Tough Turf

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Winter kill (a.k.a. winter injury) is a much-discussed topic among golf superintendents in Canada come spring. Often we talk about it as though it were one thing. It is not. When you consider the length and breadth of Canada and the differences in the types of winter weather experienced from coast to coast, it becomes even more complex.

Add the fact there are no two golf greens that are identical, let alone any two winters, and the complexity of the situation quickly multiplies. Further, while a lot is known about turfgrass winter injury, there is just as much that is unknown. Luckily, there are two very good research teams (Agriculture and Agri-food Canada, Que., and AIds College, Alta.) that have added immensely to the knowledge of winter injury, its causes and how to prevent it.

So what exactly is winter injury? There is agreement amongst turfgrass researchers that winter kill can be caused by desiccation, crown hydration, freeze injury, anoxia and snow moulds (Beard and alien, 1963). For the purpose of this article, I am only going to focus on the abiotic causes of winter injury-snow moulds will not be discussed. Knowing which type of injury you are most likely to encounter in your area is the key to prevention .

Desiccation

Desiccation is defined as the process of extracting water. Turf can suffer from dessiccation during the winter months. Injury occurs when water loss from turf plants exceeds uptake and transport from the roots. Desiccation can only occur in the absence of snow cover. It can be a result of soil drought or atmospheric drought.

Desiccation from soil drought occurs when there is minimal soil moisture due to a lack of precipitation, sloped areas with high incidence of surface runoff or elevated areas exposed to prevailing winds. Desiccation can also occur when there is adequate soil moisture. This is considered atmospheric drought and occurs when water is removed from parts of the grass plant that are above ground, through evapo-transpiration. The roots are unable to replace the water because the soil water is frozen.

Desiccation is a common problem on golf greens and other course turf in the Prairie provinces and B.C.'s Lower Mainland.

In general, annual bluegrass is more susceptible to desiccation than creeping bentgrass. Greens in full sun are also more susceptible. It can take as little as several days of high winds and low relative humidity in the absence of snow cover to cause desiccation.

Desiccation Prevention

Fortunately, there are several methods available to help golf course superintendents prevent winter desiccation. They include:

• irrigating turf prior to freeze up or before snow cover;

• installing windbreaks or snow fencing to reduce wind or to encourage snow cover;

• applying mulch or light topdressing on greens;

• covering greens with a synthetic permeable cover; • watering greens in the winter;

• minimizing thatch; and • maximizing creeping bentgrass populations.

Freeze Injury/Crown Hydration

Freeze injury occurs when plants are subjected to extremely cold temperatures or a severe rapid drop in temperature. This causes water inside and around the plant cells to freeze. Ice crystals can damage the cell membranes, resulting in the death of plant cells.

Crown hydration occurs when ice crystals form outside the plant cell (extracellular) of the turfgrass crown tissue. As these ice crystals form and enlarge, they pull water out of the cell, which results in dehydration. This type of injury is also called crown dehydration.

Another property of water is that it likes to move from a high to a low concentration. The solutes (mainly sugars) in a plant cell give the cell solution a higher concentration than the ice crystals outside the cell. This further increases the movement of water outside of the cell. At some point a dehydrated cell and cell membrane stop functioning and the result is cell death. If enough of the cells in the crown of the turf grass plant die, so too will the entire crown (Rossi, 1996).

Conditions Favoring Freeze Injury/Crown Hydration

Crown hydration is a complex phenomenon involving many .

(Continued on Page 23)

Tough Turf-

(Continued from Page 22)

Turfgrass plants are most susceptible to crown hydration in the transition period between winter and spring. At this point in the season the carbohydrates the turf plant has stored in the fall to help withstand intercellular freezing have fallen to their lowest levels. At this time, the plants are also dehardening and taking up water (Tompkins et aI., 2000).

Micro-environmental factors that contribute to crown hydration injury include areas with poor surface drainage where water collects and goes through freeze/thaw cycles. Compaction will also exacerbate this. The most serious injury occurs when the warm temperatures are followed by a rapid decrease in temperature. A rapid drop in temperature has been shown to be more damaging than a more gradual one. The length of the freeze cycle also influences the amount of damage.

Shaded turf is also more vulnerable. This may be due to the fact annual bluegrass often dominates greens in the shade. In addition, shaded greens may not produce as much carbohydrate to provide maximum winter hardiness.

Undoubtedly, turfgrass species is the most important factor determining whether there is a potential for crown hydration. Annual bluegrass is much more susceptible to such injury than creeping bentgrass. One of the main reasons is because annual bluegrass is the most susceptible to dehardening.

