Demonstration trials with winter cover protection

A Swedish – Finish Projct 2007 - 2010
Annual report winter 2008 – 2009

Maire Rannikko; HAMK, University of Applied Sciences
Boel Pettersson; SGF, Swedish Golf Federation

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1 Note for the reader

The objective of this Swedish–Finnish project is to evaluate the impact of winter covers on the winter survival of turfgrass on golf greens. It was intended that four golf greens be protected with winter covers during the winter of 2008–2009 in the respective countries. This goal was, however, not attained in Finland, as only one golf green at Lepaa Golf was covered with winter covers. This green was also provided with thermometers. The other greens selected for this experiment: one green at Lepaa Golf and two greens at Aulanko Golf were left uncovered. One of the greens at Aulanko Golf was, however, provided with thermometers. It was difficult to determine the correct time for installing winter covers in the autumn of 2008, due to varying weather conditions with fluctuating periods of frost and warmth, in addition to abundant rain.

In Sweden the covering of the greens at Timrå GK and Bodens GK worked well. Before the covering the greens, half part of each trial become sprayed by fungicide. The reason for that was to see the necessary of fungicide treatment before covering. Also this winter we have had some problems with leaking water under the covers. This has influence the results of the grass survivals. It has also been some problems with the temperature loggers, some of these have not worked properly. Due to that there isn’t temperature information from all different covering techniques.

The Finish part of the project

2 The experimental site and management of trial area in the summer 2008

Winter protection covers were laid on Lepaa Golf's ninth green. The green was covered from 8 December 2008 to 7 April 2009. The grass species on the green were velvet bentgrass (*Agrostis canina* ´Vesper´) and bentgrass (*Agrostis stolonifera* ´L-93´).

2.1 Cutting and cutting height

In October were three cuttings, the last one 13 October 2008 (Table 1).

Table 1 *Cutting height of grass on the trial green*

Period	Grass height mm	Cutting times
5.5.–5.6.2008	6,0	20
6.6.– 11.7.2008	5,0	26
12.7.–24.8.2008	4,0	32
25.8.–14.9.2008	3,8	14
15.9.–13.10.2008	4,5	12

2.2 Fertilizer inputs

The trial green was fertilized according the results of soil analysis (Table 2).

Table 2 *Fertilization time and amount of given nutrients in the summer 2008*

Date	Fertilizer type	kg per ha			
		Fertilizer	N	P	K
18.4.2008	Kemigreen START 2-5-2	25	0,5	1,3	0,5
7.5.2008	Kemigreen BASIC 6-1-3	33	2,0	0,3	1,0
20.5.2008	Greencare 13-3-12	125	16,3	3,8	15,0
29.5.2008	Kemigreen EXTRA (micronutrients)	33			
23.6.2008	Kemigreen BASIC 6-1-3	33	2,0	0,3	1,0
3.7.2008	GreenCare 18-0-16	125	22,5		20,0
10.7.2008	Iron Sulphate	50			
17.7.2008	Kemigreen BASIC 6-1-3	33	2,0	0,3	1,0
31.7.2008	GreenCare 13-3-12	125	16,3	3,8	15,0
12.8.2008	GreenCare 13-3-12	150	19,5	4,5	18,0
27.8.2008	Kemigreen AUTUMN 1-2-7	33	0,3	0,7	2,3
16.9.2008	Kemigreen AUTUMN 1-2-7	25	0,3	0,5	1,8
24.9.2008	Kemigreen AUTUMN 1-2-7	33	0,3	0,7	2,3
10.10.2008	Phosfik 3-12-15	5	0,2	0,6	0,8
Total			82,2	16,8	78,7

2.3 Fungicide treatments

The last fungicide application was 2 December 2008. The intention was to cover the greens immediately after that. Covering was delayed due to changing weather.

The following fungicides were used:
- 3.4.2008 iprodione (Rovral 75 WG)
- 18.6.2008 propiconazole (Tilt 250 EC) and pyrachlorstrobin (Comet)
- 21.8.2008 propiconazole (Tilt 250 EC)
- 9.9.2008 propiconazole (Tilt 250 EC) and pyrachlorstrobin (Comet)
- 14.10.2008 propiconazole (Tilt 250 EC) and iprodione (Viljan tautiaine 101)
- 14.11.2008 iprodione (Rovral 75 WG)
- 2.12.2008 iprodione (Chipco Green 75 WG)

2.4 Other greenkeeping managements

Brushing
- every cutting time

Watering
- 2.5.2008
- 9.5.2008
- 11.5. – 12.5.2008
- 15.5.2008
- 18.5.2008
- 20. 5.– 8.6.2008 every day
- 5.7.–14.7.2008 every day
- 16.–17.7.2008
- 19.–21. 7.2008
- 24.7.2008
- 26.7.–3.8.2008 every day

Aeration
- 28.4.2008 (spiking)
- 3.6.2008 (spiking)
- 8.7.2008 (spiking)
- 29.7.2008 (spiking)
- 21.10.2008 (hollow tining)

Verticutting
- 16.4.2008
- 1.7.2008

Sand dressing
- 29.4.2008
- 1.7.2008

Overseeding
- 29.4.2008

3 Weather data

Monthly average temperatures and rainfall during the summer of 2008 and the winter of 2008–2009, as well as respective normal values of past 30 years are illustrated in Table 3. Daily average temperatures during the winter months, as well as minimum and maximum temperatures are illustrated in Figure 1. The data is collected from the weather station of the Finnish Meteorological Institute (FMI) at Hattula Lepaa.

Table 3 *Weather data of Hattula Lepaa weather station from 1 May 2008 to 30 April 2009 (FMI) and the normal values for temperature and rainfall from the period 1971–2000 (FMI)*

Year and month	Average temperature °C		Precipitation mm	
	2008/2009	30 year normal	2008/2009	30 year normal
2008 May	10,2	9,8	26	34
2008 June	14,0	14,5	83	55
2008 July	16,4	16,4	33	80
2008 August	14,2	14,6	108	74
2008 September	8,8	9,4	26	54
2008 October	7,0	4,5	107	55
2008 November	1,3	-0,5	66	48
2008 December	-0,2	-4,5	45	42
2009 January	-5,4	-6,6	30	36
2009 February	-5,7	-7,1	22	27
2009 March	-2,4	-2,8	51	29
2009 April	4,1	2,7	19	30

As can be seen in Table 3, temperatures were above the long-term average during the late autumn of 2008 and the winter of 2008–2009. The amount of rainfall during the months of October and November was also above the long-term average.

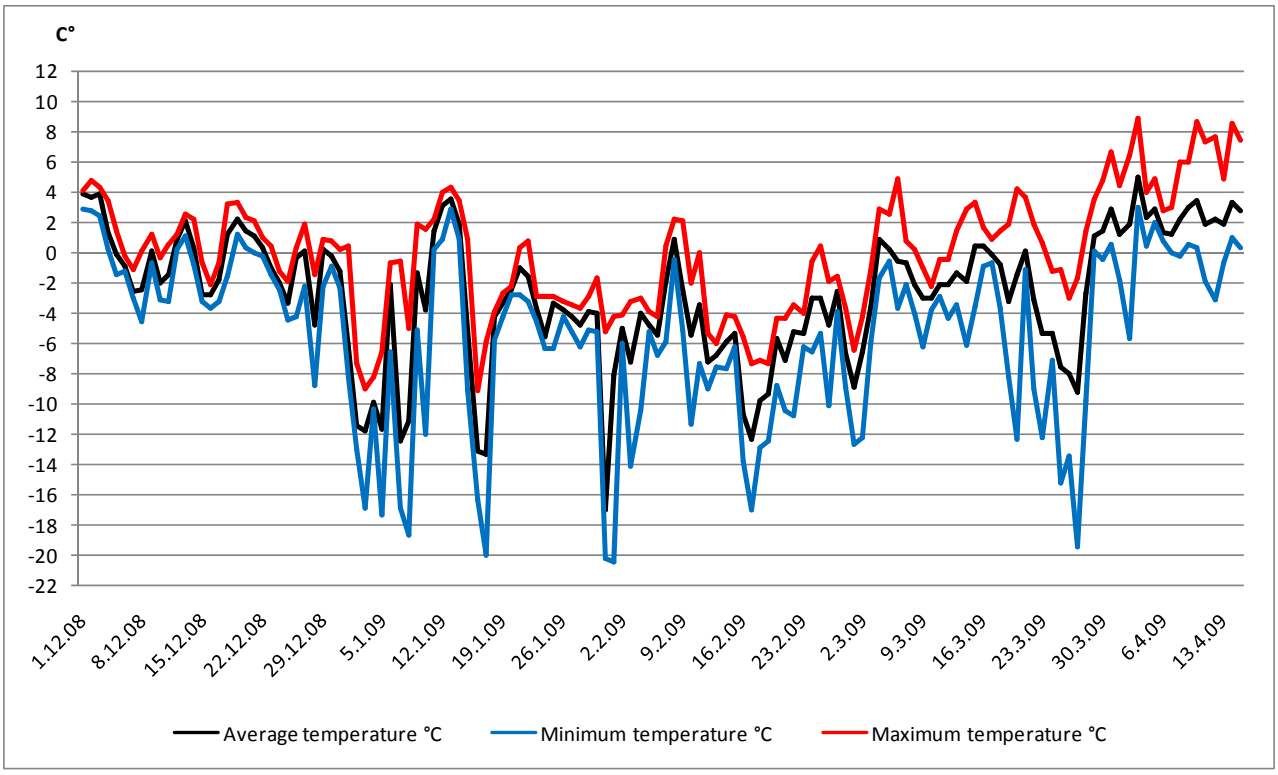

Figure 1 Daily average, minimum and maximum temperatures from 1 December 2008 to 15 April 2009 at Hattula Lepaa (FMI)

There were rapid fluctuations in the weather during the autumn of 2008. The first snow fell on 21 November, and stayed on the ground till 30 November 2008. A rainfall of 8 mm was measured as late as 2 December 2008, soon after fungicide application. This caused a delay in the installation of the winter covers.

The greens were covered with snow from 9 December 2008 onwards. During the winter of 2008–2009 there were two short periods without snow cover, as the snow melted on 19 December 2008 and 13 January 2009.

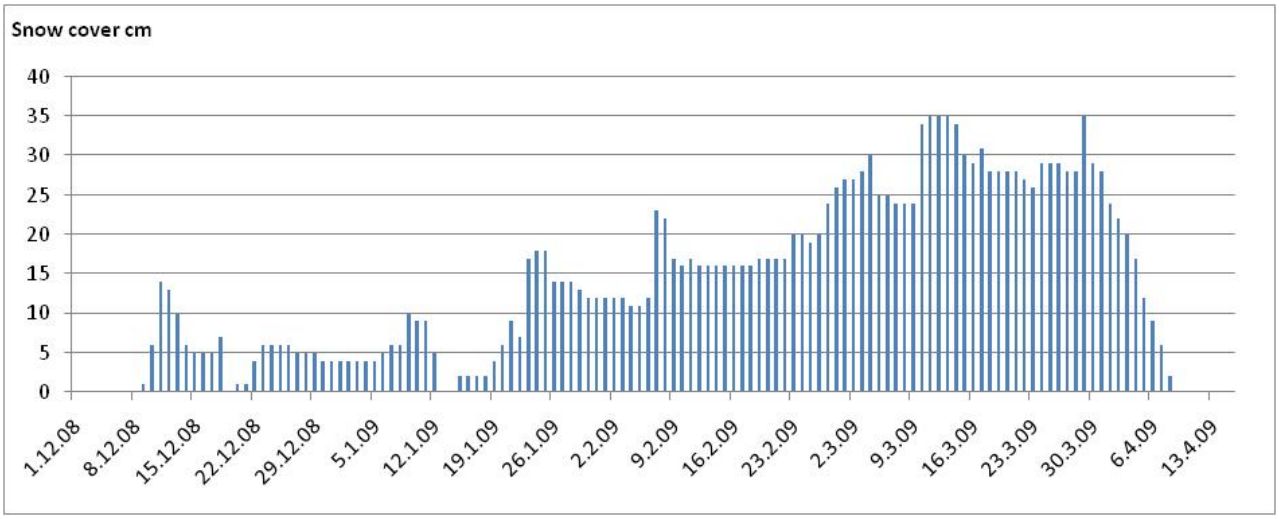

Figure 2 Depth of snow from 1 December 2008 to 15 April 2009, precipitation station Hämeenlinna Pirttikoski (FMI)

The snow cover was at its deepest from 11 March to 13 March and on 29 March 2009, when it was measured 35 cm deep.

4 Experimental plan and covers

4.1 Winter covers

The winter covers in this research included:

A Bubble plastic, 10 mm bubble size (Finnstaples) + plastic film (black and white sides)
B Bubble plastic, 13 mm bubble size (KSAB Golf Equipment Ab) + plastic film (black and white sides)
C Gromax Plus, non woven polyethene sheet 30 g/m^2 + plastic film (black and white sides)
D Evergreen (without plastic film)
E Control with no cover

The breadth of the area covered in each plot depended on the breadth of the cover material used, as shown below:

- A 3,6 m
- B 3,6 m
- C 5,3 m

- D 5,8 m
- E 5,8 m

The covering time was from 8 December 2008 to 7 April 2009. Spring cover was on the green from 17 April to 21 April 2009.

The length of the area covered was determined by the outlines of the green. Consequently, the area covered with winter cover in each plot varied from 30 to 45 m^2.

Cover D, Evergreen, had no plastic covering, and was therefore placed at one end of the experimental green. The control plot was placed at the other end of the experimental green (Photo 1).

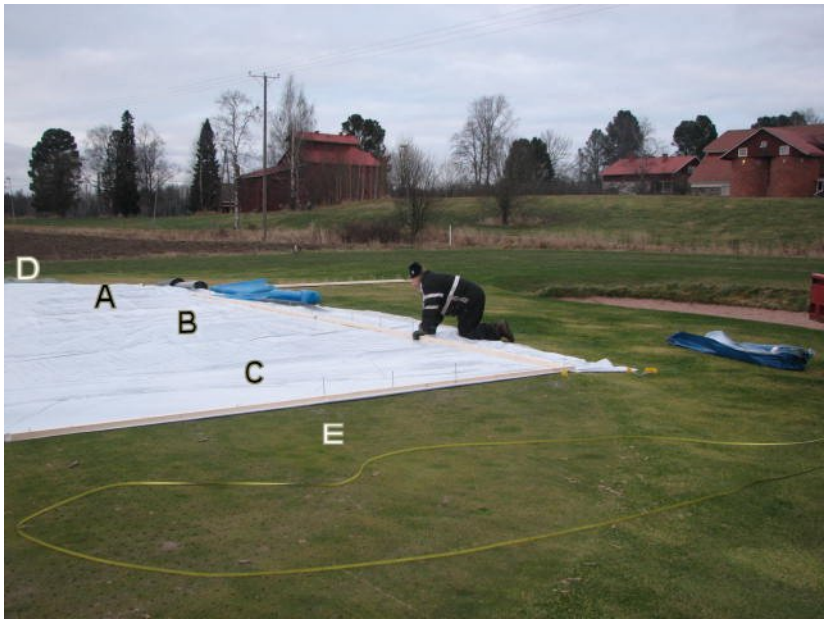

Photo 1 Covering of the green at Lepaa golf corse (Photo Petteri Lehmuskoski)

The plastic film covering plots A, B and C was installed with the aid of wooden planks and nails. The objective was to prevent water produced by the melting snow from leaking and freezing underneath the winter covers. The aim was also to prevent the installed plastic film from being blown loose by the wind (Photo 2).

