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A first evaluation of the GREENCAST prediction model for timing of fungicide applications on Scandinavian golf courses

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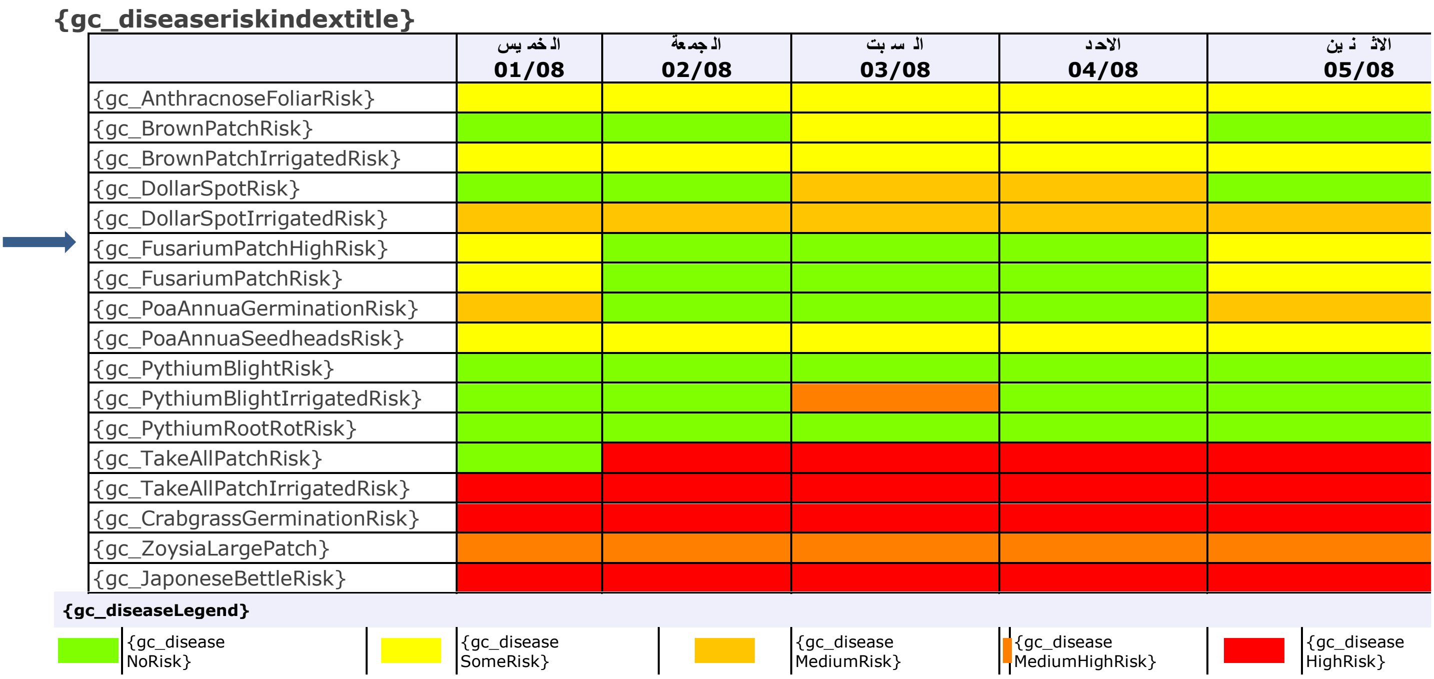

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Summary:

Syngenta's GREENCAST model was used to predict timing of fungicide application against microdochium patch and pink snow mold caused by *Microdochium nivale* on an experimental golf green with annual bluegrass (*Poa annua*) at Bioforsk Landvik, Southern Norway from 5 Oct. 2012 until 1 June 2013. From 5 Oct. until snow covered the green on 2 Dec. 2012, application of the fungicides Headway (azoxystrobin + propiconazole) or Medallion (fludioxonil) only at GREENCAST high risk warnings resulted in equal control of microdohium patch with one less fungicide application than prophylactic application every third week, application at first sign of disease or application at GREENCAST medium risk warnings. The consequences for pinks snow mold in spring could not be evaluated as the turf was killed by the combination of ice encasement and low freezing temperatures during winter.

Sammendrag:

Modellen GREENCAST fra Syngenta ble brukt for å forutsi angrep og spredning av mikrodochium-flekk og rosa snømugg (begge forårsaket av *Microdochium nivale*) på en forsøksgreen med tunrapp (*Poa annua*) på Bioforsk Landvik, Sør Norge, fra 5.okt. 2012 til 1.juni 2013. Mellom 5.okt. og begynnende snødekke 2.desember gav sprøyting av fungicidene Headway (azoksystrobin + propiconazol) eller Medallion (fludioksonil) når GREENCAST varslet høyt sjukdomsangrep like god kontroll av mikrodochium-flekk med bare to sprøytinger som programmert sprøyting hver tredje uke, sprøyting ved første tegn til sjukdom, og sprøyting når GREENCAST varslet middels sjukdomsangrep (alle med tre sprøytinger). Konsekvensen av behandlingene på angrep av rosa snømugg etter snøsmelting om våren kunne ikke bedømmes fordi gresset på greenen døde av is- og frostskader.

Trygve S. Aamlid

Project leader

Contents

1. Abstract

A principle of Integrated Pest Management is that forecasting and early warning of pests and diseases should be used whenever possible to avoid redundant use of pesticides. Our objective was to carry out a first evaluation in the Nordic countries of fungicide application according to Syngenta's GREENCAST model for infection of microdochium patch / pink snow mold caused by *Microdochium nivale* on turfgrass areas. The experiment was conducted on a green with a turf cover of *Poa annua* at Bioforsk Landvik, SE Norway, from 5 October 2013 to 1 June 2013. The experimental plan included nine treatments; an unsprayed control treatment and the fungicides Headway (3 L = 187.5 g a.i. azoxystrobin + 312 g.a.i. propiconazole per ha) or Medallion (3 L = 375 g a.i. fludioxonil per ha) applied either (1) 'Prophylactically at three week intervals' or (2) at 'GREENCAST medium risk warning'; (3) at 'GREENCAST high risk warning' or (4) at 'First sign of disease'. Following each application the turf was considered protected for three weeks.

From the start of the experiment on 5 October until the green was covered by snow on 2 December, the application criteria 'Prophylactic', 'GREENCAST medium risk warning' and 'First sign of disease' all resulted in three fungicide applications. The only criterion that reduced fungicide use was 'GREENCAST high risk warning'. All fungicide treatments except Medallion at 'GREENCAST medium risk warning' resulted in significantly less microdochium patch and higher turfgrass overall impression than in the unsprayed control treatment. