years to effectively prevent the injury.

Prior to the winter of 2006-2007 a system of covers was installed that had an impermeable white top cover over a 6mm insulating layer of closed-cell foam. Covers were installed on unfrozen turf in late October just prior to a deep permanent snow cover. Injury in the spring was severe and was predominantly in the middle of the greens and no injury occurred 3-5m in from the edge of the covering material (Fig. 1). The injury was thought to be a result of anoxic conditions that formed under the covers. Recovery time was both lengthy and costly.



Figure 1 – Anoxia injury on annual bluegrass green covered with an impermeable cover and an early heavy snow cover on an unfrozen green. Note good survivability at outer edges.

The covering system that was installed in 2007-2008 had two modifications, the insulation layer was a bubble wrap material and a ventilation system was incorporated. In order to reduce the possible effects from anoxia, ventilation tubes were installed under the covers and the greens were ventilated on a regular basis by attaching leaf blowers to the tubes and circulating air under the covers. Survivability was improved, but the conditions that winter were not as severe.

#### *The Need for Monitoring and Ameliorating Conditions under the Covers*

The superintendent of the club wanted to monitor the levels of carbon dioxide and oxygen under the covers in order to determine the optimum timing of ventilation events. As a result, a study was initiated with the following objectives:

1. Develop a cover system that would prevent winter injury.
2. Develop a system to monitor temperature and gas concentrations under the cover system.
3. Develop a system to ventilate air under the covers in order to prevent gas concentration fluctuations.

#### **Methodology**

This three year study was established in the fall of 2011 on predominantly annual bluegrass greens at The Glendale Golf and Country Club in Edmonton, AB. Greens at this golf course are a mixture of new and old construction techniques. The older greens were originally constructed with a high soil component that had been top-dressed with sand for several years creating a 75-100mm layer of sand at the surface. Five greens had been re-built with modified USGA specifications. Two greens were excluded from this trial as they were newly constructed and, based on the previous year's data, did not have significant fluctuations in gas concentrations. The observations made on the two excluded greens corroborates the findings of Rochette et al. (2006).

All greens were covered with a white impermeable synthetic cover that was laid over an insulating material. White was chosen as the colour of the covering material as it was most reflective which prevented large fluctuations in temperatures at the turf surface. The insulating material was a 12mm thick polyethylene bubble wrap type of material. Each bubble was approximately 25mm in diameter and was open on the bottom which provided an air space and the opportunity for air movement. Covers and the insulating materials were installed in early November of each year of the study.

Since the study was conducted on a golf course it was agreed that supplementary ventilation would occur on those occasions when carbon dioxide levels were greater than 5% or oxygen levels were less than 10%. In the first year of the study, these guidelines were generally adhered to, but in subsequent years supplementary ventilation occurred more frequently.

Prior to the installation of the covering system, a supplementary ventilation system was laid out on each green (Fig. 2). The supplementary ventilation system consisted of three collapsible 6ml polyethylene vent tubes with 2.5cm holes on 1m spacings. The tubes were attached to 10cm solid flexible drainage pipes at the edge of the green just under the cover. The drainage pipe then extended out and was mounted on a snow fence t-bar so that the ends would remain above the snow line. When supplementary ventilation was necessary, the drainage pipe was connected to a leaf blower (model Stihl BR600 output 712 cfm). When started, the blowers would inflate the vent tubes and the gases would dissipate around the edges of the tarp.