Photo 2 The plastic film was installed with the aid of 100 x 100 mm wooden planks and six inch nails.
(Photo Petteri Lehmuskoski)

4.2. Measurement of the temperature

Thermochron iButton -thermometers (Dallas Semiconductor) were used for measuring the temperature. The meter had an accuracy of ±0.5°C. One iButton was placed on the surface of the green underneath the winter cover, and another iButton was embedded at a depth of 10 cm in the soil. The iButton that was placed on the surface in the control plot (E) was left without cover. The iButtons that were embedded in the soil were placed in the center of a hole cut with a hole cutter, and the turf plug that was released was set on top of the embedded iButton. The iButtons recorded the temperature six times a day.

All other meters were very reliable, but the iButton underneath Gromax Plus (C) that was embedded at a depth of 10 cm did not deliver uploadable data.

4.3 Observation of the turfgrass

A visual survey of the turfgrass was made in autumn before covering and in spring when the covers were taken off. The subjects of observation were in autumn living ground cover (%) and disease damages (%), in spring winter kill (%) and diseases damages (%).

5 Results

5.1 Quality and growth of turfgrass

Turf condition was relatively good prior to the installation of winter covers in the autumn of 2008. Living ground cover was 100%. No diseases were detected.

In spring the experimental plots were first inspected on 7 April 2009, when the winter covers were removed. It was discovered that all three plots: A, B and C that had been covered with plastic film were very severely infected with snow mold. The infection was primarily caused by the fungus *Typhula incarnata,* giving rise to a disease called grey snow mold. Some snow mold was detected also in the plots E (Control) and D (Evergreen) that had not been covered with plastic film. However, white fungal mycelia could no longer be detected in these areas, and only damaged patches were found. There was a distinct difference compared to the three other areas (Photo 3).

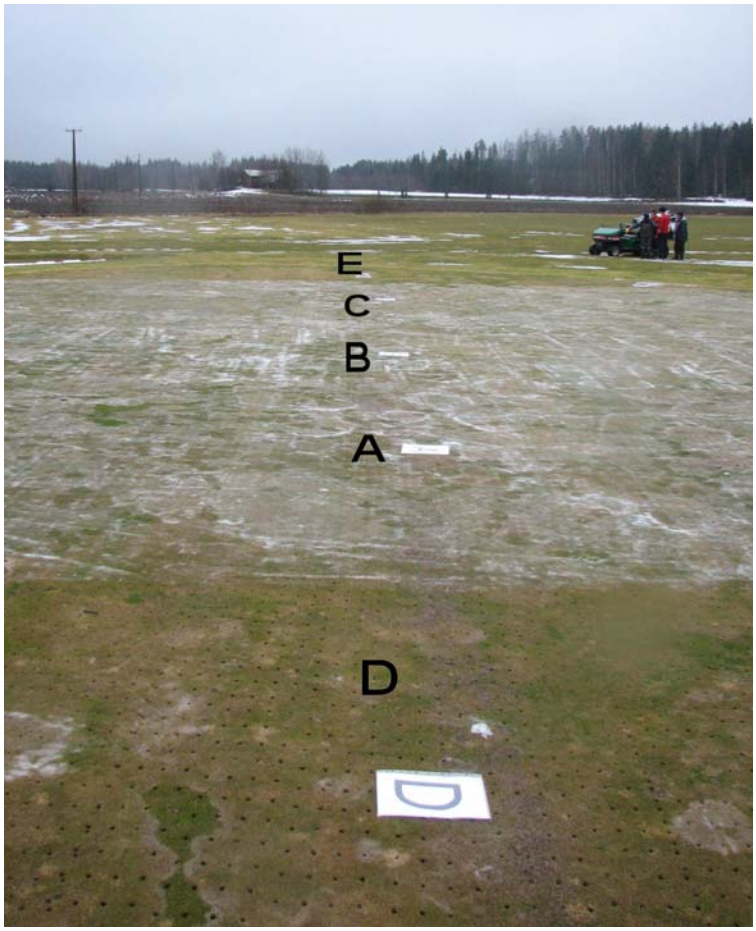

Photo 3 The areas covered with impermeable plastic film (A, B, C) stuck out on green (Photo Petteri Lehmuskoski)

No differences were found on 7 April 2009 between the bubble plastic covers (A, B) and the Gromax Plus cover (C) in turf condition or in severity of disease infection in each plot (Photos 4–6). There was a substantial amount of white mycelia and damaged patches underneath all three covers.

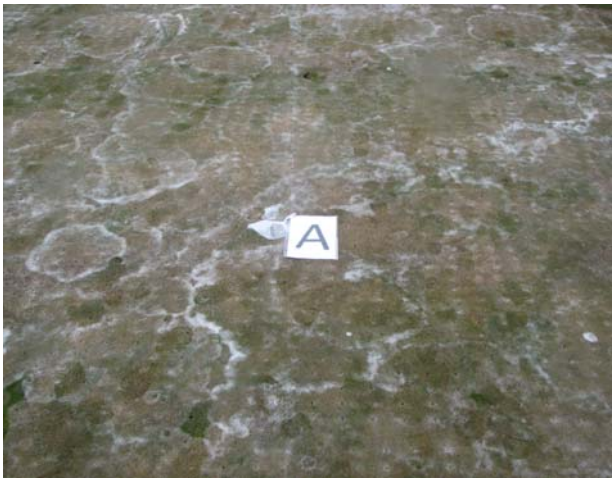

Photo 4 Turf underneath the bubble plastic cover (Finnstaples) 7 April 2009 (Photo Petteri Lehmuskoski)

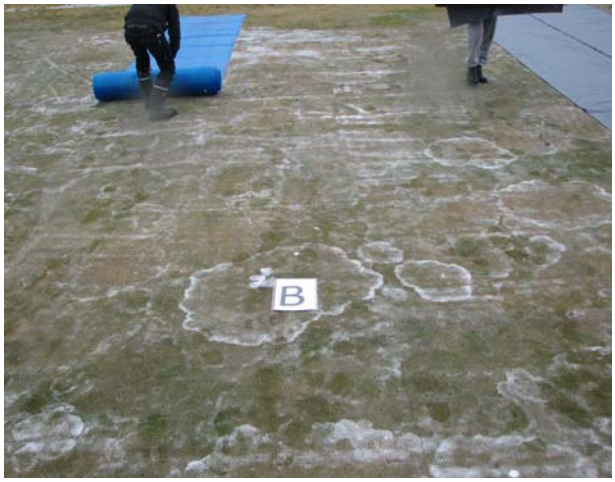

Photo 5 Turf underneath the bubble plastic cover (KSAB) 7 April 2009 (Photo Petteri Lehmuskoski)

Photo 6 There were white snow mold stripes underneath Gromax Plus cover (C), in areas where the cover had been folded and had therefore been tight. (Photo Petteri Lehmuskoski)

Living ground cover was best underneath Evergreen (D), and second best in the uncovered control plot E. There was no plastic film on top of Evergreen, whereas the permeable cover Gromax Plus (C) did have a plastic film on top.

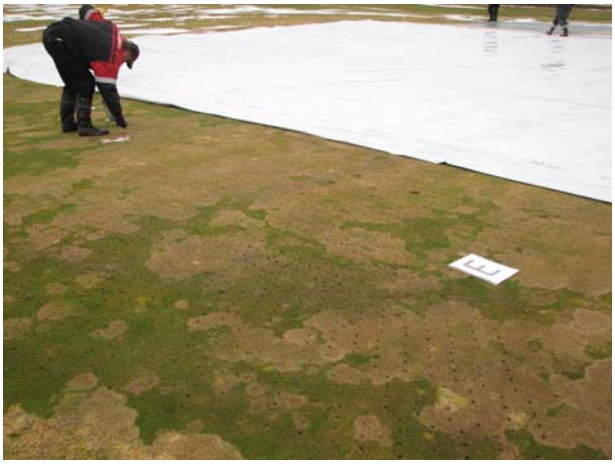

Photo 7 Turf in controll area 7 April 2009 (Photo Petteri Lehmuskoski)

Photo 8 Turf underneath Evergreen 7 April 2009 (Photo Petteri Lehmuskoski)

Turf condition remained for the most part the same during the spring of 2009. In areas that had been covered with Evergreen (D) and in the uncovered control area (E) there was some turf recovery (Table 4), in contrast to the areas that had been covered with bubble plastic (A, B) and Gromax Plus (C), where the situation remained nearly the same throughout the spring. As the infections were so severe, it was not found expedient to evaluate winter kill separately, and therefore only living ground cover was evaluated.

Table 4 Recovering of turf on Lepaa trial green

Evaluating day	Living groud cover %				
	A	B	C	D	E
7.4.2009	5	5	5	40	25
29.4.2009	5	5	5	40	30
12.5.2009	3	3	4	45	40
26.5.2009	3	3	4	45	40

The overseeding of the trial green was done 28 April 2009.

5.2 Soil surface temperatures underneath the covers and soil temperatures

Temperatures measured underneath the winter covers and at a depth of 10 cm in the soil followed the changes in air temperature with a delay of one to two days, when there was no, or only a thin, snow cover. For example when air temperature remained above 0°C from 11 January to 14 January 2009, and snow melted away, temperatures underneath the covers and in the soil reacted very swiftly to changes in air temperature (Figures 3 and 4).

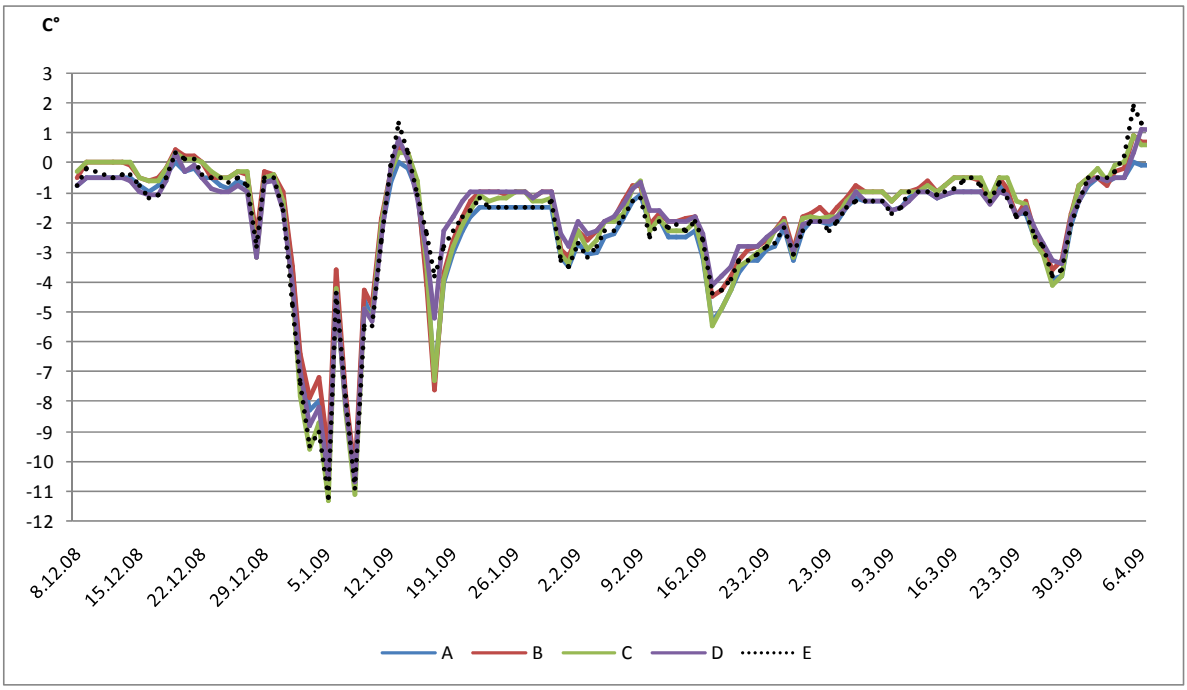

Figure 3 Daily average temperatures underneath the covers. A: bubble plastic (Finstaples), B: bubble plastic (KSAB), C: Gromax Plus, D: Evergreen, E: controll without cover

Temperatures measured on the soil surface underneath the winter covers differed only slightly from concurrent temperatures measured on the bare turf of the control plot (Figure 3). Differences between respective winter covers were also small, and could be explained by the accuracy (±0.5°C) of the measuring equipment.

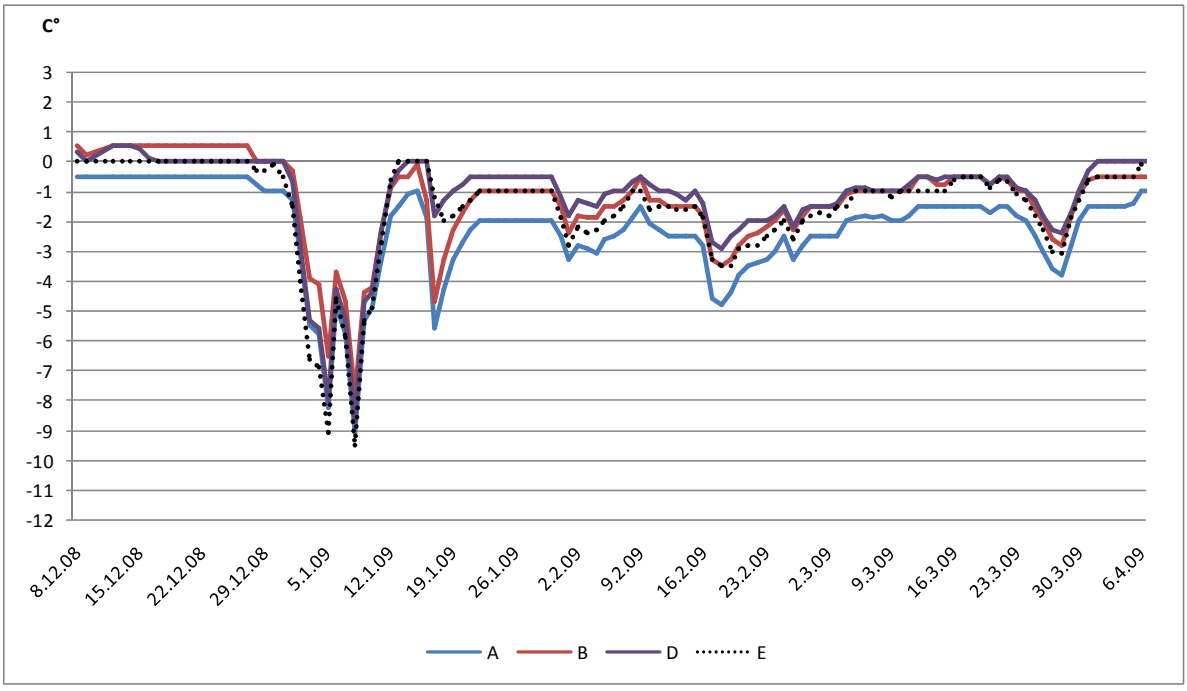

Figure 4 Daily average temperatures at a depth of 10 cm in the soil. A: bubble plastic (Finstaples), B: bubble plastic (KSAB), D: Evergreen, E: controll without cover.

There was a somewhat greater difference between various winter covers, as well as between covered and uncovered areas in temperatures measured at a depth of 10 cm in the soil. The difference between the two bubble plastic covers was parallel to the difference found between them the year before. Soil temperature was constantly higher underneath the KSAB plastic cover (B) that had bigger bubbles, than underneath the other bubble plastic cover (A) (Figure 4).

The slight difference in insulating capacities between the respective winter covers was also shown in the amount of time required for the ground to thaw. As the winter covers were removed, frost depth was controlled by pushing the 9 cm long blade of a knife into the ground (Photo 9), to the point where it was stopped by a frozen layer.

Photo 9 Melting of soil frost underneath the bubble plastic cover (A) and Evergereen (D) (Photos Kristiina Laukkanen)

It was noted that the ground had thawed somewhat less underneath the bubble plastic covers than underneath the less insulating Evergreen and Gromax Plus covers.

6 Discussion and conclusions

It was difficult to determine the correct time for installing winter covers also in the autumn of 2008. The ground was slightly frozen and some snow fell, but soon the snow melted and the ground thawed again. The months of October and November had more rainfall and were warmer than on the average. The abundant rain and rapid fluctuations in the weather also caused difficulties in timing the fungicide application that was to be done only just before the installation of winter covers.

Turf condition was clearly the weakest underneath the three covers with impermeable plastic film, compared with Evergreen that is permeable to water and air, as well as with the control with no cover at all. The differences in temperature between covered and uncovered areas remained small. The lowest temperatures measured during the winter in the entire experiment green underneath the covers and at a depth of 10 cm in the soil were -11C° and -9°C, respectively. This, together with the fact that turf condition was clearly better in the uncovered control plot than underneath the insulating bubble plastic covers, leads to the conclusion that the poor winter survival is to be explained by other factors than the temperature.

The poor winter survival of the green was evidently caused by several factors interacting with each other. The impermeable plastic film spread over three of the winter covers had been installed in a way as to prevent water from leaking underneath the winter covers and freezing on the green. The aim had also been to strengthen the installed plastic film against the effects of strong wind.

Rochette, Dionne, Castonguay and Desjardins (2006) found that an increase in oxygen consumption and carbon dioxide production occurred underneath an impermeable winter cover, especially on greens with high soil organic matter content. It was concluded that the discovered increase in oxygen consumption was due to increased soil biological activity rather than plant respiration.

Although the green at Lepaa Golf was built according to the USGA specifications with low soil organic matter, it is possible that the installation of the plastic film with wooden planks was so tight as to allow an accumulation of carbon dioxide, and respectively a reduction in oxygen concentration, thus weakening winter survival of the turf underneath the three covers: two bubble plastic covers and Gromax Plus that had plastic film on top of them.

It was discovered by Castonguay, Thibault, Rochette, Bertrand, Rochefort and Dionne (2009) that a reduction in oxygen concentration was more likely to cause damage to the turf than a high concentration of carbon dioxide. Low oxygen concentration together with a high concentration of carbon dioxide was said to cause more damage to the plants than low concentration of oxygen alone.

One factor that may have facilitated the strong growth of snow mold underneath the impermeable plastic film may also have been the fact that there was a five-days delay after fungicide application before winter covers were installed. It is therefore possible that the turfgrass was more susceptible to snow mold infection due to the reduced effect of the fungicide, especially when the turf was further weakened by the shift in CO_2/O_2 ratio during the winter.

In this trial, the impact of winter covers on winter survival of turfgrass in Finland was predominately negative during the winter of 2008–2009. The experimental green was covered for a longer period of time in 2008–2009 than in the previous year, which may have allowed the negative impact to become more evident. Furthermore, there was a deeper and more lasting snow cover in 2008–2009 than in the previous year, which may also have affected the result. It is concluded that if impermeable plastic film is to be used on top of winter covers, it is essential to develop methods for increasing air space underneath the covers. Another option would be to increase gas exchange from underneath the covers on a few occasions during the winter when the air temperature is favourable.

7. References

Castonguay, Y., Thibault, G., Rochette, P., Bertrand, A., Rochefort, S. and Dionne, J. 2009. Physiological Responses of Annual Bluegrass and Creeping Bentgrass to Contrasted Levels of O_2 and CO_2 at Low Temperatures. Crop Science 49, 671–689.

Rochette, P., Dionne, J., Castonguay, Y. and Desjardins, Y. 2006. Atmospheric Composition under Impermeable Winter Golf Green Protections. Crop Science 46, 1644–1655.

Appendix 1/1

TEMPERATURES UNDERNEATH COVER AND IN SOIL

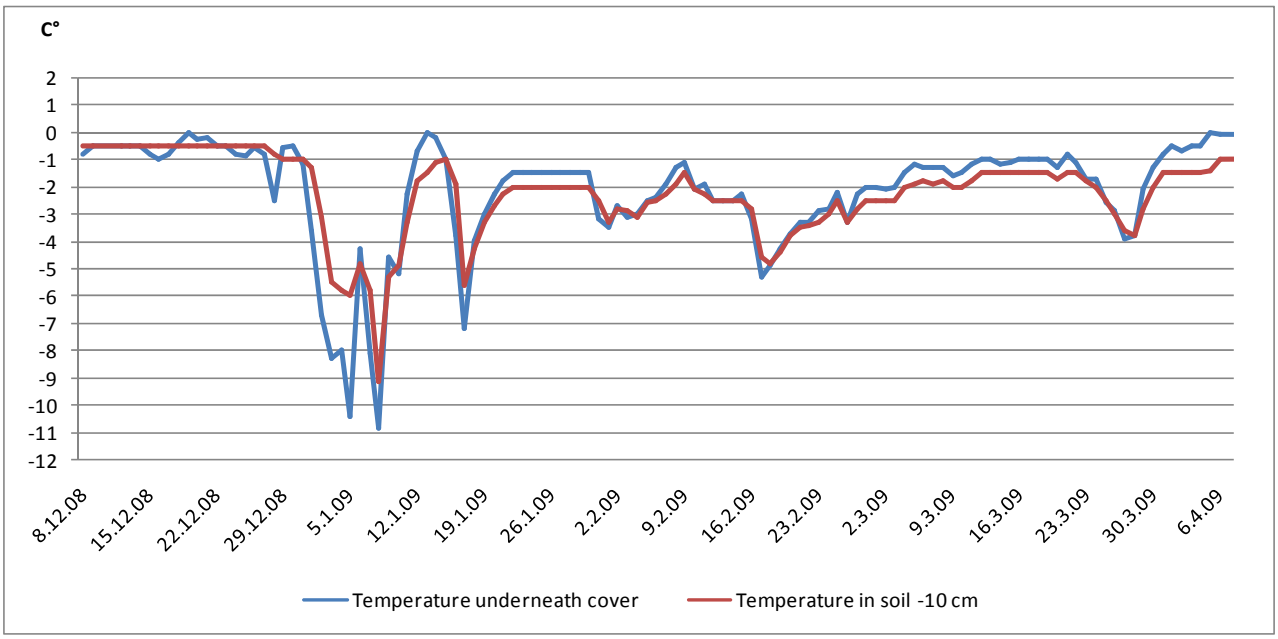

Figure 1 Temperatures underneath cover and in soil, cover bubble plastic (Finnstaples)

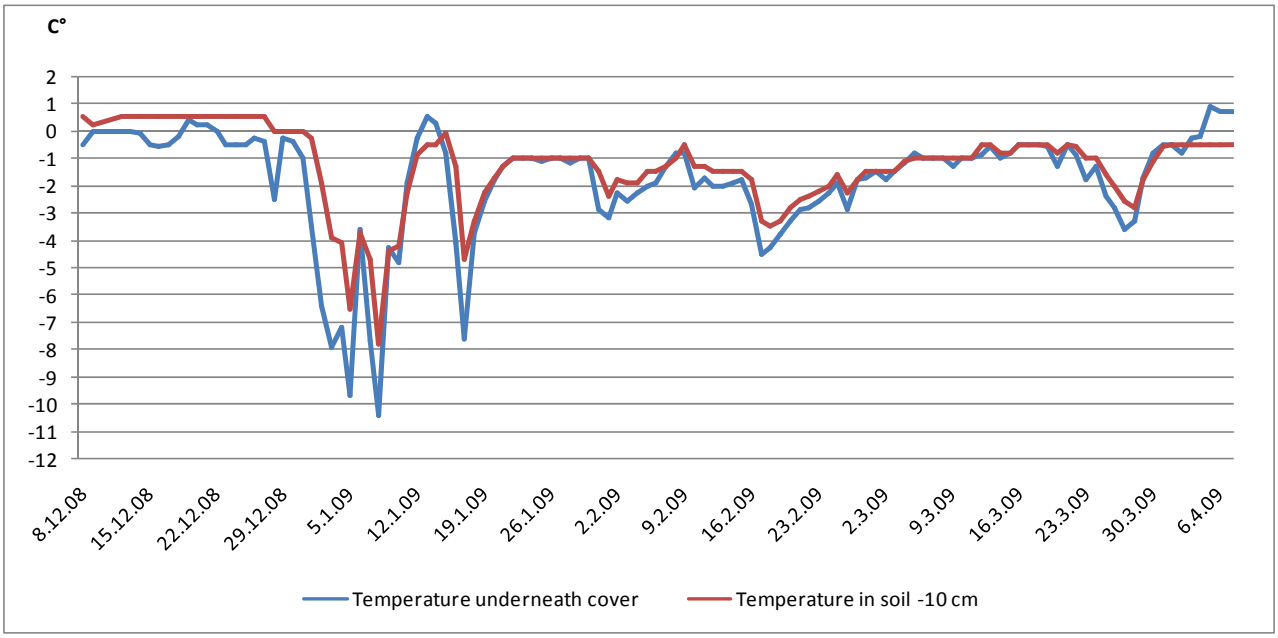

Figure 2 Temperatures underneath cover and in soil, cover bubble plastic (KSAB)

Appendix 1/2

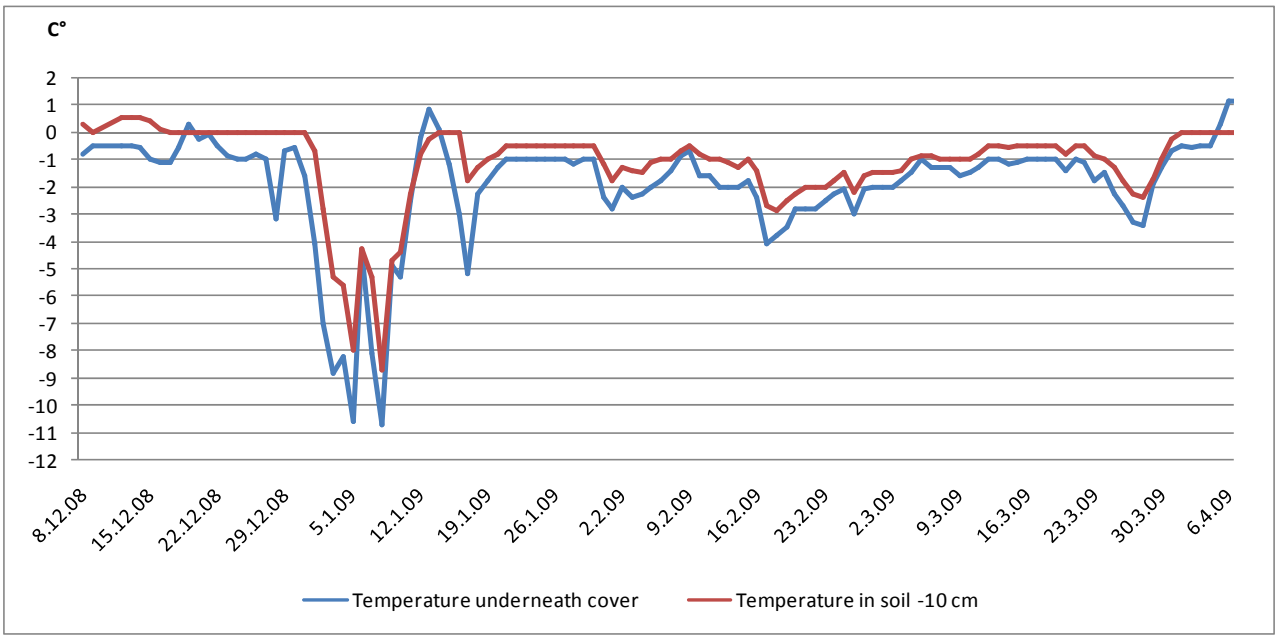

Figure 3 Temperatures underneath cover and in soil, cover Evergreen

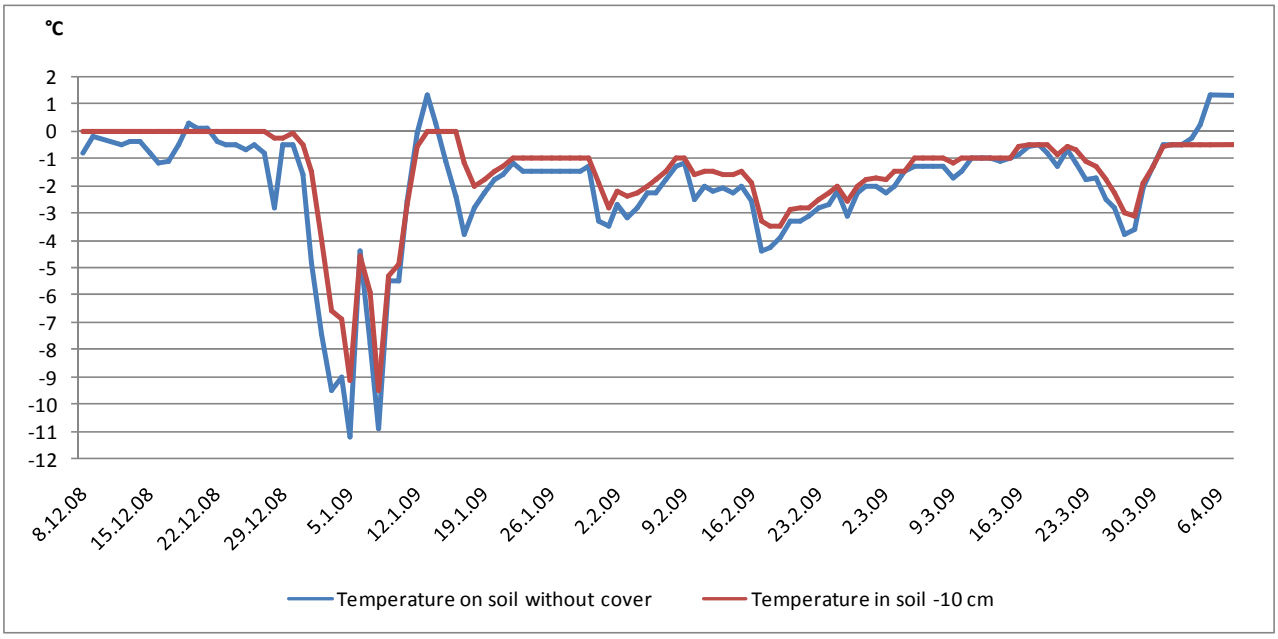

Figure 4 Temperatures in controll area

The Swedish part of the project

9 The experimental site and management of trial area in the summer 2008

At both Timrå GK and Bodens GK the dominate grass species on the greens is annual bluegrass (*Poa annua*) and Rough bluegrass (*Poa trivalis*).

The management of the greens (table 1-4) is from August (or September) until October (or November) 2008.

9.1 Mowing, mowing height, rolling and brushing

Table 1. Mowing and rolling at Timrå GK during August to October 2008

Period	Mowing height (mm)	Mowing times	Rolling
1.8 – 10.9.2008	3,5	27	32
11.9 -13.10.2008	4,5	6	18
14.10.2008→	5,0	1	2
		Last mowing 14.10	Last rolling 24.10

Table 2. Mowing, rolling and brushing at Bodens GK during September to October 2008

Period	Mowing height (mm)	Mowing times	Rolling	Brushing
1 – 30.9.2008	4,3	14	6	18
1.10.2008→	4,3	2	-	7
		Last mowing 4.10	Last rolling 30.9	Last brushing 13.10

9.2 Fertilizers inputs

Table 3. Fertilization time and amount of given nutrients from 1 of August at Timrå GK

Date	Fertilizer	N (kg/100m^2)	P (kg/100m^2)	K (kg/100m^2)
4.8.2008	Wallco 5,1-1-4,3	0,088	0,017	0,074
11.8.2008	Wallco 5,1-1-4,3	0,075	0,015	0,063
19.8.2008	Wallco 5,1-1-4,3	0,075	0,015	0,063
28.8.2008	Wallco 5,1-1-4,3	0,057	0,011	0,048
4.9.2008	Wallco 5,1-1-4,3	0,057	0,011	0,048
11.9.2008	Wallco 5,1-1-4,3	0,044	0,008	0,037
18.9.2008	Wallco 5,1-1-4,3	0,038	0,007	0,032
25.9.2008	Wallco 5,1-1-4,3	0,025	0,005	0,021
4.10.2008	Wallco 5,1-1-4,3	0,025	0,005	0,021
10.10.2008	Wallco 5,1-1-4,3	0,018	0,004	0,015
20.10.2008	Wallco 5,1-1-4,3	0,012	0,002	0,010
Total		**0,457**	**0,100**	**0,432**

Table 4. Fertilization time and amount of given nutrients from 1 of August at Bodens GK

Date	Fertilizer	N (kg/100m^2)	P (kg/100m^2)	K (kg/100m^2)
4.8.2008	Arena Green Plus 12-1-15	0,3	0,025	0,375
25.8.2008	Arena Score 12-1,3-14	0,24	0,026	0,28
8.9.2008	Höstgrön 4,5-1-14	0,135	0,03	0,42
Total		**0,675**	**0,081**	**1,075**

9.3 Fungicide treatments

At Timrå GK were following fungicides used during autumn.

