A Proposed Solution to Turf Kill under Impermeable Covers

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A Proposed Solution to Turf Kill under Impermeable Covers Caused by Long Periods of a Mild Winter in the Montreal Region

a. Introduction

The use of straw as a winter protection for sports turf was known before the year 1951 (Beard, 1973) . The impermeable covers, as well as the wooden fibers and the polyethylene tarpaulins were under testing before the year 1961 (Ledeboer and Skogley, 1967 ;Watson et al., 1960 ; Watson and Wicklund , 1962). Later , some improvement has been made to this technique of turf winter protection (Cooper , 1975 ; Lettener , 1988 ; Roberts , 1991 ; Roberts , 1989 ; Roberts , 1986) .

The winter protection of golf greens with cereal straw and impermeable (they are not 100% impermeable) covers has been a popular practice in Quebec for the last ten years or so due successful spring green-ups obtained for a few consecutive winters on a number of golf courses in Quebec because these covers were able to prevent water from killing or injuring the greens .

Over the years , the golf course superintendents have substituted the straw for different materials such as felt canvas, plastic covers containing air pockets , braided mats of wooden fibers...without obtaining conclusive results every year . Some superintendents have also used wooden frames in lieu of the straw aiming at introducing some air layer between the impermeable cover and the turf surface (Badra , 1991) .

The green-up results obtained from each winter protection method varied from one course to another every spring for many resasons . Nevertheless, the use of impermeable cover with a layer of cereal straw produced encouraging results on some golf courses for a number of consecutive cold winters . Thus, this straw- impermeable cover method became popular without having been tested in a mild winter . Researchers at Laval University have evaluated the efficacy of different methods of winter protection and also found varying green-up results for the same method from one winter to another and one region to another (Dionne and Desjardins, 1996) .

Despite the excellent efforts and improvements made by the golf course superintendents in the right direction to minimize the kill or injury to golf greens , to date , the use of any method of winter protection (straw, felt canvas , wooden frames , plastic covers containing air pockets...) is still a gamble.

Granted , these different methods of winter protection are not the only factors contributing to a spring green-up. The management of the greens (mowing height , dethatching , balanced nutrition , adequate irrigation...) , the state of the soil (compaction , drainage...) , the turfgrass species (annual bluegrass , Poa annua L. versus creeping bentgrass , Agrostis palustris Huds...) along with the weather experienced in the year prior to installing the winter covers play a major role in preparing the greens to tolerate the harsh winters . Strange though it may be , every winter remains a riddle to every golf course superintendent in this region.The dilemma facing the superintendent job is that winters are variable in the Montreal region and the same protection method that proved to be highly successful during winter 1997 turned out to be a crushing failure in winter 1998 even if turf management was excellent in the growing season of 1997.

b. Advantages of the Different Methods Used to Date to Protect Golf Greens in Winter

The different winter protection methods used to date (straw , felt , wooden frames , air pocket plastics ... covered with an impermeable material) have solved two main causes of kill or injury to golf greens, namely :

1. Preventing water from reaching the green's surface (Beard , 1964 ; Beard , 1969) .

2. Reducing the severity of cold but only in very cold winters.

c. Turf Problems Created by the Use of Impermeable Winter Covers

Some hidden problems attached to the use of winter covers were not very obvious in winters prior that of 1997-1998 . In fact , the covers being tightly attached to the ground , in particular, the presence of the straw layer contributed to the development of other problems in the mild winter of 1997-1998 such as :

1. A lack of air flow and a heat build-up on turf surface .

2. Some undesirable leaf growth under the covers due to heat .

3. An increased severity of infection by gray snow mold (Typhula spp.) that is attributable to a soil warm-up and the presence of leaf wetness.

d. Main Causes of Kill or Injury to Greens during Winter 1997-1998

Prior to winter 1997-1998 , the golf course superintendents were able to maintain the impermeable covers so tightly attached to the ground by means of staples , stones , lumber , ropes and stakes...to prevent any water from infiltrating under the green's cover . This waterproofing achieved good spring green-ups only during the cold winters because the ground temperatures remained less yet closed to the freezing point . On the contrary , this waterproofing proved to be suffocating in winter 1997-1998 , particularly in the Montreal region . The main causes of kill or injury , noticed in April 1998 , were as follows :

d. First Case

Symptoms : A dark brown or light brown foliage noticed **immediately** after removing the impermeable covers with or without straw . Depending on the severity of this case , the crowns and /or the roots were or were not killed .

