Survivability of Annual Bluegrass under Impermeable Winter Covers
The Glendale Study

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Introduction

Winter Injury under Ice Cover and Impermeable Covers

Previous research conducted at the Prairie Turfgrass Research Centre (Olds, Alberta, Canada) showed that there was a rapid loss of relative hardiness of annual bluegrass plants between 45 and 60 days under continual ice cover (Tompkins, Ross and Moroz, 2004), while plants in non-iced conditions lost hardiness very slowly. The fact that air cannot be replenished under ice cover, or an impermeable covering of any sort, was thought to be a factor contributing to the injury. Research conducted in Quebec found that under an impermeable cover oxygen was depleted and carbon dioxide increased (Rochette et al, 2006). This increase was attributed to use by the plants and to low temperature microbes. When oxygen is completely depleted, the condition is known as anoxia.

In earlier research, Beard (1965) had similar results and found that injury to annual bluegrass occurred 75 days after continual ice cover. However, it seems that creeping bentgrass is affected much less and in our research was still alive after 120 days of continual ice cover. Other researchers found that differential sensitivity to conditions of anoxia was common amongst various plant species (Bertrand et al, 2001).

So what happens to annual bluegrass between 45 and 60 days when air cannot be replenished?

It seems that under conditions of anoxia a rapid depletion of stored foods occurs. We know that these stored foods act as an anti-freeze agent for plants so when they are completely depleted the plants have lost their ability to resist freezing. And, of course, once they freeze irreversible cell damage occurs and plants die.

At this point, we think that when oxygen is fully depleted rapid utilization of food reserves occurs, which in turn causes a rapid loss of hardiness (between 45 and 60 days). Once food reserves are depleted, the plant begins to utilize energy that is provided by a process called, glycolysis. However, the energy produced is not sufficient to sustain the plant. This deficit also leads to the induction of fermentation metabolism and to an increase in the production of potentially phytotoxic metabolites such as ethanol, lactic acid and carbon dioxide (Rochette et al, 2009).

So it appears that injury results from either a toxic build-up of these gases or from a complete depletion of food reserves. In the Quebec study, high levels of carbon dioxide did not produce mortality, so that may be an indication that the depletion of food reserves is the reason for the injury.

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 considerable winter injury at The Glendale and many strategies have been tried over the years to effectively prevent the injury.

Prior to the winter of 2006-07 a system of covering 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 greens. The injury was thought to be as a result of anoxic conditions that formed under the covers. Recovery time was lengthy.

The same covering system was installed in 2007-08, with one modification. 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. One green was damaged between the tubes, but generally, the greens came through very well.

The Need for Monitoring Conditions under the Covers
Superintendent, Darryl Asher, wanted to take the process a step further so that he might be able to determine critical levels of gas concentration under the covers and to determine the specific timing of ventilation events.

Objectives of the Glendale Study:

1. Develop a cover system that will prevent winter injury from desiccation, low temperature, anoxia and ice cover.
2. Develop a system to monitor temperature and gas concentrations under this cover system.
3. Determine relative hardiness of annual bluegrass plants in spring.
4. Determine organic matter levels on greens and compare with gas concentrations and relative hardiness.

Methodology
The greens at The Glendale are an annual bluegrass/creeping bentgrass mixture. The older greens were constructed with a high soil component that have been topdressed with sand for the last number of years creating a 75-100mm layer of sand at the surface. Five greens have been re-built with modified USGA specifications, although one green 'doesn't really act like a sand green because it drains so poorly'. The other sand greens were considered to be 'our best performers'.

A two layer covering system was installed with a white impermeable cover sold by Greenjacket over a 6mm insulated closed-cell foam material. Two greens used a 12mm bubble wrap material as the insulating material instead of the foam. Each bubble was approximately 25mm in diameter. No bottom cover was used. The system was installed in early November.

Prior to the installation of the covering system ventilation tubes and the monitoring equipment was laid out on the putting green. Three collapsible vent tubes with 2.5cm holes punched every meter were installed on each green. These tubes were made of 6mil polyethylene and had a 15cm diameter when inflated. The collapsible vent tubes were attached to 10cm solid Big O drain pipe and ran to the edge of the green. The solid pipe was connected to a leaf blower using a 4" straight connector. Three temperature meters (Johnson Controls A419) were installed per green and sensors (Johnson Controls A99BB-200C Silicon PTC Temperature Sensor) were placed in the front, middle and back of each green. The sensors sat on the surface of the turf, underneath the insulation and the cover. 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.

Leaf blowers (model Stihl BR600) were attached to the solid drain pipe. Output of the blowers was 712cfm. The intent of the blowers was to inflate the covers and then let the gases exhaust through the solid drain pipe when the blowers were removed. However, over the course of winter, the snowpack became dense and ice formed, inhibiting the inflation of the covers.

Permanent snow cover occurred on December 10 and all greens were completely clear by April 15, 2009. Maximum snow depth was about 40cm. Snow was not removed and was allowed to naturally melt. In late January one green was cleared by blowing off the snow down to a depth of 5 cm so that the cover could be inflated thus assisting in ventilation. In early February the same thing was done to another for the same purpose.

Data was collected weekly with regards to gas concentrations and turf surface temperatures. Those greens that had oxygen concentrations below 15% or carbon dioxide concentrations above 4% were ventilated. In addition, following cover removal sample plugs were removed from each green and a freeze test was performed in order to determine relative hardiness levels. Samples will also be collected from each of the greens and an organic matter determination will take place.

Results

Generally, gas concentrations under the covers were close to atmospheric conditions (21% O_2, 0.04% CO_2). However, as soon as permanent snow cover occurred O_2 concentrations decreased and CO_2 increased. This year when snow arrived temperatures under the covers were well below freezing and, in fact, were frozen by the middle of November. Greens stayed frozen until the end of March. Temperatures above freezing would be expected to have a greater impact on gas concentrations as microbial activity is greater.

Gas concentrations were very different when comparing sand based greens with the older soil based greens. The sand based greens never had CO_2 concentrations that were higher than 3%, whereas the soil based greens routinely had readings greater than 6%. O_2 concentrations for the sand based greens were consistently above 17%, while the soil based greens were often below 10%. However, neither of these gas concentrations is thought to be lethal to the turf.

The effect of ventilation appeared to be quite minimal. On one occasion gas concentrations were measured 24 hours after ventilation. At that time, O_2 levels only increased by 2.1% on average, while CO_2levels only decreased by about 0.5%. It was thought that there would be a greater effect from the ventilation event.

At time of writing, plant recovery from the freeze test was not yet complete. Relative hardiness levels will be compared with gas concentrations and organic matter content to determine if a relationship exists.

It appears that this winter was not a worst case scenario. Full hardiness was attained, soil was frozen prior to permanent snow cover, and the snow was sufficiently deep that it had good insulation properties. As well, the snow stayed late and was quickly removed.

A full report will be completed once all data is collected.

Future Testing

The effect of the ventilation was less than desired. A different system that may employ either an active or passive method, or a combination of the two will be examined.