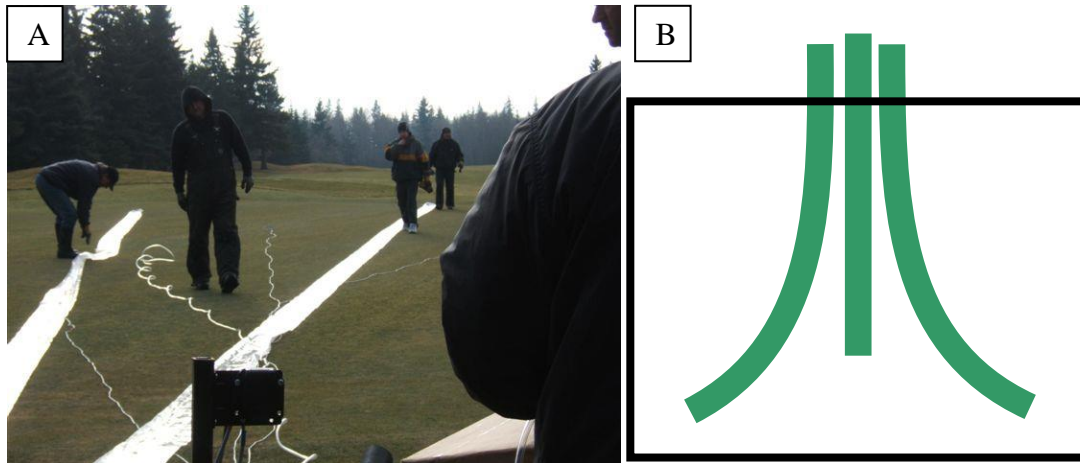


Figure 2. A. Supplemental ventilation and monitoring equipment installed on greens. Photo shows collapsible tubing, temperature sensors and sampling tube. B. Diagram shows the configuration of the supplementary ventilation system.

At the same time, monitoring equipment was installed to determine temperature and gas concentrations under the covers. A portable temperature meter (Johnson Controls A419) was used to collect data from individual sensors (Johnson Controls A99BB-200C Silicon PTC Temperature Sensor) that were placed in the front, middle and back on the turf surface under the insulating material. Carbon dioxide and oxygen were monitored using a Portable Multi-Gas Detector (RKI Instruments Inc. Model: Eagle 71-0028RK). A single sampling tube was laid out and extended to the middle of each green. Both temperature and gas concentration values were collected at a similar time of day each week beginning in November and ending in April.

The experiment was established in a Randomized Complete Block Design with four treatments and four replications. Blocking was done by grouping greens that had similar gas concentrations as determined by the previous winter's readings.

Treatments included four ventilation systems:

- Supplemental ventilation (control )
- Supplemental + Exhaust vents only (exhaust only)
- Supplemental + “Roof turbine” vents (passive venting)
- Supplemental + Vent tube matrix (vent tubes).

The ‘exhaust vents only’, had four solid drain pipes inserted under the cover on the opposite side of the green away from the supplementary ventilation system (Fig. 3). It was thought that these exhaust vents would facilitate air movement during supplementary ventilation and might also allow movement of gases from areas of high to low concentration between supplementary ventilation events. The third treatment, referred to as ‘roof turbine vents’, had a passive ventilation system installed where 60 cm (24”) roof turbines were installed on an approximately 2 m (6’) tall wooden tower (Fig. 4). Two solid drainage pipes were attached to each tower and then extended under the cover for at least 1 m. At that point, the solid drain pipe was attached to rigid perforated drain pipe that extended across the green. On the opposite side of the green, the perforated drain pipe was attached to a solid pipe that extended out beyond the cover and was attached to a snow fence t-bar. Two towers were installed per green which meant there were four individual drainage pipes spaced approximately 4-5m apart. The fourth treatment, called the ‘vent tube matrix’, consisted of a series of tubing under the insulation material that was

expected to provide more inlets and outlets from which gas exchange could occur (Fig. 5). Six solid drainage pipes were connected to perforated pipe that were interconnected under the covering system.