Causes : This kill was caused by some heat build-up at the turf surface (telephone conversation of April 19th, 1998 with James Beard , Professor Emeritus of Turfgrass Science , Texas A & M University) . The direct heat injury caused to the turf involves the denaturation of protoplasmic proteins in living cells . Gross symptoms of heat injury appear as browning and decay of the affected tissue (Beard , 1973).

The turf warm-up under the impermeable covers was not the only cause of kill . In fact , a lack of air flow under the covers , in combination with heat , activated the decomposition of organic matter (of the soil , of killed turf , and even of the straw) to release toxic gases that injured or killed the turf. The section entitled " rotten odour " throws light on this topic .

Some superintendents I met in April 1998 were surprised of this significant kill or injury during winter 1997-1998 , because they have successfully used this straw- impermeable cover method for the last eight consecutive years . In fact, this kill or injury was present in the past winters , but its severity was insignificant and the turf was able to recover rapidly because cold winters greatly reduced the heat build-up and organic matter decomposition , whereas the winter of 1997-1998 was exceptionnally mild for this region .

To better illustrate the previous paragraph regarding the impact of a cold versus mild winter on turf when using the same winter protection , take some plugs of live turf including its soil . Place them in a transparent waterproof plastic bag . Close it thightly and put it in the sun for a few days . Turf will die . Some wetness will be seen on the turf that will smell the rot . A high temperature was the main cause of kill backed up by toxic gases released from the decomposition of organic matter due to lack of oxygen . Thus , a lack of air flow becomes critical in case of heat .

On the other hand , instead of placing the bag in the sun , cool the turf plugs gradually similar to how nature does it in late autumn . Then place them in the bag and put it in the freezer for a few days at -8°C . Take the bag out . After a gradual thaw , you notice that turf is still alive. This freezer case demonstrates that a lack of air in the bag was not detrimental to turf at very low temperatures

Consequently , during cold or very cold winters , the impermeable covers (with or without straw) were able to maintain a healthy turf without sufficient air flow under the covers due to a substantial reduction in temperatures (a lower respiration rate from the turf and microbes) and in anaerobic decomposition of organic matter . The case was different in winter 1997-1998 where a continuous flow of air was badly needed by turf during the mild weeks .

The presence of straw , felt canvas , plastic covers containing air pockets ...between the impermeable cover and the turf did not allow sufficient air flow during this mild winter to reduce the heat and dissipate the toxic gases . These materials (straw , felt , air pocket plastics ...) are not needed to protect the turf from the cold . Annual bluegrass can tolerate -10°C (creeping bentgrass is even winter hardier) . Moreover , the presence of these materials obstruct the air flow under the covers .

Solutions:

1. Turfgrass was not entirely dormant . During mild periods , monitor the turf temperatures by means of thermocouples . Should heat build up , let air pass across the turf . An air flow can be accomplished by opening several corners of the covers or by the technique I suggest at the end of this article .

2. Start building up soil fertility (P , K , Mg , Ca ...) of each green by mid-August .

3. Do not mow too short in September and October to improve rooting .This is crucial to turf survival .

4. The thick thatch layer undergoes an anaerobic decay and releases toxic gases to turf under the covers . Practice decomposing the harmful thickness of the thatch.

5. Aerify the compacted soil several times a year to increase the air exchange . In a well aerated soil , turf tolerates better some heat for a short period of time until it gets fresh air .