Research has shown that a rise in temperature to 8 C (46 F) for 48 hours is sufficient to deharden annual bluegrass (Tompkins and Ross, 1997). It is also known annual bluegrass comes out of dormancy earlier than creeping bentgrass and the crown tissues become hydrated, which also contributes to annual bluegrass susceptibility. It has been demonstrated there is a range in hardiness amongst annual bluegrass biotypes (Dionne et aI.,2001), but as a species they are by far the most susceptible.

Freeze Injury/Crown Hydration Prevention

Maximizing cold hardness can help reduce the risk of crown hydration injury. Management practices that help the hardening process are:

- late fall fertilization;
- increased mowing height in the fall.

Other factors that help prevent crown hydration are:

- maximizing creeping bentgrass populations;
- providing adequate surface drainage and minimizing soil compaction;
- minimizing shade;
- controlling thatch.

Protective covers are used in many areas to prevent freeze injury and crown hydration. Different covers or cover combinations are recommended depending on location, the amount of snowfall and the type of injury prevalent. For instance, in the Quebec City area, where adequate insulating snow cover is predictable, impermeable covers alone are recommended. In the Montreal area, where the amount of snow each winter varies, a system of a permeable cover, an insulating layer (usually straw) and an impermeable cover is recommended.

Permeable covers can also be used in the spring when winter protective covers are removed (Dionne, 2000). Dionne also recommends temperature under the protective covers be monitored throughout the winter.

To further the art and science of protective cover use, the University of Massachusetts and the United States Golf Association (USGA) Green Section, in cooperation with golf superintendents from the northeast United States region, are involved in a research project in which they are monitoring the temperature underneath a variety of different covers.

Anoxia

Anoxia, defined as lack of oxygen, is a condition that can occur under an ice cover or winter protective cover and can kill turf. Under covers, turf plants use up oxygen while other toxic gases such as carbon dioxide (C02) can build up. During the winter, under snow, ice or covers, turfgrass plants respire. In this process, organic sugars within the plant are mobilized in the presence of oxygen to provide energy to keep the plant alive. The equation for respiration is as follows: C6H1206 (hexose sugar) + 602 (oxygen) 6C02 (carbon dioxide) + 6H20 (water) + energy

In a closed system where there is no gas exchange, under anoxic conditions, this process or reaction can not occur. If this happens, the plant will run out of energy and eventually die. The other aspect of respiration in a closed system is that as oxygen is depleted, carbon dioxide builds up with potentially phytotoxic effects.

In addition to respiration from turfgrass plants under covers, there are also soil bacteria that are respiring. This further contributes to the oxygen depletion and the carbon dioxide buildup. Factors that affect the rate of respiration of plants and soil bacteria are temperature, soil water content, degree of plant dormancy and soil organic matter content. Usually anoxia can be detected by the foul smell that emanates from a green when it is uncovered in the spring. The smell is a result of the build-up of gases under the cover and is usually accompanied by turf injury.

Factors Affecting Anoxia

Again, as with all other forms of winter injury, the species type has a big impact on whether or not anoxia will result in turf injury. Research conducted at Olds College in Alberta (Tompkins et al., 2004) found ice-encased annual bluegrass plants were all dead after 45 days while creeping bentgrass plants could withstand 90 days.

In the Quebec City area, many golf courses have been using winter protective covers consisting of a permeable cover, straw and an impermeable cover. There were some greens that recurrently came out of winter with dead turf, in spite of being covered. The death of the turf could not be attributed to freezing stress, excess water or snow mould.

Rochette et al. (2006) set up an experiment with greens that had recurrent damage under covers and those that overwintered successfully with covers. They measured temperature, O2 and CO2 levels under the covers throughout the winter.

What they found was the greens that had recurrent damage had anoxic conditions by day 90, where the greens that overwintered successfully had sufficient O2 levels up to the end of the winter (day 130).

The greens with recurrent damage also had high levels of CO2 by day 90 and the other set of greens that overwintered well had equal amounts of O2 and CO2, The greens that suffered recurrent damage under cover had a 69 per cent higher respiration rate on average than the greens that overwintered successfully.

These two sets of greens were annual bluegrass, so the differences in respiration could not be attributed to the species. The difference in respiration, and hence oxygen depletion, were due to the soil biological activity. The greens with recurrent damage had significantly higher total nitrogen and total organic carbon. To verify these results, researchers tested the respiration rates of soil-based greens vs. USGAspecification greens. They found the soil-based greens consistently had higher respiration rates than the USGA specification greens.

(Continued on Page 24)

Tough Turf-

(Continued from Page 23)

Ice Encasement, Ice Cover and Winter Hardiness

Separate from the issue of how ice covers affect the 02 and CO2 levels, research has shown ice cover and ice encasement lowers turfgrass winter hardiness levels. Tompkins et al. (2004) conducted research to determine whether or not it is beneficial to remove an ice sheet from a putting green. To determine this they looked at cold hardiness levels of annual bluegrass and creeping bentgrass under ice cover or ice encasement for various lengths of time in a laboratory and in the field.