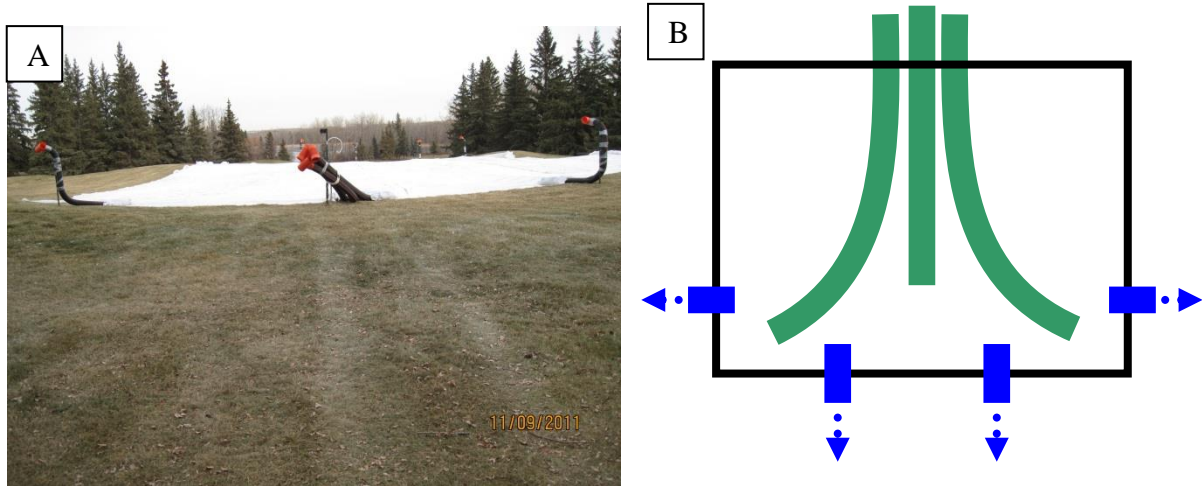


Figure 3. A. Supplemental ventilation system (centre) and exhaust vents only (perimeter piping). B. Diagram shows the configuration of the supplementary ventilation system with the 4 exhaust vents.

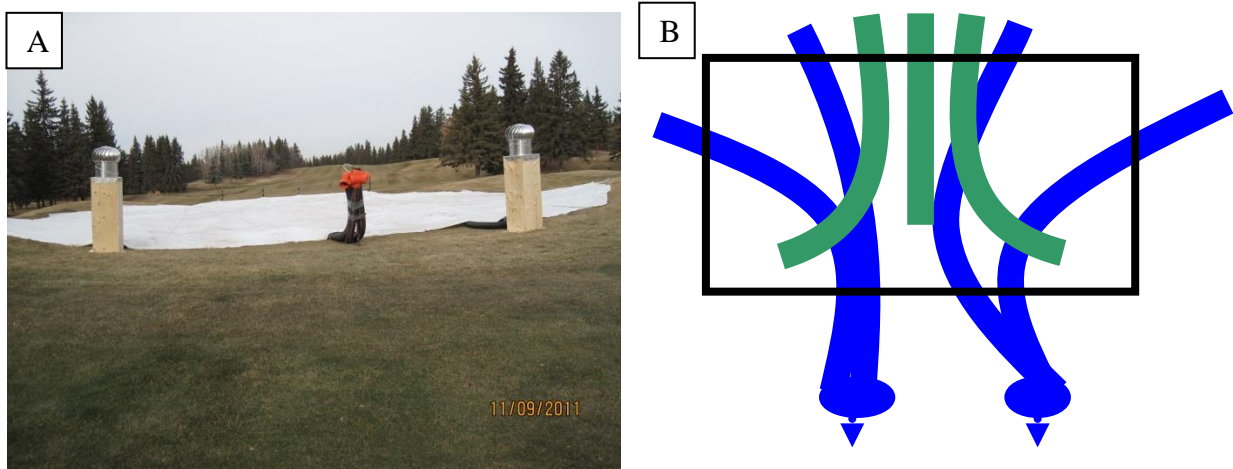


Figure 4. A. Supplemental ventilation system (centre) plus “roof turbine” ventilation system. B. Diagram shows the configuration of the supplementary ventilation system with the 2 roof turbine vents.