6. The dead foliage noticed immediately after removing the covers in April does not imply a total kill . Take some plugs . Put them inside , syringe them regularly for growth . Examine the state of the roots and crowns in several places of the green . Seed or sod without delay in case you suspect a kill . Always plan to have sufficient sod from your course nursery in the spring (Badra , 1996) .

d. Second Case

Symptom : A chlorotic foliage (yellowish) . The crowns and roots may or may not be injured .

Cause : Some warm-up took place under the impermeable cover that stimulated some growth in the absence or insufficient light .

Solution :

1. Verify the temperatures under the cover . Should you detect some heat build-up , let a flow of air pass across the turf to stop this undesirable growth .

2. Do not overdose the late-autumn nitrogen application . Avoid it during the hardening-off period of turf for your region . The hardening-off period for the Montreal region is not the late-autumn period .

The application of a quick- release nitrogen material at 0,5 kg N /100 m^2 (1 lb N /1000 ft^2) is to be avoided by early November for the Montreal region because the turf is usually covered the following week or so . The nitrate of this nitrogen undergoes a denitrification under the covers to release toxic gases to turf , such as nitrite (NO^2) , nitric oxide (NO) , and nitrous oxide (N^2O) .

These toxic gases can also be released from the decomposition of any organic matter such as thatch , straw , dead plants and soil organic matter (Tisdale et al ., 1985) . To date , there is no research in Quebec that quantifies the amount of toxic gases released to golf greens under the covers from the proper rate , date , and nitrogen material applied in late-autumn . The kill or injury that turf experienced in winter 1997-1998 cannot be attributed to the proper nitrogen application . All the more so, many superintendents have not applied any nitrogen in late-autumn 1997 . Yet , their greens were similar to the other golf courses in the kill severity under the impermeable covers .

d. Third Case

Symptoms : A white or gray-white foliage observed **immediately** after removal of the impermeable covers . Search for the presence of black or gray or brown sclerotia (1 mm) on the dead foliage or in the thatch . These sclerotia may not always be present .

Cause : The presence of gray snow mold (Typhula spp.) caused this injury or kill . The sclerotia germinate at temperatures from 10 to 18°C (Smiley et al., 1992) which coincides with late September and early October for the Montreal region . During a normal late-autumn , ambiant air temperatures gradually diminish in October to reach +10°C by mid-October and lower than the freezing point by the 10th of November where winter covers are installed on the greens. These covers (with or without straw) cause an ideal thermal condition for the development of sclerotia .

Solutions :

1. Reduce the thick thatch.

2. Let an air flow circulate across the turf during the mild winter periods.

3. Monitor the early October temperatures , if they are above normal for your region , spray preventively a fungicide at the beginning of October . If the temperatures remain warm during October , spray again in the third week of October . Finally , treat a fungicide before installing the covers by the second week of November . However , if October is cold and the ground freezes rapidly , the fungicide treatment of November is enough to control this disease .

4. The pathogen Typhula infects the turf that has low carbohydrate reserves. A good turf management during all the growing period should increase these reserves. Moreover , a late-autumn nitrogen application is particularly useful , assuming the nitrogen material is well chosen and spread at the adequate rate and time .

A suggestion has been put forth to banish the late-autumn fertilization of turf in Quebec (Pedneault , 1996) . This suggestion has not been supported by any scientific research in Quebec . On the contrary , research abounds to affirm that the advantages of late-autumn fertilization of turfs outweigh the disadvantages by far when cleverly applied in relation to the weather , turf species and management .