- 4.9.2008 Prokloraz (1 litre/hectar Sportak)
- 26.9.2008 Prokloraz, Bitertanol (1 litre/hectar Sportak, 1kg/hectar Baycor)
- 28.10.2008 Iprodion (7 kg/hectar Chipco Green)

At Bodens GK were following fungicides used during autumn

- 27.10.2008 Iprodion (7 kg/hectar Chipco Green)

9.4 Other treatments

At Timrå GK were following product used

- 18.9.2008 Verdera Turf PG (*Gliocladium*) 10 litre/hectar

9.5 Other greenkeeping managements

9.5.1 Timrå GK

During August until October following management were done at Timrå GK

Verticutting

- 6.8.2008 0,5 mm in 3 directions
- 26.8.2008 1 mm in 2 directions

Top dressing

- 6/8, 19/8, 27/8, 9/9, 24/9 and 21/10.2008. Total 6 times during this time.

Aeration

- 19.8.2008 knifes, 4 cm depth
- 8-9.9.2008 solid 12 mm ø
- 24.10.2008 knifes, 5 cm depth

9.5.2 Bodens GK

During September until October following management were done at Bodens GK

Top dressing

- 2/9, 8/9, 15/9, 22/9, 29/9, 6/10 and 13/10.2008. Total 7 times during this time.

Aeration

- 1.9.2008 Pre core, cross tines 13 mm ø, 8 cm depth
- 9.10.2008 Knifes (deep aerator)

10 Weather data

10.1 Timrå GK

Figure 1 shows the monthly precipitation between August 2008 and April 2009 at Timrå GK. At the end of October the first snow come. In November the precipitation was both as rain and snow and in the end of the month most of the golf course was covered by ice. During December until March most of the precipitation was in form of snow and the snow depth varied 10 to 75 cm. Under the snow there was a 2-4 cm layer of ice. In April only a small amount of snow was fallen, the most precipitation was in form of rain. The most of the trials were free from snow and ice 20 of April 2009. Temperature in Timrå between 1 of August 2008 and 30 of April 2009 is showed in figure 2.

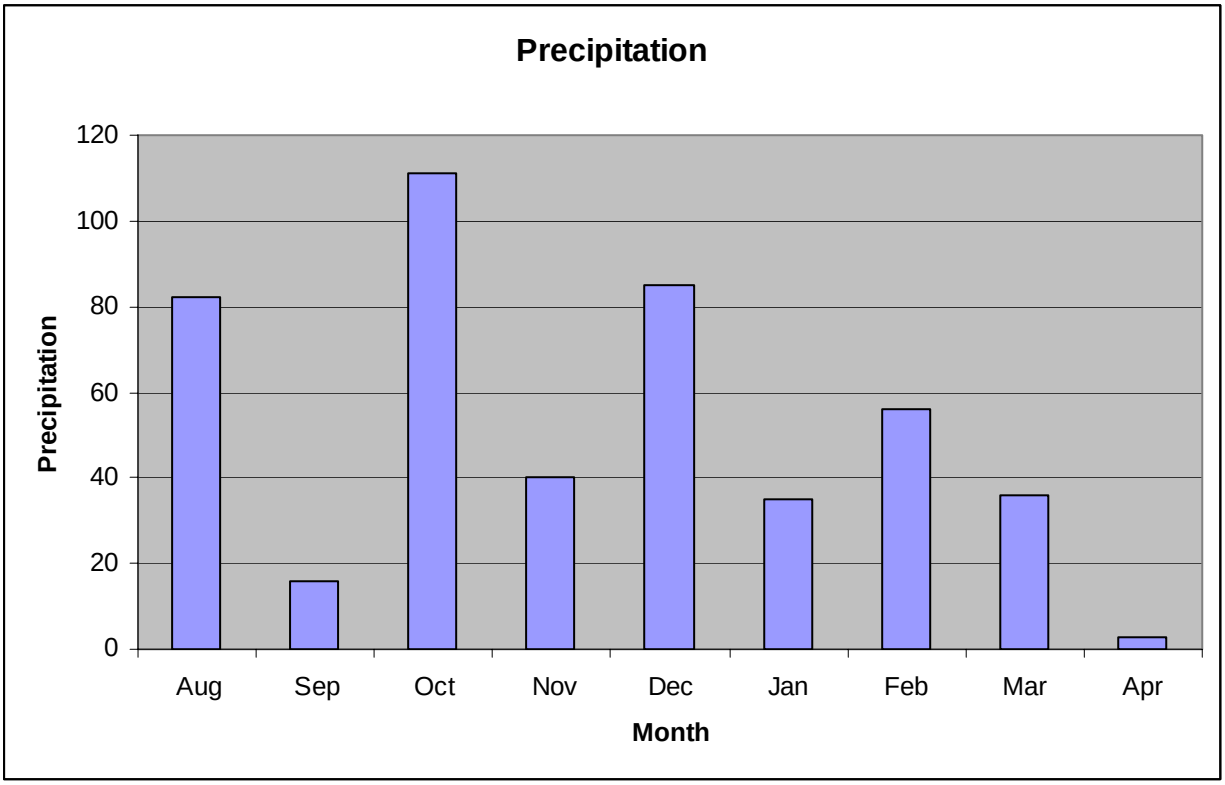

Figure 1. The measurement of precipitation at Timrå GK has been done from 1 of August 2008 until 20 of April 2009.

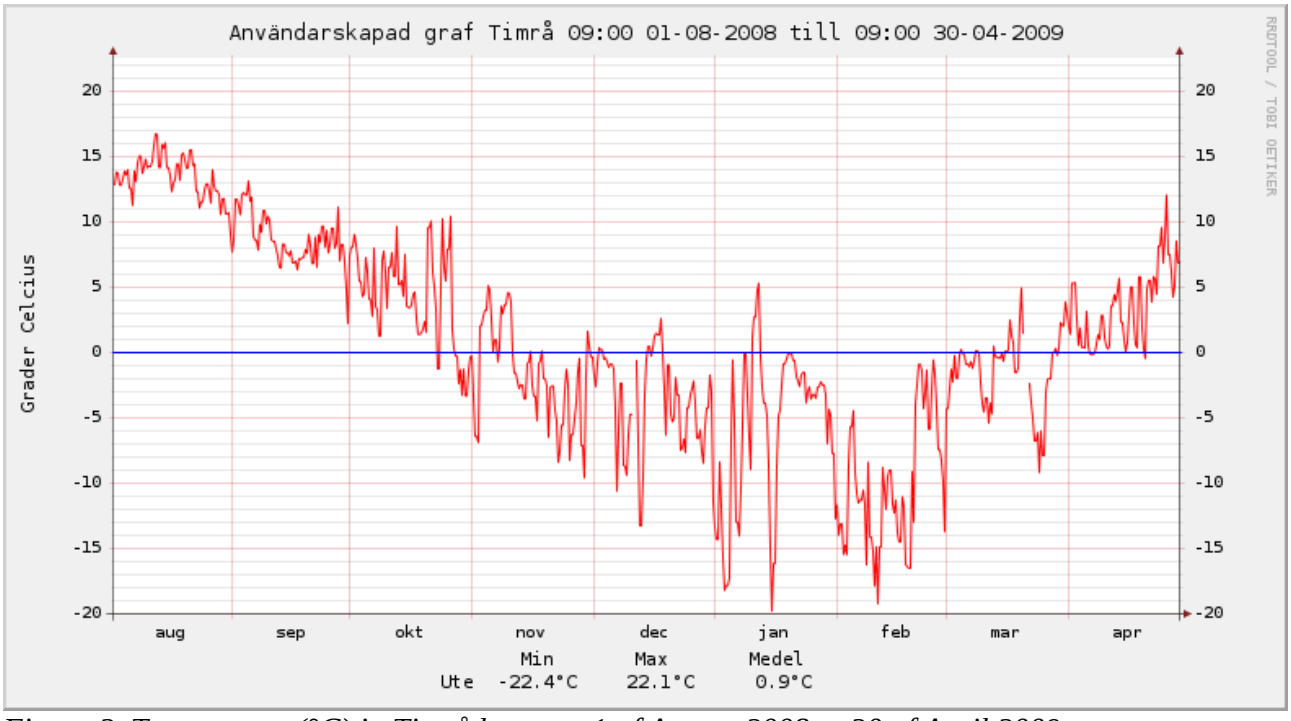

Figure 2. Temperature(°C) in Timrå between 1 of August 2008 to 30 of April 2009 (www.temperatur.se)

10.2 Bodens GK

At Bodens GK was no account of precipitation done during the autumn and winter. The first snow come in the beginning- middle of November and the trials were free from snow in the end of April 2009. During the winter, the snow depth was up to about 100 cm and more or less no ice at the golf course. Temperature in Boden between 1 of August 2008 and 30 of April 2009 showed in figure 3.

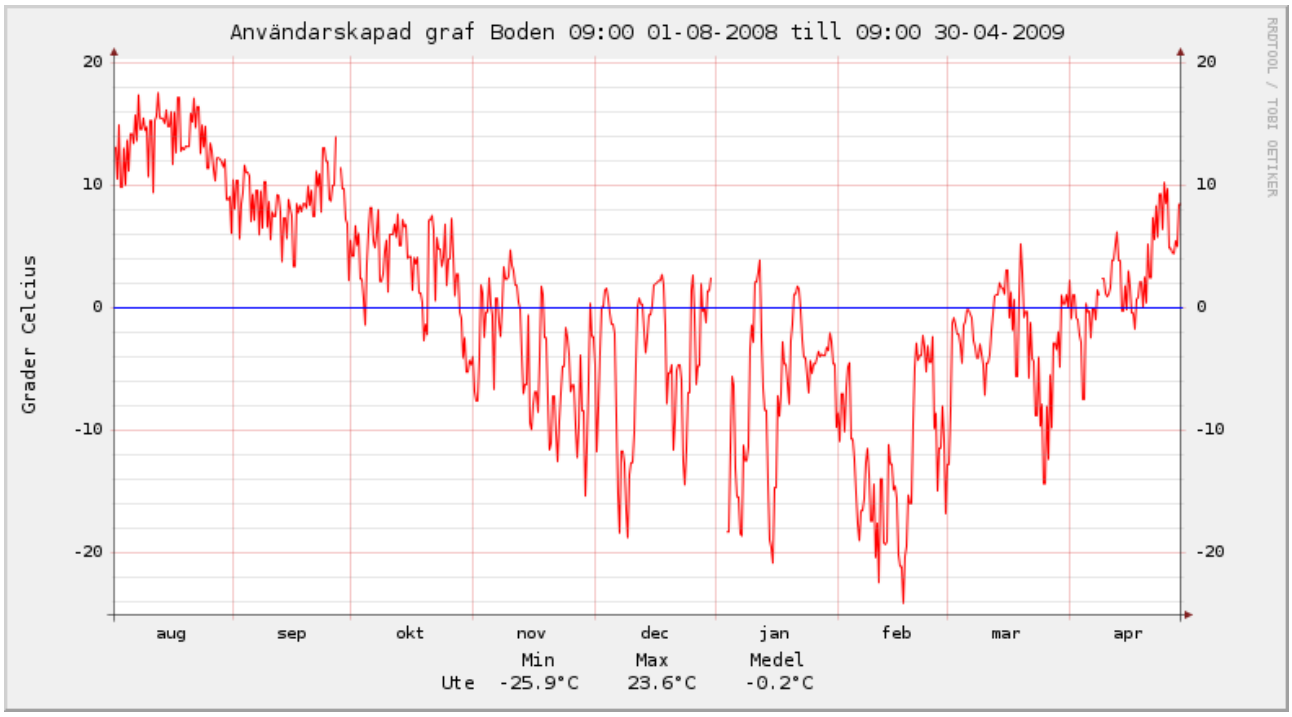

Figure 3. Temperature(°C) in Boden between 1 of August 2008 to 30 of April 2009 (www.temperatur.se)

11 Experimental plan and covers

11.1 Winter covers

At Timrå GK were the greens covered between 6 of November 2008 and 20 of April 2009. At Bodens GK the covering time was between 4 of November 2008 and 29 of April 2009. After that date was the permeable cover ("spring cover") left on the greens (including control area A).

The winter covers were

A. Control
B. KSAB Evergreen (permeable cover)
C. KSAB Evergreen + KSAB Ice shield (impermeable cover)
D. KSAB Evergreen + "bubble plastic" (isolation) + KSAB Ice shield
E. KSAB Evergreen + Plastic cover from Lantmännen Park och Mark

In an attempt to create a better "air space" between the impermeable cover and the ground, "Leca" ("light expanded clay aggregate") is use in area C and E (see photo 1).

Photo 1. "Leca" ("Light expanded clay aggregate") tested as a method too creates a better "air space" between the permeable and the impermeable cover. Photo: Boel Pettersson (2008-11-04)

To test the effect and the necessary of using fungicides before covering, only the half of the greens sprayed by Chipco Green (Iprodion) and the other part was no treated.

11.2 Measurements of the temperature

Temperatures measured by using Omega Temperature Loggers. At each green was one logger placed in the soil (only Timrå GK) under cover (at 10 cm depth). One logger measured ground temperature under each area (A to E) and one logger measured the air temperature. All loggers saved data every 2,5 hour during the covering time. Unfortunately, some of the logger did not work properly and due to that, there is not temperature information from all different covering techniques.

11.3 Observation of the turfgrass

A visual survey of the turfgrass made in the autumn before covering and in spring after the covers taken off. The subjects of observations were in autumn; living ground cover (%), visual density (scale 1-9, ther 9 is maximum density) and disease damages (%). In spring, observation of winterkill (%) and disease damages (%) were done.

12 Results

12.1 Quality and growth of turfgrass

12.1.1 Timrå GK

In autumn 2008 (evaluation date 4 of November) both greens were in very good condition. No or very small differences in quality were seen between the different areas (A-E) of the greens. See table 5.

During the winter, plugs of grass collected from area A and the survival of the grass checked. From the end of November, the greens of the golf course had a 1-4 cm ice layer. The grass samples collected in the middle of January, February and March. The survival of the grass checked after 7-10 days. During this time the grass plugs were first placed in a temperature of about +5°C (about 1 day) and after that about +20°C. From this simple check of survival, we saw a re-growth of grass

from the plugs collected in January and February (se photo 2 and 3 below). The re-growth of the plug collected in March was very bad; more or less all the grass in the sample was dead, see photo 4.

Evaluation	G7A	G7B	G7C	G7D	G7E	G16A	G16B	G16C	G16D	G16E
Height of grass (mm)	4,5	4,5	4,5	4,5	4,5	4,5	4,5	4,5	4,5	4,5
Living ground cover (%)	100	100	100	100	100	100	100	100	100	100
Visual density (1-9)	9	9	9	9	9	8	9	9	9	9
Disease damages (%)	0	0	0	0	0	0	0	0	0	0

Table 5. 4th of November, an evaluation of the turf quality were done at Timrå GK.