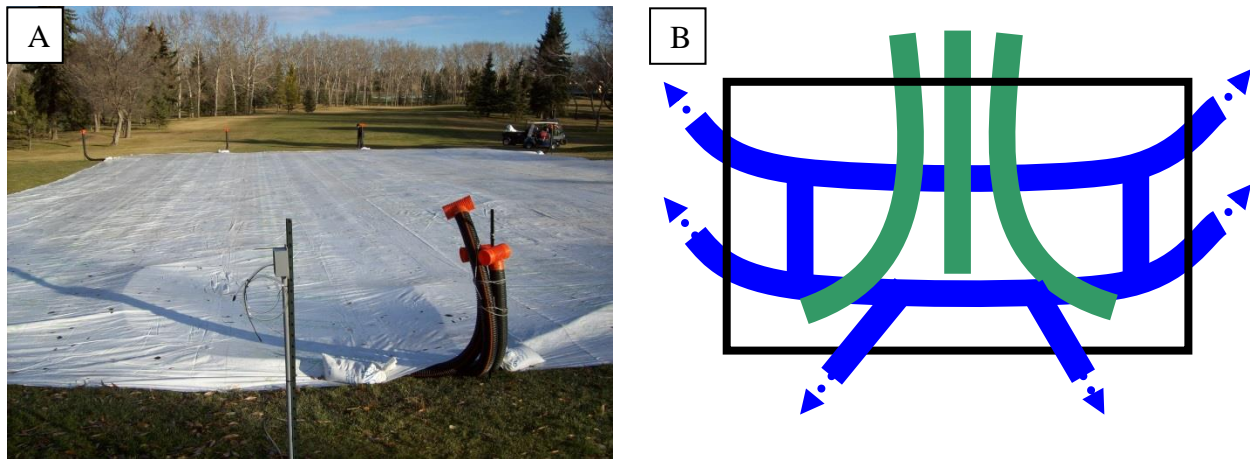


Figure 5. A. Supplemental ventilation system plus matrix ventilation system. B. Schematic of the supplemental ventilation system plus the vent tube matrix.

## Results

### *Weather Conditions – Edmonton Area*

Snow cover was below normal for the winter of 2011-2012 (Asher, personal communication, November 2014.). The first appreciable snow fall was November 17, but warm temperatures at the end of November and through December reduced the snow cover to almost nil. The next appreciable snowfall was the end of February and it was retained until the end of March. Generally, the winter was very mild with only a short period (5-6 days) of cold temperatures in mid-January. Temperatures at that time dropped to the mid  $-30^{\circ}\text{C}$  with little to no snow cover. Consequently, winter injury on golf course greens in Alberta was severe in the spring of 2012.

Snow cover was much above normal for the winter of 2012-13. The first appreciable snow fall was in early November and maximum snow depth was over 100cm. Snow melt was very late and greens were not completely uncovered until after mid-April. Temperatures were near normal and cold periods did not appear to adversely affect temperatures under the covers.

For the winter of 2013-14, there was above average snow cover and the duration of the snow cover was longer than normal. Temperatures were generally below normal for much of the winter.

### *Temperatures under the Winter Covers*

The covers were successful at protecting the plants from exposure to killing temperatures when ventilation occurred. Over the course of the three years of the study, temperatures under the covers were as low as  $-7^{\circ}\text{C}$ , but most typically were between  $-1^{\circ}\text{C}$  and  $1^{\circ}\text{C}$  (Table 1). The overall mean temperature under the tarps was  $-0.45^{\circ}\text{C}$  (Table 1). In Alberta, fully hardened annual bluegrass can withstand temperatures of around  $-21^{\circ}\text{C}$  in November and will gradually lose hardiness throughout the winter (Tompkins, Ross and Moroz, 2000). The temperatures under the covers were at no time of concern for winter injury.

### *Winter Damage to the Greens During the Study Period*

There was no damage to any of the greens involved in this study in any of the 3 years. Therefore, the impermeable covers were successful at preventing damage even in the very harsh conditions of the first year when temperatures dropped below  $-30^{\circ}\text{C}$  for several days with minimal snow cover.

Table 1. Summary of Temperatures under the winter covers.

	2011-2012	2012-2013	2013-2014
Max ( <sup>0</sup> C)	1.00	1.33	6.00
Min ( <sup>0</sup> C)	-7.00	-1.5	-3.70
Mean ( <sup>0</sup> C)	-1.99	0.17	0.48

Secondly, the absence of damage to any of the greens meant that even the control (supplemental venting system) did not experience conditions of anoxia to a point that plant injury occurred. However, it is important to note that the supplementary ventilation may have prevented the buildup of carbon dioxide or low levels of oxygen.