In case of a sound management , even if the weather would be against all expectations following a thoughtful late-autumn fertilization , the disadvantages that may result from this fertilization would not be detrimental to turf compared to those resulting from a lousy management backed up by a poor choice of the fertilizer , its dosage and application period . In general , the superintendent who understands what he is doing , and does a good job at maintaining his course in perfect shape , knows how to use the late-autumn fertilization to the advantage of his turf .

d. Fourth Case

Symptom : The foliage appeared dark green , water-soaked **immediately** after cover removal (with or without straw) in April 1998 . The straw remains dry under the impermeable covers . The foliage may have survived the mild temperatures and low levels of toxic gases . Nevertheless , it has been stressed . The severity of stress varied a lot from one course to another and from one green to another within the same course due to several factors detailed in the section " Cases of some golf greens..." .

I noticed that as soon as the course employees have finished removing the cover off a green in early April 1998 , they moved to the next one without monotoring the green that has just been uncovered . As a result of this hurry , the green uncovered early in the morning and was in good colour **immediately** afterwards , turns brown after a few hours of sun and/or wind .

Causes : The wetness on the foliage , as little as it may be , observed **immediately** following the cover removal , originated mainly from the condensation on the turf surface of soil water , of dead , and live but stressed leaves by the heat . This humidity remained trapped under the cover . A porous well aerated soil loses a lot less water through evaporation under heat stress and condenses less than a compacted soil (telephone conversation of April 23rd, 1998 with Jean Caron , Professor of Soil Physics and Thermodynamics , Laval University) .

This foliage wetness dried out rapidly after the removal of winter covers during a sunny and/or a windy day through atmospheric winter desiccation . The sun and /or the wind continued to remove water from the foliage that was already stressed under the cover . Since the soil was still cold , the roots were not able to absorb soil water for the rapid atmospheric desiccation of the leaf . Consequently , the leaves turned light green , then brown within a short time varying from a few hours to a few days depending on the severity of the weather conditions and the state of the turfgrass health (telephone conversation of April 19th, 1998 with James Beard , Professor Emeritus of Turfgrass Science , Texas A & M University) .

Solutions:

1. If at all possible , do not choose a sunny or windy day to uncover the greens . A light wind can rapidly desiccate a stressed foliage .

2. In case you do not have enough employees , do not try to uncover the maximum number of greens per working day . Immediately after uncovering , the decisions you make minute after minute are critical to the green's survival . Get the equipment ready for any need that might crop up (syringing , spraying a fungicide, fertilizing ...) . Keep an eye on the water-soaked green in order to salvage as much stressed turf as possible . Should the symptoms of desiccation appear on the foliage , syringe . The amount of water depends on the temperature and wind . Syringe very little at a time as needed but frequently . Adding too much water requires too much heat to resume growth . The goal is not to push for growth . Rather , it is to prevent the atmospheric leaf desiccation .

3. After cover removal , spray preventively a fungicide against pink snow mold (Microdochium nivale) and Fusarium patch (Fusarium nivale) . This spray prevents the diseases , should you decide to syringe frequently .

4. Put the cover back and continue to watch the heat build-up under the cover with an infra red thermometer . If necessary , let a mild air move across the turf and continue to monitor closely the foliage colour .

5. In case all the above procedures did not succeed in maintaining the colour , spray only on the stressed greens with 0.1 kg/100m^2 (0.2 lb/1000 ft^2) of nitrogen (N) per 15 litres of water . An overdosage of nitrogen may infect the green with diseases (Badra , 1997) .

e. A Rotten Odour under the Winter Covers

A rotten odour emanated from the turf after removal of the impermeable covers in early April 1998 and persisted for a few days in the case of some greens . This odour resulted from the aerobic and anaerobic decomposition of organic matter under the impermeable cover during winter .

e. 1. Aerobic Decomposition of Organic Matter

Due to a heat build-up under the cover , the turf as well as micro-organisms from the soil and the straw consumed continuously some amount of oxygen , then released carbon dioxide (telephone conversation of April 21st, 1998 with Richard Hull , Professor of Plant Physiology , University of Rhode Island) . This is why in a mild winter , a thin air layer between the turf surface and the impermeable cover that is tightly attached to the ground is not enough to provide a sufficient amount of oxygen that protects the turf without a continuous air flow from outside the impermeable cover .

These micro-organisms decomposed soil organic matter and part of the straw in the presence of air by enzymatic oxidation to release carbon dioxide as follows (Brady and Weil , 1996) :

R----(C , 4H) + 2O^2 ----- microbial activity ------CO^2 + 2H^{2}O + energy

In case of a very high concentration of CO^2 released and trapped under the cover , it may kill the turf (telephone conversation of April 19th, 1998 with James Beard , Professor Emeritus of Turfgrass Science , Texas A & M University) .

e. 2. Anaerobic Decomposition of Organic Matter

As the oxygen under the cover rarifies increasingly , other micro-organisms become active for lack of air (oxygen) to anaerobically decompose the dead plant , the soil organic matter , and even the straw to release organic acids , alcohol and methane as follows (Brady and Weil , 1996) :

4 $C^2H5COOH$ + $2H^2O$---microbial activity ----$4CH^3COOH$ acetate + CO^2 carbon dioxide + CH4 methane

CH^3COOH ----microbial activity ---CO^2 carbon dioxide + CH4 methane

CO^2 + $4H^2$ ----microbial activity-----$2H^2O$ water + CH4 methane

Methane represents the major part of gas toxicity under the cover (telephone conversation of April 27th , 1998 with Leon-Etienne Parent , Professor of Soil Chemistry , Laval University) . However, many other toxic gases could have been released too , such as hydrogen sulfide H^2S ,

nitrite (NO^2) , nitric oxide (NO) , and nitrous oxide (N^2O) . In fact , the rotten odours that emanated after the removal of the covers originated mainly from the anaerobic decomposition of the organic matter (telephone conversation of April 9th , 1998 with Yves Desjardins , Professor of Plant Physiology , Laval University ; and with Jean Caron , Professor of Soil Physics and Thermodynamics , Laval University) . Some decomposition of organic matter took place at temperatures below the freezing point . However , this decomposition was very slow and was influenced by a limited number of micro-organisms (Hausenbuiller , 1985) .

The aerobic and anaerobic decompositions of organic matter start effectively at approximately +5°C then , increase rapidly by heat build-up under the impermeable cover (telephone conversation of April 27th , 1998 with Leon-Etienne Parent , Professor of Soil Chemistry , Laval University) . The main gases released by this anaerobic decomposition were CO^2 , CH4 , N^2O , NO^2 , NO which are gases contributing to the greenhouse effect . Brady and Weil (1996) quoted that one molecule of methane is 30 times more powerful than one molecule of carbon dioxide in trapping the outgoing radiation to increase the warming potential . Leon-Etienne Parent recommends a flow of air pass across the turf to let the soil microbes metabolize methane in presence of air . Thus reducing its toxic effect on turf .

e. 3. Problems Incurred by the Presence of Straw between the Turf and the Covers

The straw is an organic material easily decomposable (i.e. can be broken down to a compost) by microbes . The mild winter of 1997-1998 has contributed to some decomposition of the straw which released toxic gases to the turf , such as methane and carbon dioxide that increased the killed area of live turf. The thicker the straw layer the more probability of toxic gases that were released (telephone conversation of April 27th , 1998 with Leon-Etienne Parent , Professor of Soil Chemistry , Laval University) .

Since the superintendent cannot anticipate the winter weather before installing the covers in November , it would be important to choose the winter protection method that produces satisfactory results in cold and in mild winters as well . According to research conducted by

Laval University in the Montreal region , the concentration of oxygen was quite often extremely low of 1 to 3 % under the impermeable covers in winter 1997-1998 compared to outside air oxygen concentration of approximately 20 to 21 % per volume (telephone conversation of April 24th , 1998 with Michel Tardif , Researcher , Laval University) . Thus , an anaerobic decomposition of organic matter took place to cause turf injury or kill .

f. Cases of some Golf Greens killed , Injured , or Survived during Winter1997-1998 .

My visits to many golf courses in April 1998 allow me to state and comment on the following cases :

f. 1. Greens without Winter Protection

In general , the greens (in annual bluegrass or creeping bentgrass) that have not been protected all winter 1997-1998 were healthy in early April 1998 because winter temperatures were not very cold ,compared to a normal winter in the region . The snow and ice covers melted earlier than expected in March and faster than usual . It seems that the atmospheric wind desiccation was insignificant in the case of turf non-stressed by winter covers .

However , some depressional areas in annual bluegrass , poorly drained of these non-protected greens were killed by ice cover . Beard (1973) reported that two hypotheses were put forth as causes of direct ice cover kill . The first is that kill results from oxygen suffocation caused by an exhaustion of the oxygen supply required for the respiration process . Whereas the second involves the accumulation of toxic gases such as carbon dioxide (CO^2) and cyanide (CN) that have evolved from the respiration or oxidation of living tissues , thatch , soil organic matter , soil organisms , or certain fungi . It has been suggested that the latter hypothesis is the more likely cause of direct ice cover injury to turfs (Freyman , 1967) because there is no conclusive evidence to support the former hypothesis .

I think that the injury or kill under ice cover in winter 1997-1998 was not the direct result of just one cause . Rather , it was the combined results of many factors acting in time to varying degrees . Under very low temperatures , turf is usually dormant . Thus , the oxygen insufficiency is relatively harmless . However , in our case , as temperatures increased under the ice cover , turf was not always dormant . It consumed some oxygen and so did soil microbes . As oxygen diminished to very low concentrations under the ice cover along with the temperature being above the freezing point , the turf physiological processes suffered because it cannot survive anaerobically for a long period of time . Under these conditions , an anaerobic decay of soil organic matter and straw took place to release toxic gases such as methane (CH4) , , nitrite (NO^2) , nitric oxide (NO) , nitrous oxide (N^2O) and hydrogen sulfide H^2S (which is a respiratory poison that resulted from the reduction of sulfate , SO4) .

Beard (1973) also suggested that another cause of kill under ice cover is the increased crown hydration by standing water during periods of alternating freezing and thawing . Consequently , turf injury or kill observed immediately after the cover removal in early April 1998 was not solely caused by carbon dioxide and cyanide . In fact , later research found that aerobic respiration in many plants is not strongly inhibited by cyanide (Lance et al., 1985 ; Lambers , 1985 ; Siedow and berthold , 1986) . Such plants contain an oxidase enzyme that exhibits a cyanide-resistant respiration whereby the mitochondria possess both the normal electron transport pathway and an alternate cyanide-resistant pathway (Kaufman et al., 1989 ; Taiz and Zeiger , 1991 ; Salisbury and Ross , 1992) . It was not stated as to how this cyanide-resistant respiration applies to turf .

f. 2. Greens Protected with Permeable Covers only

The greens (in annual bluegrass or in creeping bentgrass) that were protected only with permeable covers were also healthy because they did not suffer a heat build-up and a lack of an air flow .

f. 3. Greens Protected with Impermeable Covers (with or without Straw , or with Air-Pocket Plastic)

Due to a relatively mild winter 1997-1998 , the protection methods of impermeable cover with straw (it was a layer of 5 to 30 cm thick) as well as the plastic containing air pockets have killed or injured the annual bluegrass greens by lack of an air exchange ,a heat build-up , and an anaerobic decomposition of the organic matter . The rotten odour was still present in early April 1998 after a few days from cover removal .