Photo 2. Grass plug collected at Timrå GK 2009-01-10, photo taken 2009-01-16 by Håkan Blusi

Photo 3. Grass plug collected at Timrå GK 2009-02-16, photo taken 2009-02-28 by Håkan Blusi

Photo 4. Grass plug collected at Timrå GK 2009-03-17. It was more or less no survival of the grass one week later. (Photo Håkan Blusi)

In spring, 2009 the first observation were made 20 of April and the evaluation of the quality 23 of April (result, see table 6, 7).

Evaluation	**G7A**	**G7A***	**G7B**	**G7B***	**G7C**	**G7C***	**G7D**	**G7D***	**G7E**	**G7E***
Winter damage (%)	100	100	100	100	90	90	95	80	50	50
Diseases (%)	-	-	-	-	-	2	-	3	-	5

*Table 6. Result from the evaluation of the trial green number 7 in spring. * = area untreated by fungicide.*

Evaluation	**G16 A**	**G16 A***	**G16 B**	**G16 B***	**G16 C**	**G16 C***	**G16 D**	**G16 D***	**G16 E**	**G16 E***
Winter damage (%)	95	95	100	100	5	5	20	20	5	5
Diseases (%)	-	-	-	-	<0,5	1	0	0,5	0,5	3

*Table 7. Result from the evaluation of the trial green number 16 in spring. * = area untreated by fungicide.*

The survival both between the greens and between the different cover techniques differ, see photo 5-10. Most winter injuries are probably cause by water at both green 7 and 16.

Photo 5. A sharp border was between permeable cover (B) to the right and impermeable cover (D and C) to the left. Green 16 at Timrå GK 20.04.2009 (Photo Boel Pettersson)

Photo 6. During the field day for Course managers 20.04.2009 we look at green 7, most survival in area E. Photo Boel Pettersson

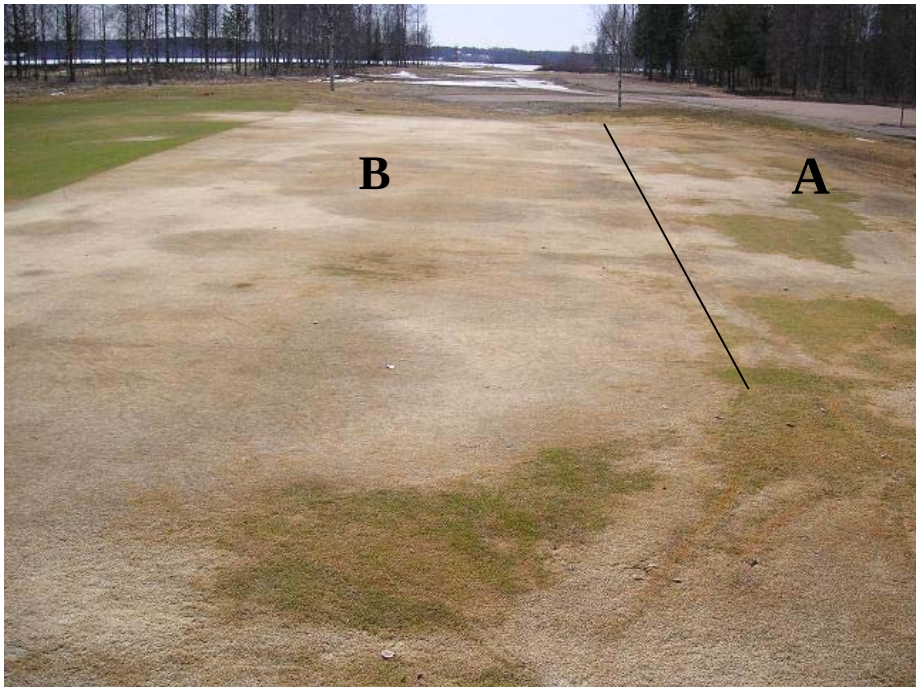

Photo 7. The survival of the grass was bad in control area (A, right) and with permeable cover, Evergreen (B, middle). Photo shows green number 16, the 23 of April 2009. Photo Boel Pettersson

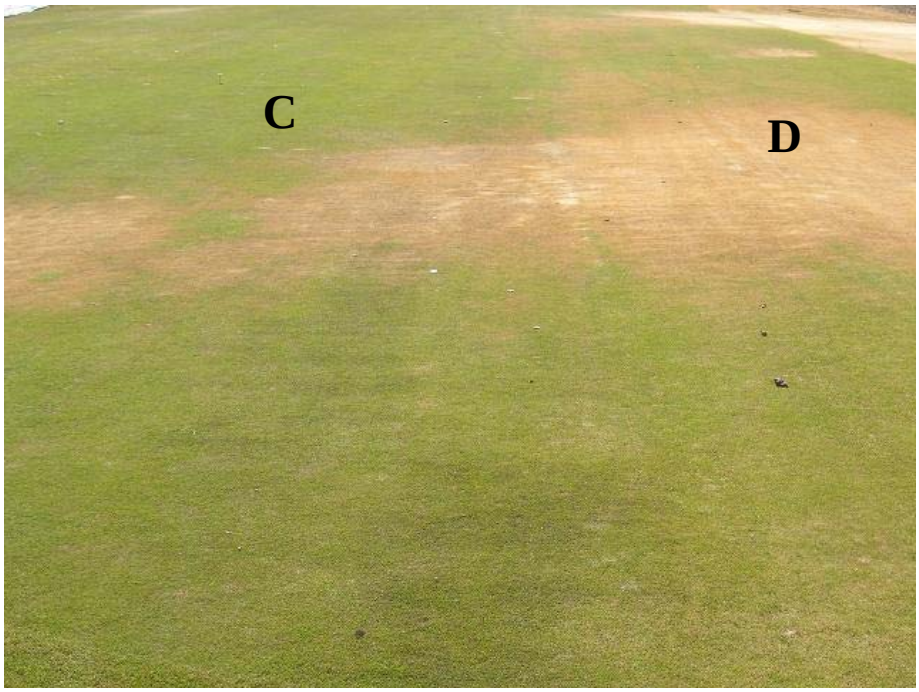

Photo 7. The survival of the grass was better in area C (Ice Shield) and in area D (Bubble plastic). Dead parts of the green are due to leaking water from area A and B. Photo shows green number 16, the 23 of April 2009. Photo Boel Pettersson

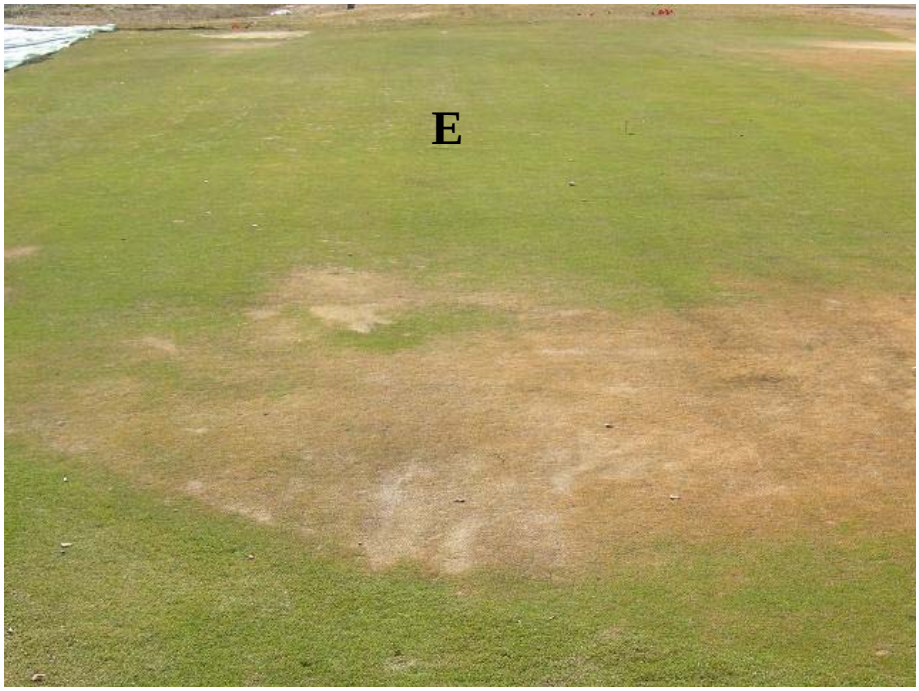

Photo 8. The survival of the grass was quite good in area E (impermeable plastic). Photo shows green number 16, the 23 of April 2009. Photo Boel Pettersson

Photo 9. The half part of the greens, at Timrå GK, was untreated by fungicides. This picture shows area E, behind the line the green is untreated. Photo Boel Pettersson (23.04.2009)

Photo 10. It was good survival on back part of green number7, area D (no fungicide treated area). Photo Boel Pettersson (23.04.2009)

12.1.2 Bodens GK

In autumn 2008 (evaluation date 21 of October) both greens were in very good condition. It was no differences in quality between areas (A-E) of the greens. On green 11, only covering technique A, B, C and D was possible to use. See table 8.

Evaluation	G11A	G11B	G11C	G11D	G11E	G12A	G12B	G12C	G12D	G12E
Height of grass (mm)	4	4	4	4	-	4	4	4	4	4
Living ground cover (%)	100	100	100	100	-	100	100	100	100	100
Visual density (1-9)	8	8	8	8	-	8	8	8	8	8
Disease damages (%)	0	0	0	0	-	0	0	0	0	0

Table 8. Result from the evaluation of the trial green number 7 in spring.

At Bodens GK grass plugs were collected. The plugs managed in the same ways as at Timrå GK. The green was check from the end of January until the time of cover off. More or less no ice was form during this period and the greens were cover by 30-100 cm of snow. Plugs of grass were collected 4 of March and 1 of April and the survival of the grass is seen in photo 11 and 12. The grass that survived was both *Poa annua* and *Poa trivalis.*

Photo 11. Grass plug collected at Bodens GK 2009-03-04, photo taken 2009-03-12 by Boel Pettersson

Photo 12. Grass plug collected at Bodens GK 2009-04-01, photo taken 2009-04-09 by Boel Pettersson

In spring, 2009 the first observation and evaluation were made 29 of April (result see table 9).

Evaluation	**G11 A**	**G11 B**	**G11 C**	**G11 D**	**G12 A**	**G12 B**	**G12 C**	**G12 D**	**G12 E**
Winter damage (%)	40	50	10	10	50	70	5	10	10
Diseases (%)	10	<5	<5	<5	<5	<5	<5	<5	<5

Table 9. Result from the evaluation of the trial greens in spring.

The survival has been rather good comparing to latest years in this region. Only small injuries cause by diseases were noted. Problems with water have caused some winter damages on the greens. The survival both between the greens and between the different cover techniques differ, see photo 13-16.

Photo 13. Green 11 at Bodens GK 29 of April 2009. To right area A (control) and left area D (bubble plastic and impermeable cover). Photo Boel Pettersson.

Photo 14. Green 11 at Bodens GK 29 of April 2009. Nearest camera, area B (permeable Cover) and behind, area C (permeable and impermeable cover). Photo Boel Pettersson.

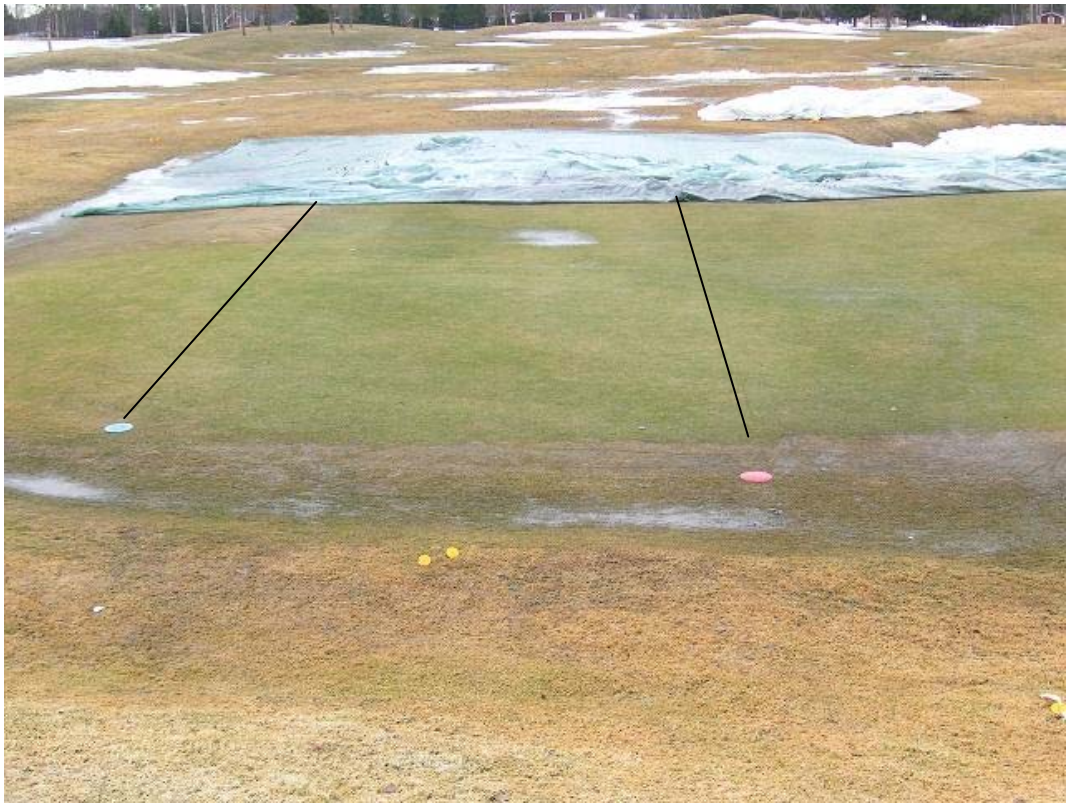

Photo 15. Green 12 at Bodens GK 29 of April 2009. To left, area B (permeable Cover), in the middle, area E (permeable cover and impermeable cover "Lantmännen") and right, area C (permeable and impermeable cover, KSAB). Photo Boel Pettersson

Photo 16. Green 12 at Bodens GK 29 of April 2009. In middle, area D (bubble plastic and impermeable cover) and right, area A (control). Photo Boel Pettersson

12.2 Soil surface temperatures underneath the covers and soil temperatures

12.2.1 Timrå GK

As last year, some of the temperature loggers have not worked properly during this winter. Temperature from green 7 (area A, B and C), green 16 (area A, B and E), air and soil temperatures is to be find in appendix 1. The air temperature varied between - 28°C and + 8°C during the winter. During late March and April the temperature raise up to about +10°C (or more) under some days (probably due to thermometer in sunshine). The temperature at the ground, at area A (control) was the temperature below 0° under the whole winter. In the end of January, the lowest temperature -11°C noted. The situation was more or less the same under cover area B. Under the impermeable cover (area C) the lowest temperature was about -8°C, and under the impermeable in area E, the lowest temperature was about the same during these days in the end of January.

12.2.2 Bodens GK

The majority of the temperature loggers worked this year in Boden. Temperature from green 11 (area C, D and E), all from green 12 and air temperatures is to be find in appendix 1. No soil temperature measured at Bodens GK. The air temperature varied between -31°C and +5°C during the winter. During late March and April the temperature raise up to about +10°C (or more) under some days (probably due to thermometer in sunshine). It was small differences in temperature between the different cover techniques. Under the winter, the temperature was between 0 to -5°C (with some exceptions) under all covers and the control area (A).