*Effect of Ventilation Systems on Carbon Dioxide Concentrations under Winter Covers*

There was considerable variability in the carbon dioxide concentration data which reduced the ability to determine differences between the various covering systems. In the initial analysis, there were no significant year, or year by treatment interactions so the data were analyzed with the three years combined. There were no significant differences between the ventilation systems for carbon dioxide concentration under the winter covers (Tables 2 and 3).

Table 2. Analysis of Variance for impact of ventilation system on carbon dioxide concentration under a winter cover.

Source	df	SS	MS	Obs. F	Prob > F
Treatment	3	11.36	3.79	2.62	0.063
Error	44	63.56	1.44		
Total	47	74.92			

Table 3. Mean values for carbon dioxide concentration associated with different ventilation systems used with a winter cover.

Ventilation System	Mean <sup>*</sup>
Exhaust vents only	4.3a
Vent tube matrix	3.8a
Control (no vents)	3.2a
Passive venting	3.1a

<sup>\*</sup>mean values followed by the same letter are not significantly different at p=0.05.

*Effects of Various Ventilation Systems on Oxygen Concentrations under Winter Covers*

There were no significant treatment differences for impact of ventilation systems on oxygen concentrations under the winter covers (Table 4). Similar to the carbon dioxide data, there was substantial variability in the data, but none of the ventilation systems tested demonstrated any improvement over the control treatment which had only the supplemental aeration system.

Table 4. Mean values for oxygen concentration associated with different ventilation systems used with a winter cover.

Ventilation System	Mean <sup>*</sup>
Passive venting	15.3a
Control (no vents)	15.3a

Vent tube matrix	14.4a
Exhaust vents only	12.5a

\* mean values followed by the same letter are not significantly different at  $p=0.05$ .

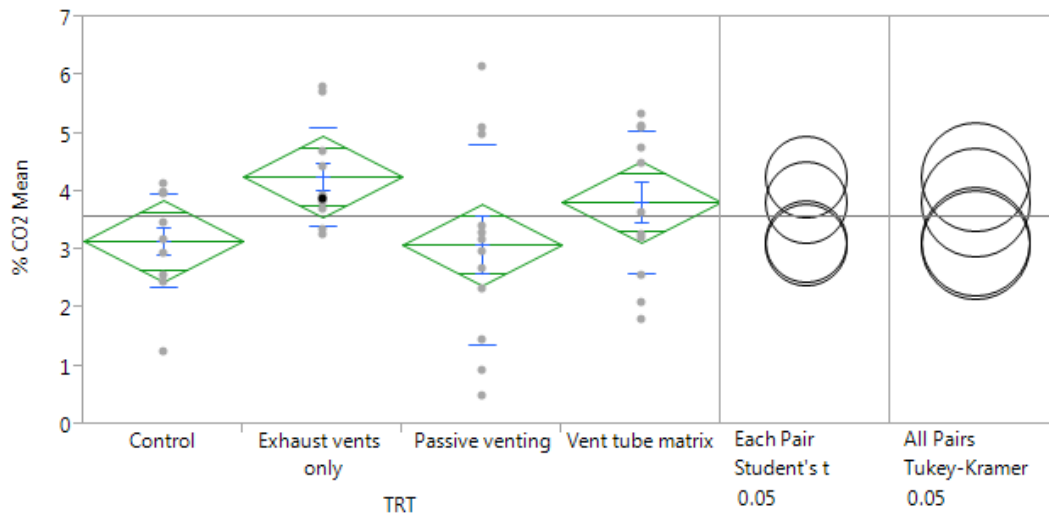
## Discussion

### *Carbon Dioxide and Oxygen Concentrations under Impermeable Winter Covers*

Statistically we did not see any differences between the 4 ventilation treatments so the null hypothesis ( $H_0$ ) that there are no treatment differences (all treatments responded equally) must be accepted (Table 1). It is important to note that the cut off value for rejecting  $H_0$  is 5%; our data resulted in an F value of 6% so the possibility of a type II error must be considered (Table 1). Type II errors occur when statistically we must accept that there were no treatment differences ( $H_0$ ), while there were indeed treatment differences. With this in mind, an examination of the average (mean) response of the carbon dioxide concentration data, the systems that have the lowest carbon dioxide levels are the passive venting system (i.e. “roof turbine”) and control treatments (Table 2).