On the other hand , the annual bluegrass greens that were protected with impermeable covers (without straw) have suffered some injury or kill but to a lesser extent than those with straw and impermeable covers , in particular , where ice cover melted early enough in March 1998 on top of the impermeable covers allowing the wind to shake the covers and let air flow across the turf .

f. 4. Greens Protected with Impermeable Covers (with or without Straw) of Unexpected Ventillation

The case of annual bluegrass greens protected with impermeable covers and straw that were accidentally not tightly attached to the ground and were shaking with the winds , apparently received sufficient unexpected ventillation that reduced the heat build-up under the covers and maintained the turf in a reasonably healthy state . Likewise , the annual bluegrass greens that were protected only with impermeable cover (without straw) but were not tightly attached to the ground , have also received sufficient air flow in winter and remained in a healthier state than those protected with impermeable covers and straw under unexpected ventillation .

Due to a shortage in impermeable covers , a superintendent left some corners of three annual bluegrass greens numbers 4 , 8 , and 12 exposed to the wind using a 15 cm of straw layer under the covers , similar to what he did for the other greens that were tightly attached to the ground . In April 1998 , the greens 4 , 8 , and 12 of short covers that were shaking with the wind were healthy in major parts while the other greens received a heat build-up and were injured or killed in major parts .

f. 5. The Killed Area under the Impermeable Cover Was Proportional to the Green's Area

In almost all the annual bluegrass greens affected by the heat build-up under the impermeable covers due to a lack of an air flow (with or without straw) , I noticed that the kill or injury was located rather towards the centre of the greens while an edge of 1 to 2 m in width located near the fringe to the inside of the greens , all circuling the green , was healthy without any discolouration , possibly due to an air flow from the border of the impermeable covers that was able to reach this edge only . This injured or killed area was larger in the presence of straw than without , suggesting that in the absence of straw , air was able to reach a farther distance towards the centre of the green to keep the turf healthy .

Within the same course (with or without straw) , the larger the green's area the greater the injury or kill due to the lack of an air flow across a larger area of the green . On a particular course where all the greens were protected with the air-pocket plastics and impermeable covers , all the small -size greens were healthy in April 1998 , while all the medium- and large-size greens were injured to varying degrees or killed .

f. 6. Accidental Holes in the Impermeable Covers Have Salvaged some Turf

Among the annual bluegrass greens affected by the heat during winter 1997-1998 , there were some peculiar circular shapes of 10 to 150 cm in diameter of a healthy turf surrounded with very large areas of brown dead turf . A closer look at a particular case showed a large hole that was caused accidentally in the impermeable cover . After cover removal in early April 1998 , the straw layer of 30 cm in thickness underneath the hole was heavily water-soaked in a circular shape , precisely to the area of the healthy turf under the straw .This observation unveiled the secret of this puzzle . In fact , this large hole in the impermeable cover let air pass through . There was some water infiltration too , probably of insufficient amount to kill the turf but enough to reduce the heat build-up under the hole and maintain the turf healthy .

The central zone of many annual bluegrass greens affected by the heat build-up contained parallel rows of 5 to 30 cm in width having a healthy turf across the length of the green . These rows were clearly seen in the case of impermeable cover without straw but to a lesser extent in the case of impermeable cover with straw (depending on the thickness of the straw layer) . Incidentally , these rows of healthy turf happened to be located under the line of stitches joining any two pieces of impermeable covers together . These stitches probably let air pass through the cover and avoided the heat build-up on turf surface . I can also hypothetically assume that some water infiltrated through the stitches to reduce the warm -up of turf during the mild days while the neighbouring areas of a few centimetres apart were totally killed

f. 7. A Little Amount of Water under the Impermeable Covers Served as Thermal Insulator during this Mild Winter

The green number 10 of another course resembles somewhat to the previous example . It was in annual bluegrass of a compacted and poorly drained soil . Although it has been protected with impermeable cover and straw (10 cm thick) similar to previous winters , being fully located in a low ground , water used to infiltrate under the cover to kill the turf every winter . The golfers were used to see it brown every spring , with the exception of spring 1998 where the infiltrated water appeared to have maintained low temperatures at the turf surface and prevented a heat build-up . This green was exceptionally healthy in April 1998 , while the straw (10 cm thick) was very wet indicating the effect of water as a thermal insulator in a mild winter .