13 Discussion and conclusions

The weather situation at covering time was better this year, compare to last winter (2007-2008). The greens were dry and no snow had fallen before the covering. It was also possible to treat the greens with fungicide before covering**.** In an attempt to create a better air space between the grass and the cover, Leca ("light expanded clay aggregate") used on area C and E on one green on each course. At Bodens GK only the half part of area C and E covered by Leca, but no differences in survival was possible to see in these areas. At Timrå GK area C and E at green 16 covered by Leca, and compared to green 7, the survival was much better on green 16.

Leaking water under the covers occurred at both Timrå GK and Bodens GK in some extent. It shows the importance of cut down all edges of covers if you suspect water is able to reach the green. The problem is with a "test" like this, with different covers over the greens, is that water will run between the different areas (see photo 5). At green 7 at Timrå GK the survival of the green was fairly bad at some parts of the green (see photo 10). The reason for that is difficult to explain, leaking water under the covers can be one reason, but not the only reason. Due to fact that we do not know the reason for the bad survival on this green, it had been interesting to measure oxygen and CO_2 level.

At some of the greens, it has been problem during thaw periods or rain with water collected on the cover. This has often results in dead areas in the low spots on the green. This can probably be avoid by some extra distance (drainage pipe etc.) between the covers and ground, but of course, the best solution of the problem is to rebuilt this area of the green.

After two years of the project (and earlier years experience) I will emphasize following important things (as I can see) about covering.

- When should the golf courses cover the greens? Due to "normal" autumn in north part of Norrland, I suggest it is best to cover in the beginning of November. In south part of Norrland, maybe it is enough to cover in the middle of November. You have to be awake

and follow the weather forecast carefully. Of course, frost in the ground and close to snow is the best time for covering, but usually some snow comes in the end of October to the middle of November and this snow often become “sleet” or ice after some days with warmer weather. Due to low temperatures (close to 0°C) and short days, this “sleet” did not melt. That is the reason why I think it is better to cover the greens quite early, before the green become wet or icy, later in November.

- Is it necessary to use impermeable cover? My recommendation will be, always use an impermeable cover in this part of the Sweden, due to the fact of ice formation more or less every year. Shorter winter or more stable snow cover, perhaps it is not necessary with impermeable cover.
- The best survival of the grass has been under the impermeable covers and the “greenest grass” has been under the bubble plastic. As I can see, it also shows the importance of enough with air under the covers. Because of this, I think it is often necessary to create a ventilation or air volume, especially during long periods of covering.
- Another important thing is to dig the edges of the covers in the ground, if you suspect water can leak into the green. Another solution is to have enough with cover so you can cover a bigger area of green surroundings to avoid water from smaller slopes to reach the green.

14 Appendix

Temperatures underneath cover, in soil and air temperatures Appendix 1/1
Timrå GK