One explanation for the lack of statistically significant differences can be explained by the high level of variability present for treatments in this study (Fig. 6). With respect to the carbon dioxide levels the passive venting treatment data have a relatively large range of carbon dioxide concentrations from 0.5% - 6.2% (Fig. 6). The active venting of all the greens in the trial with the leaf blowers resulted in similar responses amongst all the treatments. These data justify why we have moved from in-use annual bluegrass greens, where total failure of the green would be unacceptable by all participants in the study, to doing growth chamber experiments in the laboratory.

Figure 6. Oneway analysis of carbon dioxide overall mean by treatment. The green diamonds represent the confidence intervals.



Overall we saw that the ‘control’ with only the supplemental venting system described in Fig. 2, in combination with frequent supplemental ventilation with backpack blowers responded equally as well as any of the other ventilation systems. Therefore, it can be confidently stated that in this experiment, none of the complex ventilation systems tested reduced the carbon dioxide concentrations under the winter cover system relative to the control treatment.



It is important to remember that the reason this study was initiated on actual in-use putting greens was because there was a history of problems with winter injury on this course. This study was initiated with the following objectives in mind:

1. Develop a cover system that would prevent winter injury from desiccation, low temperature, and ice cover .
2. Develop a system to monitor temperature and gas concentrations under this cover system.
3. Develop a system to ventilate air under the covers in order to prevent gas concentration fluctuations.

Over the 3 years of this study there were weather conditions in the Edmonton area that would typically contribute to low temperature injury. The insulation material used under the system of white impermeable covers provided sufficient buffering capacity to prevent low temperature injury. For example, in the first year, there was a period of  $-30^{\circ}\text{C}$  temperatures for several days in mid-January with no snow cover that would typically cause significant damage to an annual bluegrass putting green. However, temperatures under the cover were maintained in a range that prevented low temperature injury.

One problem associated with the use of impermeable covers is the development of anoxia and/or the buildup of phytotoxic gases that, presumably, occurred at the club during the winter of 2006-2007. As there was no damage to any of the greens in this study during the 3 years of data collection, these phytotoxic conditions were avoided.

Therefore, the first goal of this study was accomplished. A cover system was used that prevented low temperature injury and all of the ventilation systems studied prevented injury from anoxia or the buildup of phytotoxic compounds.

A relatively simple system of monitoring carbon dioxide and oxygen was developed that did allow the course to monitor conditions under the covers. This accomplished the second goal of the study. In hindsight, it was not surprising that there was no damage associated with the use of the impermeable covers as there was a system in place to regularly ventilate when carbon dioxide levels rose or oxygen levels dropped. For the duration of the study, carbon dioxide and oxygen were maintained within an acceptable range, even for the control treatment that only had the supplemental ventilation system.

The third goal is related to this second goal. Since the course was able to monitor conditions under the covers, they were able to ventilate in a manner that would prevent major gas concentration fluctuations.

It is perhaps surprising that the control treatment with only the supplementary ventilation system was as effective as the other systems. However, from a management perspective, this may simply mean that a simpler system worked equally well as the more complex ventilation systems.

Unfortunately, from this study it was not possible to determine whether the passive ventilation system (i.e. the use of the "roof turbines") would have prevented the development of anoxic conditions without the supplemental ventilation with the leaf blowers. If this system was effective it would eliminate considerable labour throughout the winter months. However, it

would be impractical for a golf course that has had significant problems in the past to be willing to take the chance of losing several greens. Controlled environment studies currently being conducted at Olds College will hopefully shed more light on developing best management practices for the use of impermeable tarps on golf greens. In particular, with the development of action thresholds, so a superintendent will have definitive percent oxygen and percent carbon dioxide numbers for determining when they should be refreshing the air under the tarps.

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