The green number 2 of a course in the south shore of Montreal is quite an extraordinary case . This green was in annual bluegrass of a compacted and poorly drained soil with 10 cm of snow at the beginning of December 1997 . Since there was no time to clear the snow , the superintendent packed the snow , then laid down an impermeable cover on the top of a 15 cm of straw layer , similar to the way he protected the other greens of the course . This snow layer apparently prevented the heat build-up on the turf surface in such a mild winter . This green was healthy in April 1998 after cover removal and immaculate from any symptoms of gray snow mold .

f. 8. An Excess of Water in a Compacted Soil Is Lethal to Turf Regardless of Winter Temperatures

An excess of water for extended periods of time is lethal to turf regardless of the winter temperatures . During this mild winter , two annual bluegrass greens numbers 4 an d16 were protected with straw (10 cm thick) and impermeable covers . The soil was poorly drained with some depressional areas that accumulated lots of infiltrated water under the covers that were shaking with the wind . In April 1998 , these two greens were healthy due to an air flow under the covers , while the depressional areas were killed from excess of water accumulation and crown hydration .

g. The Use of Plastic Perforated Tiles to Maximize the Winter Survival of Turf through Air Flow under the Impermeable Covers

It is probably very difficult to find an infaillible prescription for all the golf courses regardless of the winter weather in the Montreal region . However , the following method aims at maximizing the air flow across the turf under the impermeable cover to prevent the heat build-up and minimize the decomposition of organic matter during a mild winter while frequently removing the toxic gases . It is not necessary to use any material such as the straw or felt or air-pocket plastics between the turf and the impermeable cover . The turf will be well prepared to tolerate low temperatures from -5 to -10°C (including annual bluegrass) in a sound management programme .

1. Spread sinuously (spaced 50 to 100 cm apart) a perforated (big holes) plastic tile (5 to 7 cm in diametre) on the turf surface . It is better to spread two tiles , eachone covers one half the green's area to increase the number of aeration holes .

2. Place wood chips under the tile in order not to lean against the turf for ease of air flow and avoidance of marks on the turf .

3. Fix the tile to the ground with staples to keep it sinuously stable .

4. The end of each tile goes beyond the cover length . This tile end of outside the cover does not need to be perforated to facilitate the air exchange . Drive a solid stick of 150 cm in height near each tile end , and attach it to the stick , leaving the tile end up to facilitate an air flow . Slide an elbow in the tile end to prevent water and snow from blocking it

5. Place thermocouples on the turf surface to verify the temperatures all winter . Do not install any cover on turf without a means to continuously monitor the turf temperature .

6. Place light wooden trellis on top of the tile to prevent the cover from sinking in between the tile rows due to the ice and/or snow weight . Place the impermeable cover on top of the trellis and fix it to the ground . An air exchange by diffusion takes place through the tile .

7. Maintain continuously temperatures between -5 to -10 °C on turf surface by passing a cold air into the tile by means of a powerful blower . The shorter the tiles the easier and the faster to blow the air in . In case the cover has neither snow nor ice , one sunny day is enough to build up sufficient heat (greenhouse effect) and injure or kill the turf . The wooden trellis does not eliminate some heat build-up under the cover . During very cold days , e.g. -30°C, the turf temperature under the impermeable cover does not drop that low . Anyway , if you think that turf must be protected against such very cold temperatures , you may block temporarily the opening of each or some tile ends .

8. The way each green is managed to go through winter , along with its location (an elevated green exposed to winds , or a low-ground green with reduced wind effect) influence the level of its tolerance to stresses such as heat , cold , diseases , toxic gases ... under the cover . The management and location of each green answer the question as to why the same winter protection technique may yield variable spring green-ups from one green to another on the same course under the same management .

9. I suggest to experiment with this method of winter protection and adapt it to your course conditions . For example , it would be advantageous to increase the number of tile openings to the area of each green to maximize the air flow .

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