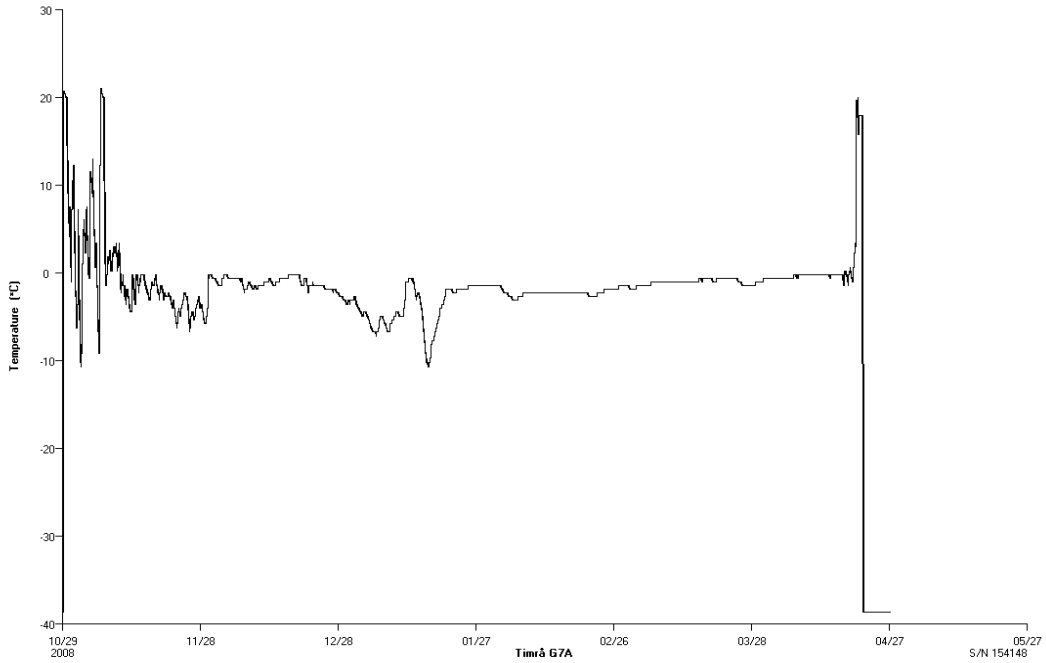

Fig.1. Temperatures, control green 7

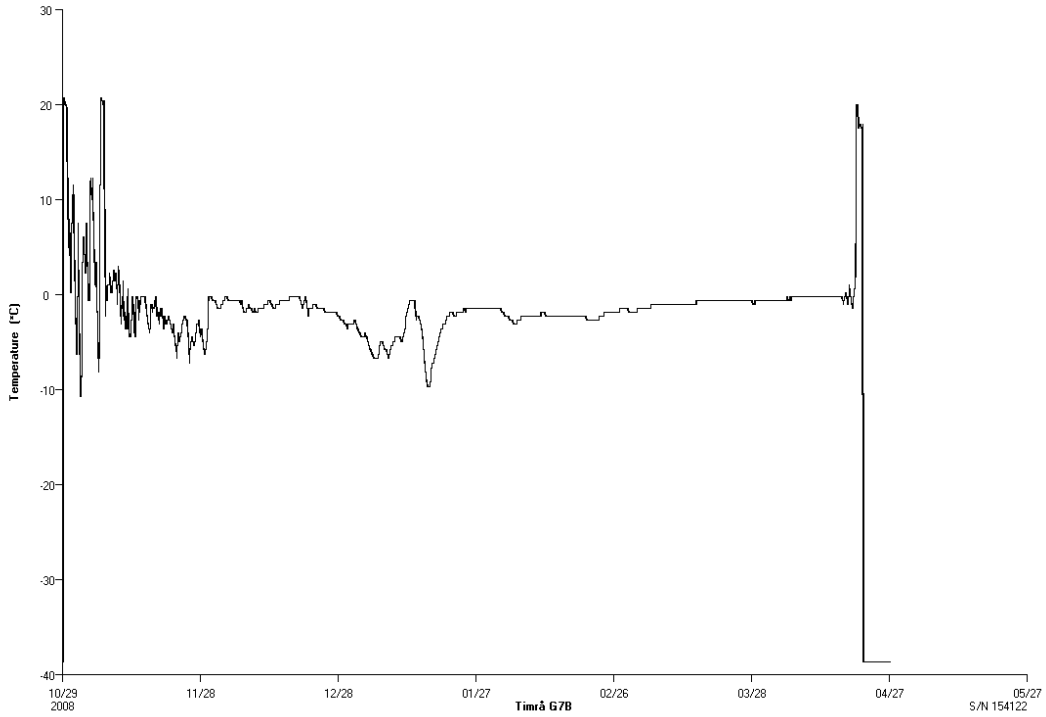

Fig.2. Temperatures underneath cover, Evergreen (KSAB) green 7

Appendix 1/2

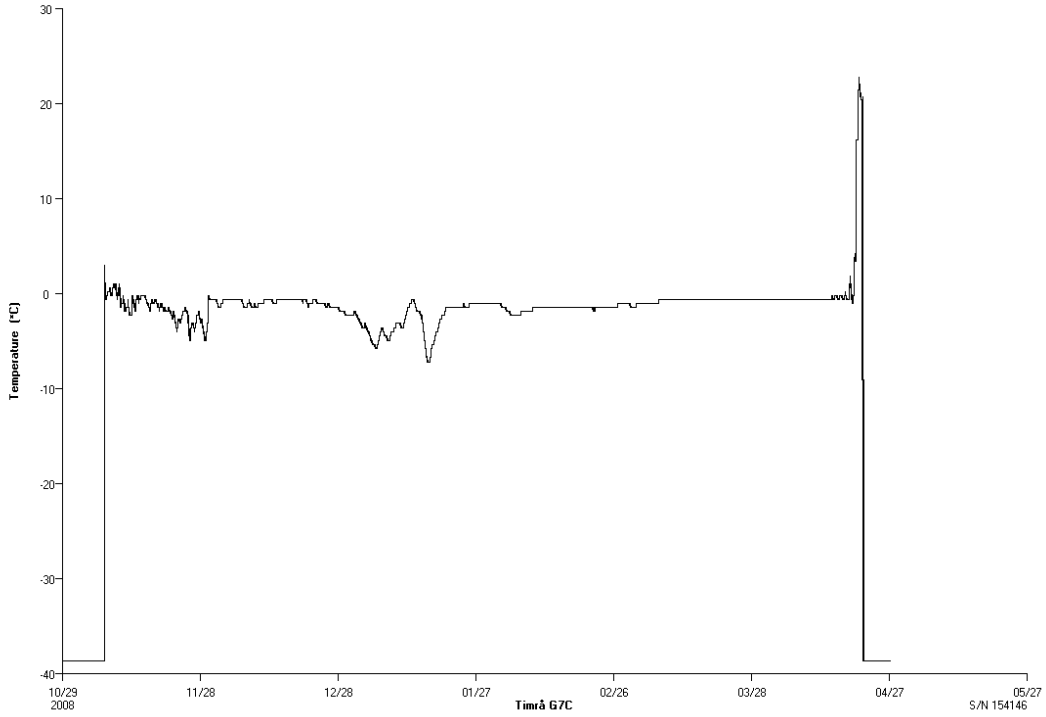

Fig.3. Temperatures underneath cover, Ice Shield (KSAB) green 7

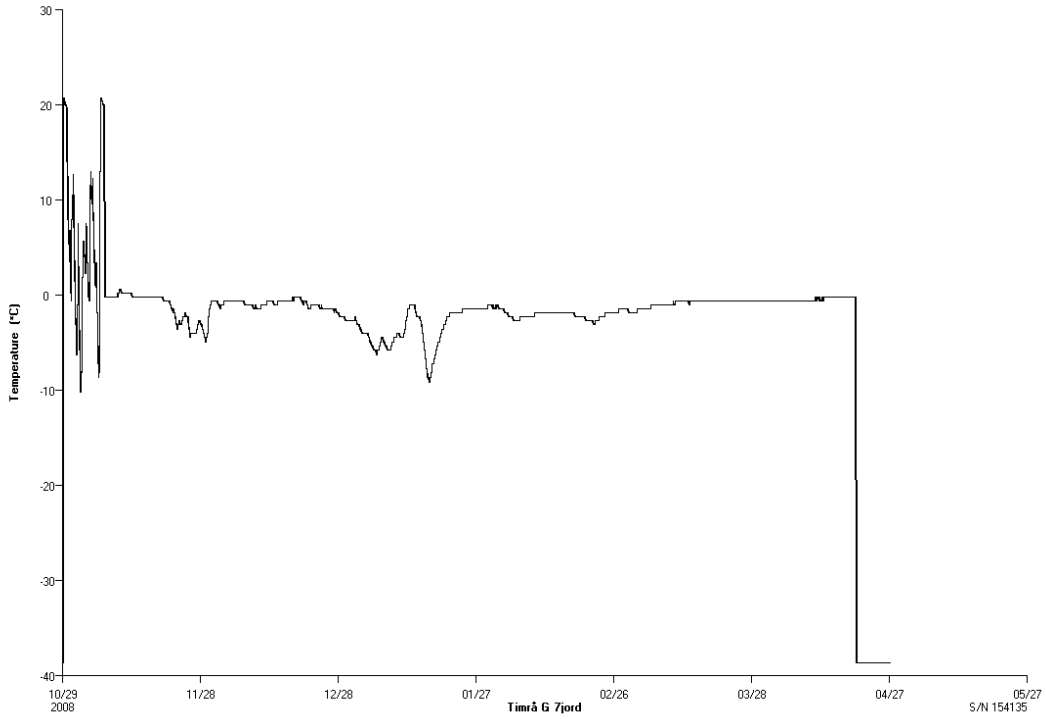

Fig.4. Temperatures in soil (depth 10 cm), green7

Appendix 1/3

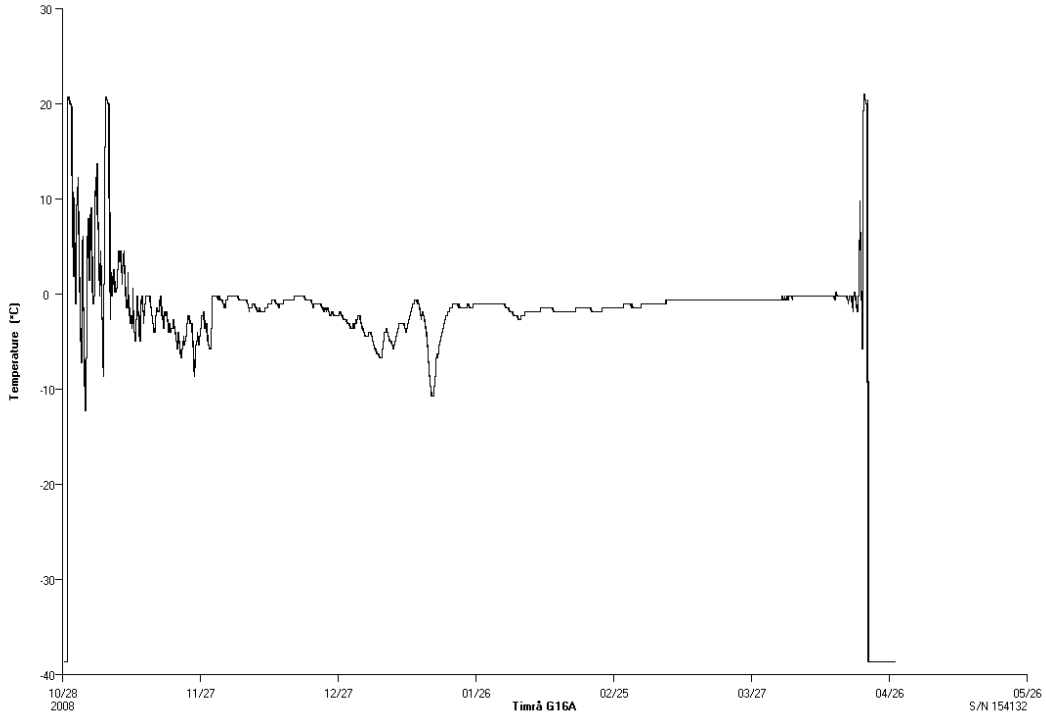

Fig.5. Temperatures, control green 16

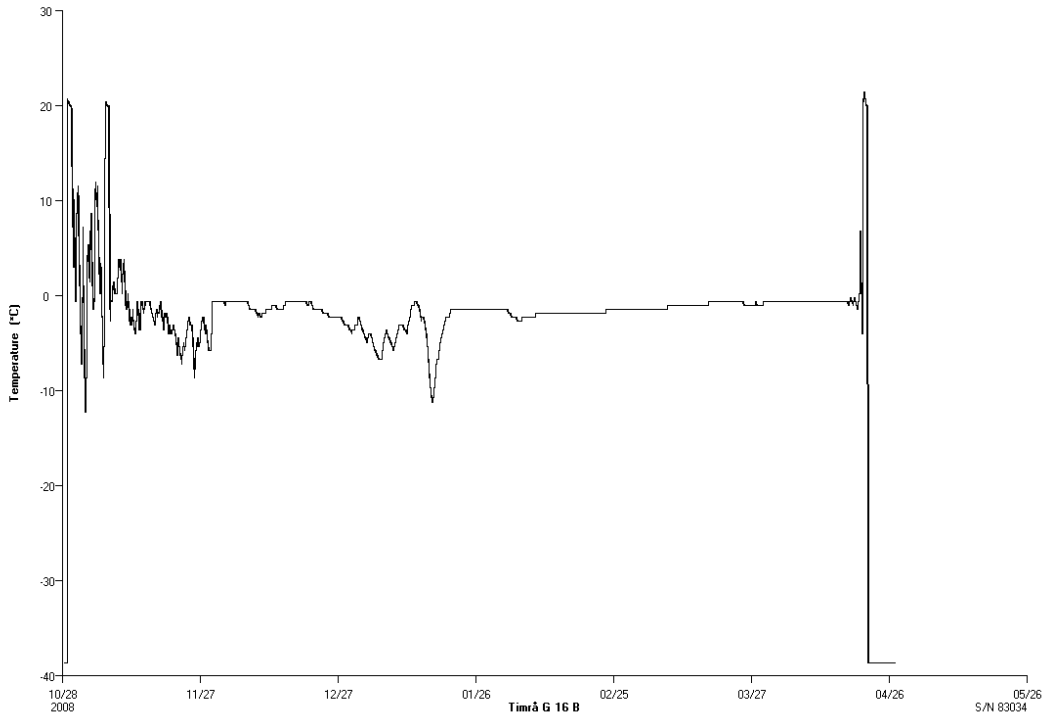

Fig.6. Temperatures underneath cover, Evergreen (KSAB) green 16

Appendix 1/4

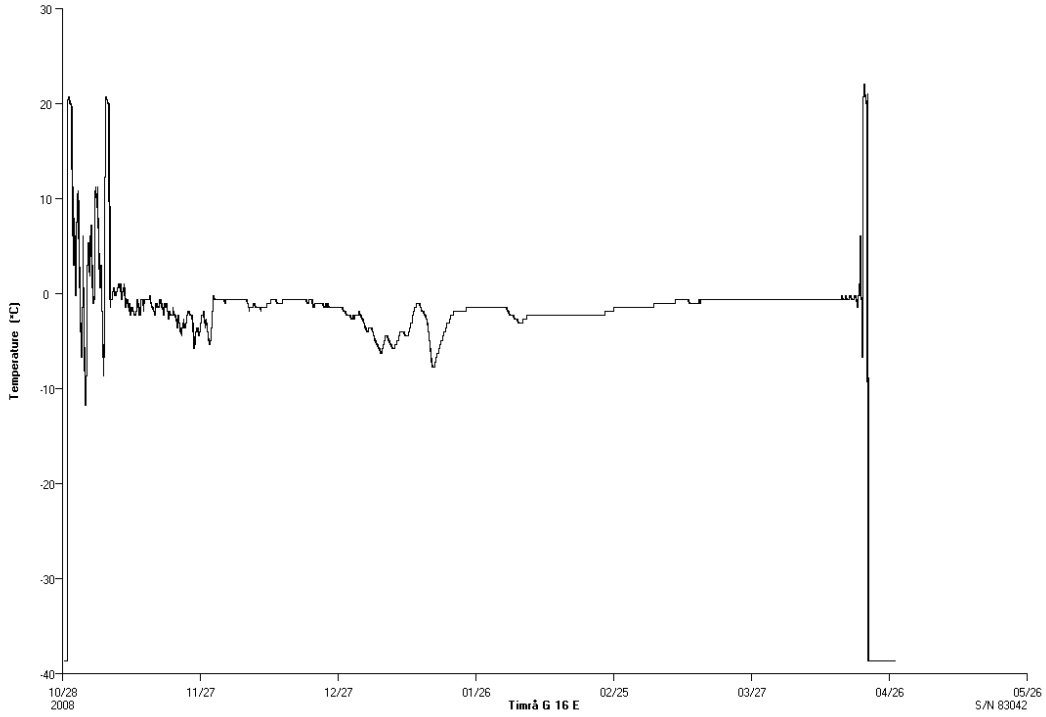

Fig.7. Temperatures underneath cover, impermeable cover (Lantmännen) green16

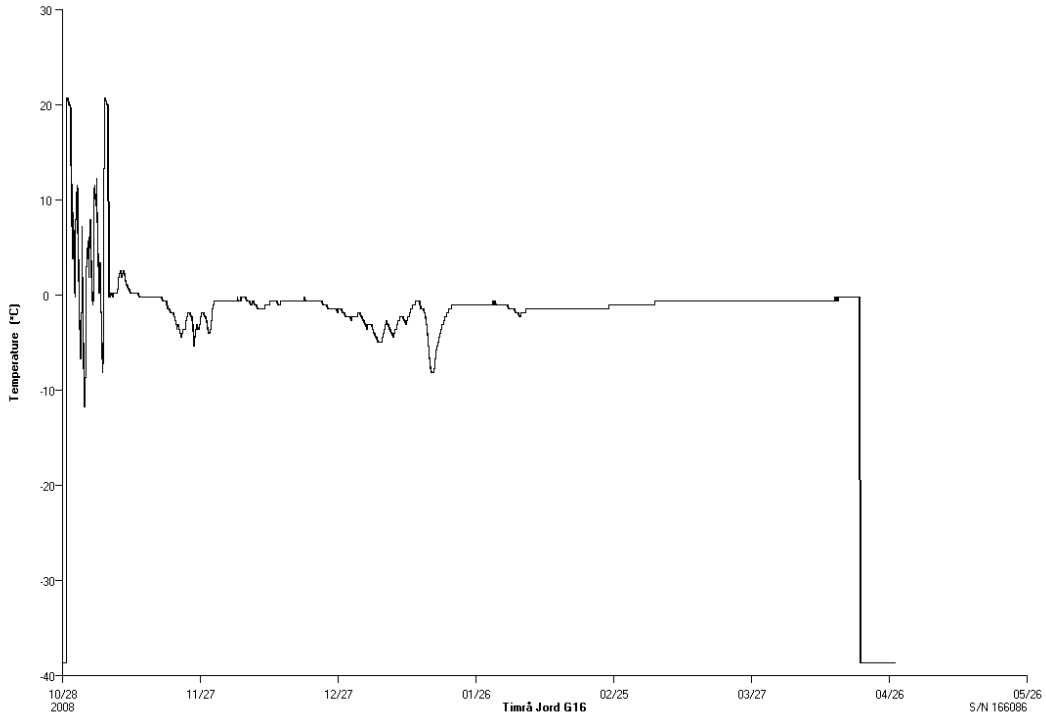

Fig.8. Temperatures in soil (depth 10 cm), green 16

Appendix 1/5

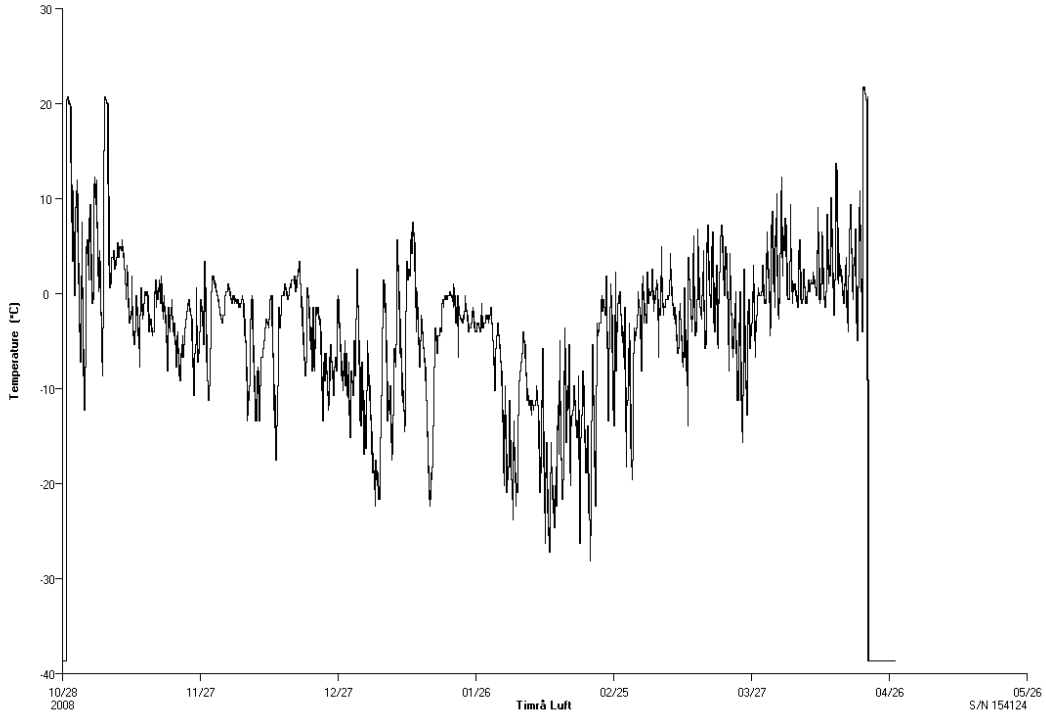

Fig.9. Temperatures in air, Timrå GK

Bodens GK

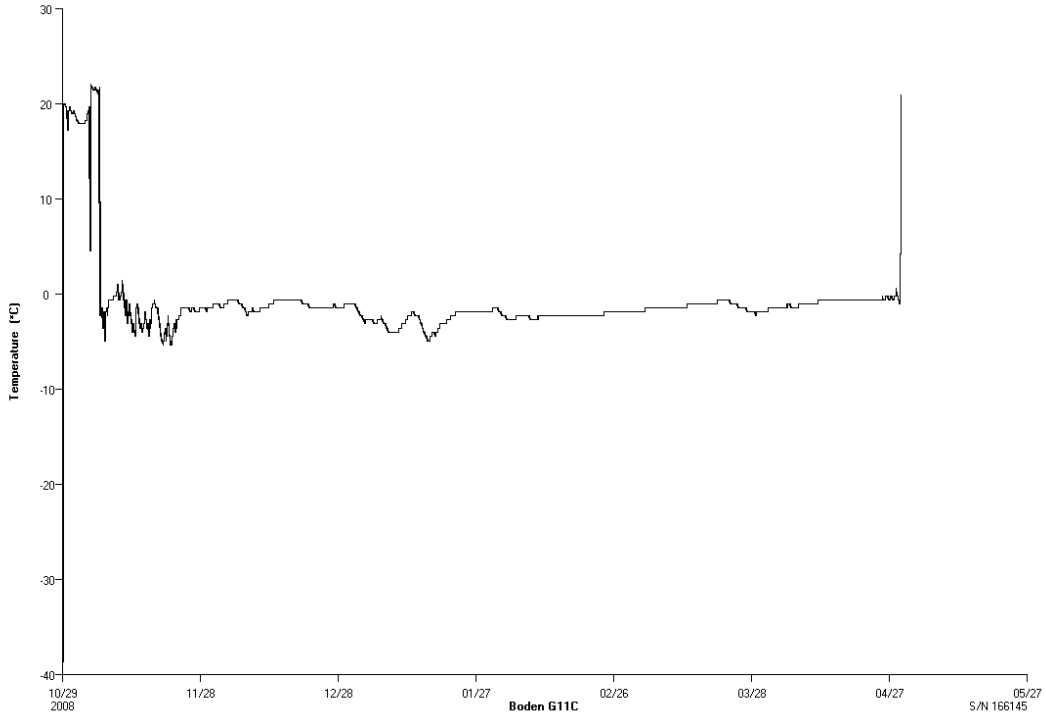

Fig.10. Temperatures underneath cover, Ice Shield (KSAB) green 11

Appendix 1/6

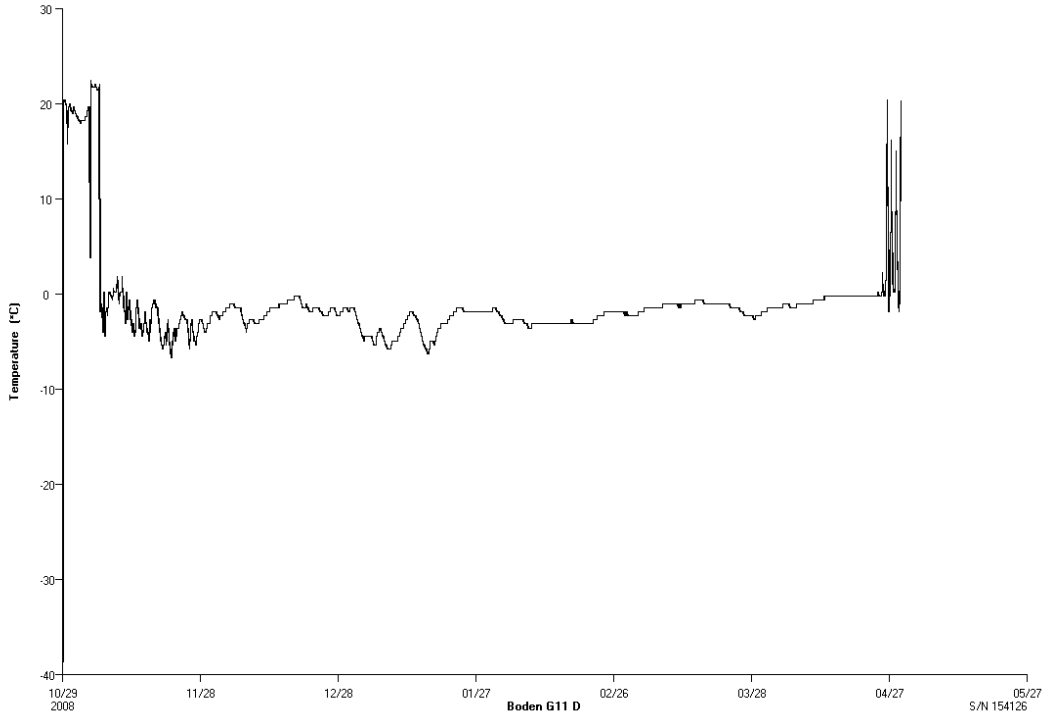

Fig.11. Temperatures underneath cover, Ice Shield and bubble plastic (KSAB) green 11