In the laboratory study, plants in the ice cover treatment were covered with a 2.5-cm (I-in.) thick layer of ice, which was formed gradually by spraying the surface of the turf with a mist bottle in a freezer. Ice encasement was accomplished by completely saturating the soil of a turf grass plug and then adding the 2.5-cm layer of ice as described above for the ice cover treatment. The control treatments had a thick layer of snow cover maintained throughout the experiment.

Snow-covered treatments maintained cold hardiness for the longest period of time and ice encasement produced the most rapid loss of cold hardiness. The differences were greater for annual bluegrass than creeping bentgrass. At 90 days after treatment, snow-covered annual bluegrass had cold hardiness levels of -18 C (-0.4 F), while the ice-covered plants had cold hardiness levels of -4 C (25 F) and ice-encased annual bluegrass plants were dead.

Ice-covered annual bluegrass had a rapid loss of hardiness between 75-90 days after treatment, and ice-encased annual bluegrass rapidly lost hardiness between 45-60 days after encasement. By contrast, creeping bentgrass began to lose hardiness 90 days after treatment in both ice treatments, but retained moderate hardiness levels for 150 days. In the field study, annual bluegrass had a more rapid loss of hardiness than in the lab. Annual bluegrass plants subjected to ice encasement lost cold hardiness between day 45 and 60.

In addition to the potential for development of anoxia under ice cover, there is also a loss of cold hardiness. In fact, they may be related to one another. High respiration rates under the ice covers may use up the plant's stored energy, leaving it more susceptible to the cold. High respiration rates could also contribute to the buildup of toxic gases that injure plants.

Anoxia Prevention

In the case of annual bluegrass putting greens with ice encasement, the study conducted by Tompkins et. al. (2004) showed all were dead after 45 days of ice encasement. It would be advisable to attempts to remove ice before the 45-day mark to prevent anoxic conditions from killing turfgrass plants. This can be accomplished through the use ofdark-colored topdressing materials that absorb heat. These can range from natural organic fertilizers to colored topdressing sands, inorganic amendments, etc. These products honeycomb the ice layer allowing for gaseous exchange.

In the case of soil-based greens with high organic matter under straw and impermeable covers, it is recommended they be vented using perforated drainpipe under the impermeable covers. These pipes must vent to the outside of the greens covers without letting water in under the covers. The optimum spacing of these pipes is not known, but many superintendents are experimenting on venting methods and venting spacing.

Recommendations for Successful Overwintering

There are many agronomic practices that can help prepare turf for the onslaught of the various winter stresses Mother Nature has up her sleeve. Regardless of the type of winter injury, the following sound turf management practices should be followed:

- raise the mowing height in the fall;
- fertilize with nitrogen and potashin the fall to increase winter hardiness levels;
- provide adequate surface drainage;
- maximize creeping bentgrass populations;
- minimize shade;
- minimize thatch;
- alleviate soil compaction.

Specific factors contributing to each type of winter injury and prevention methods are summarized in Table 1.Winter injury is a complex physiological phenomenon and may occur as a result of and interaction between the plant, soil, the micro-environment and the climate. More than one type of winter injury may be involved. We continue to learn more each year due to research into winter injury and there are many factors we can control. Ultimately, though, we are at the mercy of the weather and a great deal of luck is involved.

TABLE 1: Winter Injury—Contributing Factors and Prevention

Winter Injury	Contributing Factors	Prevention
Desiccation	• annual bluegrass more susceptible than creeping bentgrass • lack of snow cover • soil drought • dry winds when soil is frozen more prevalent on sloped and elevated areas	• irrigate prior to freeze up • install windbreaks and/or snow fencing • apply mulch or light topdressing • winter watering • cover greens with permeable covers • maximized creeping bentgrass populations
Freeze injury/ Crown hydration	• annual bluegrass more susceptible than creeping bentgrass • rapid and severe drop in temperature • poor surface drainage • shade • low carbohydrate reserves • freeze/thaw cycles in late winter	• supply adequate surface drainage • minimize thatch • supply adequate nitrogen (N) and potassium (K) • maximize creeping bentgrass populations • cover greens with permeable covers, insulation and impermeable covers
Anoxia	• annual bluegrass more susceptible than creeping bentgrass • presence of ice cover longer than 45 days • high soil carbon under impermeable covers • high temperatures under impermeable covers	• maximize creeping bentgrass populations • vent impermeable covers on soil-based greens • melt ice with dark-coloured topdressing materials • mechanical disruption of ice covers