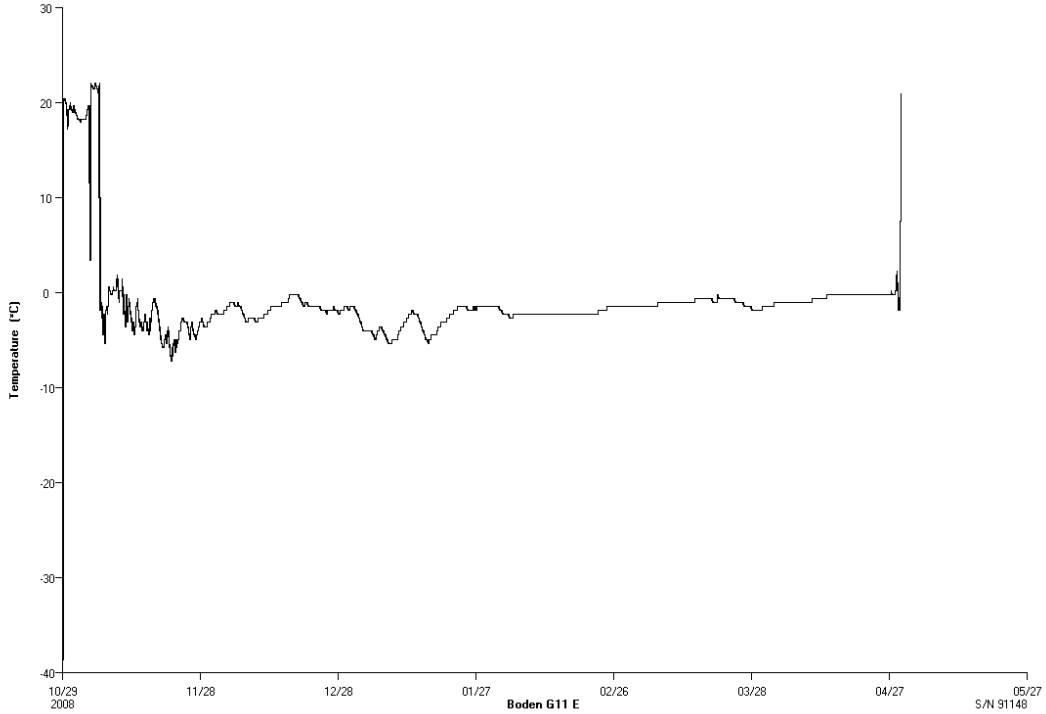

Fig.12. Temperatures underneath cover, impermeable cover (Lantmännen) green11

Appendix 1/7

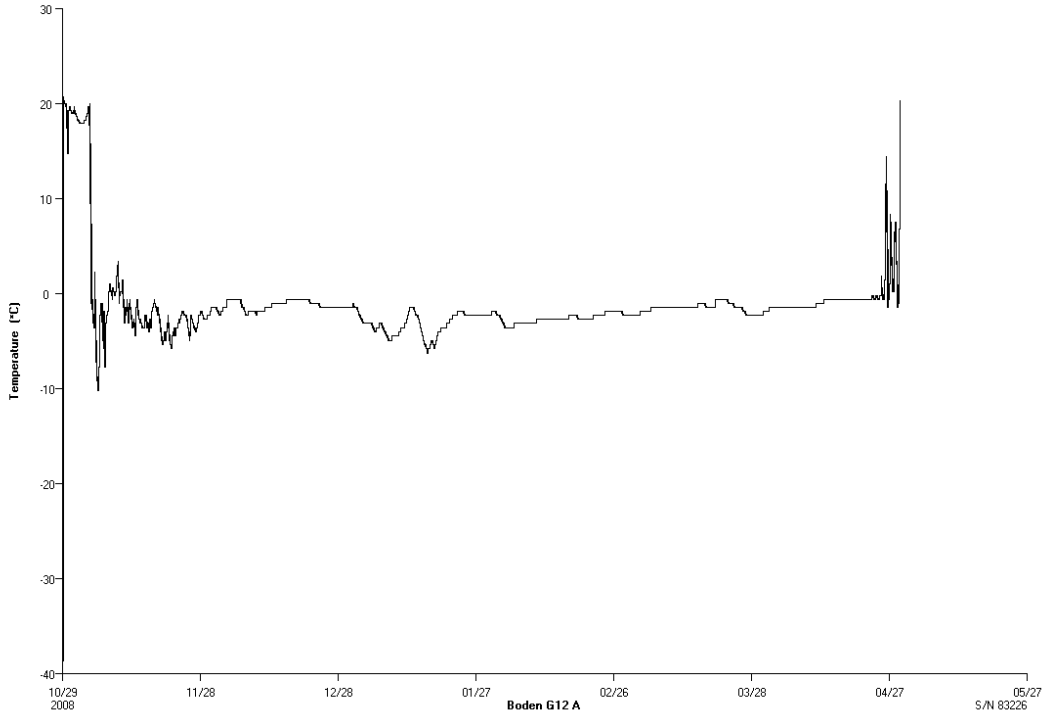

Fig.13. Temperatures, control green 12

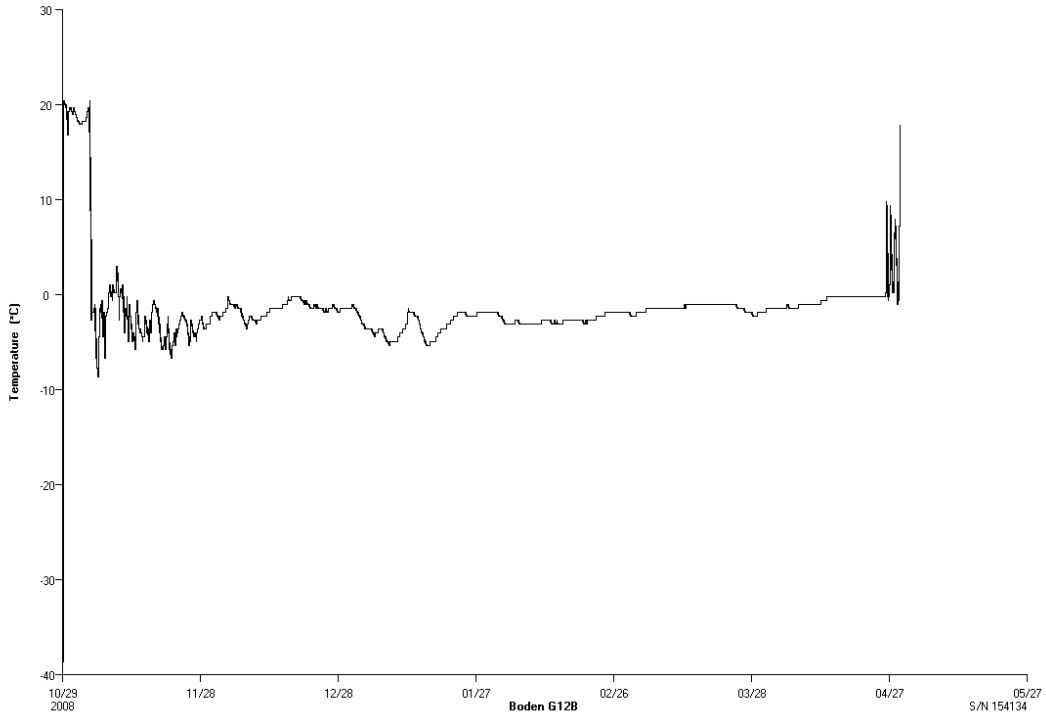

Fig.14. Temperatures underneath cover, Evergreen (KSAB) green 12

Appendix 1/8

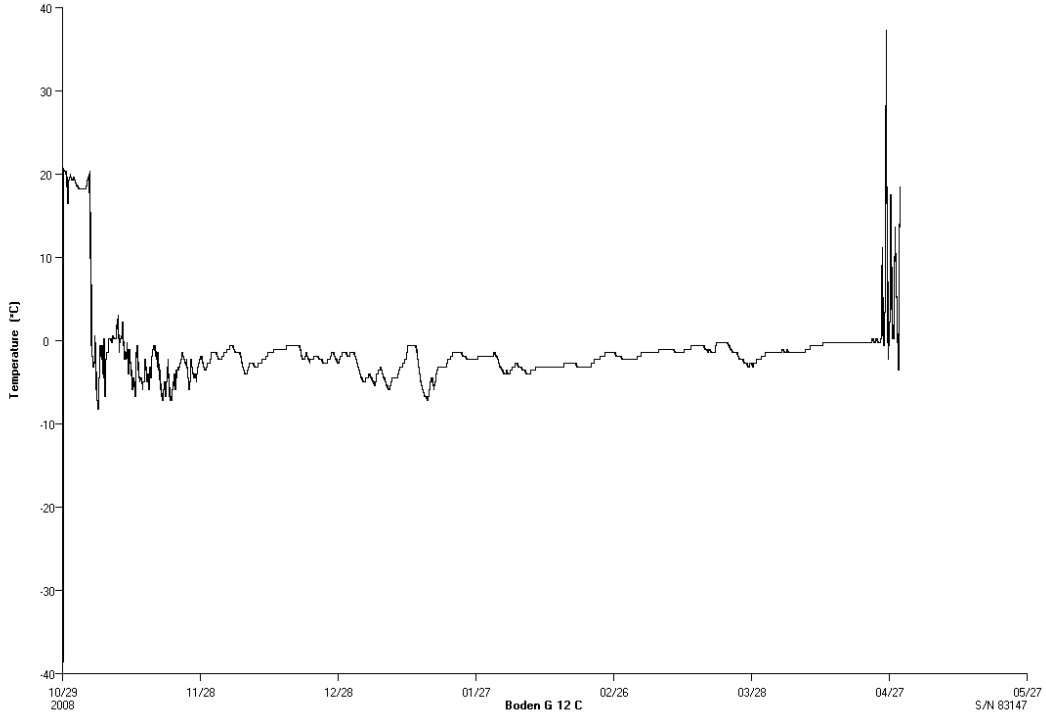

Fig.15. Temperatures underneath cover, Ice Shield (KSAB) green 12

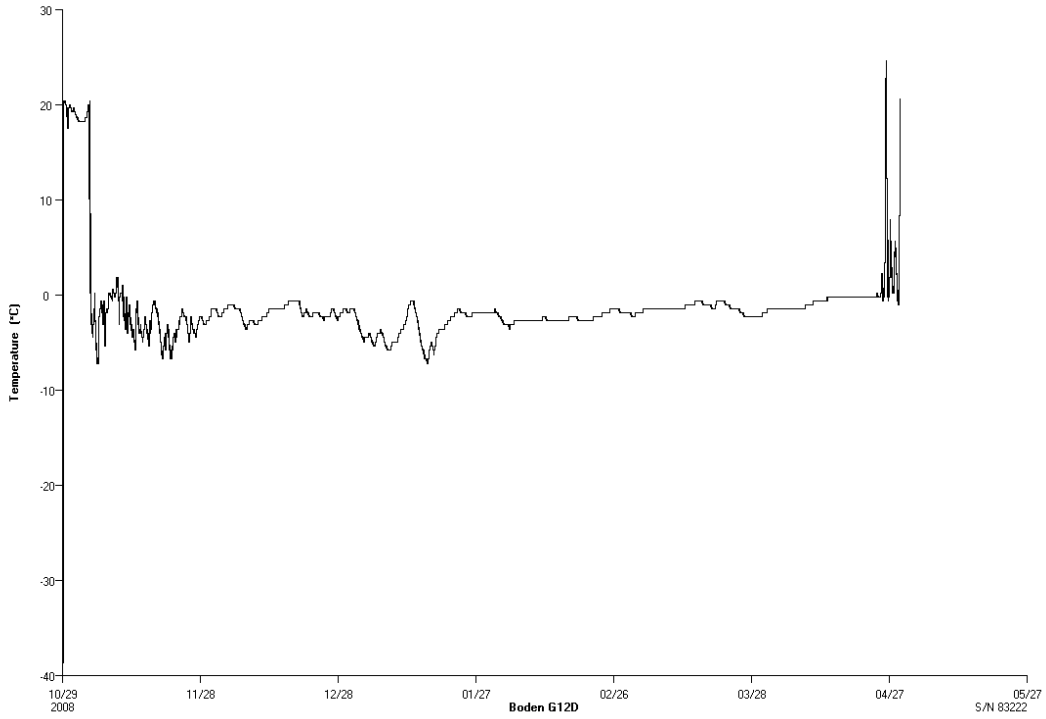

Fig.16. Temperatures underneath cover, Ice Shield and bubble plastic (KSAB) green 12

Appendix 1/9

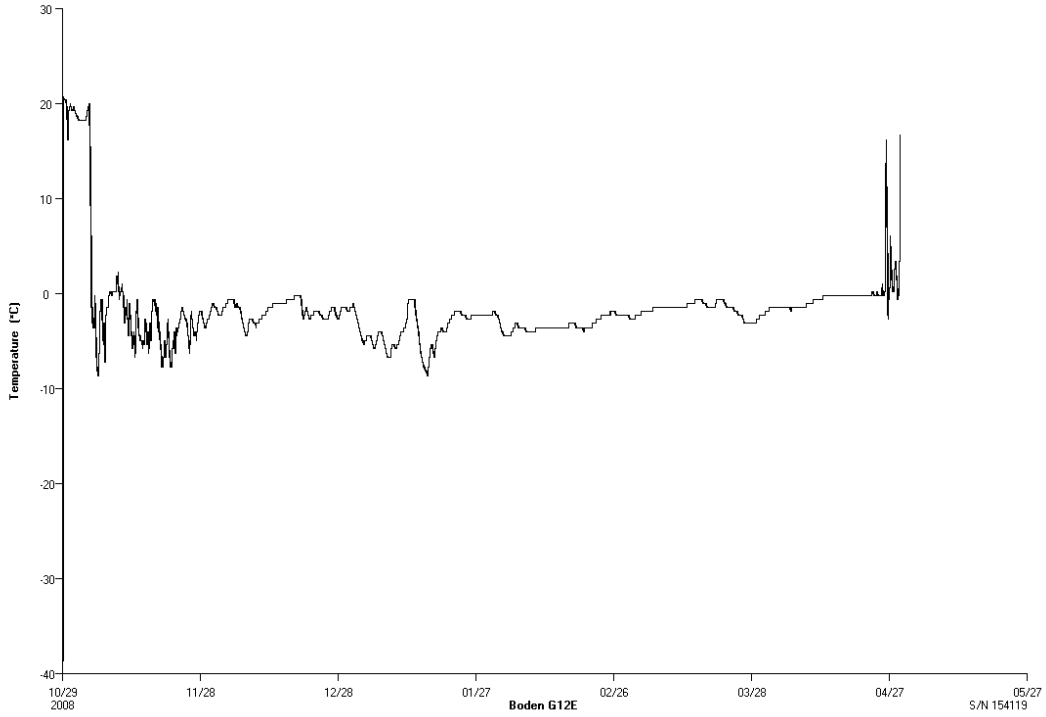

Fig.17. Temperatures underneath cover, impermeable cover (Lantmännen) green12

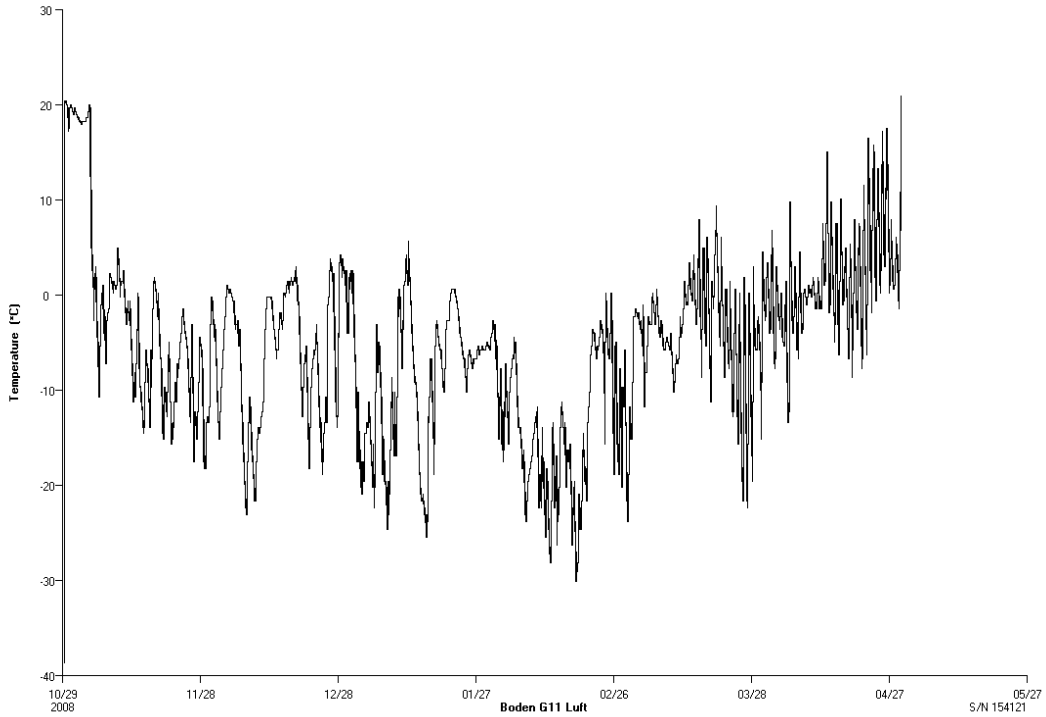

Fig.18. Temperatures in air, Bodens GK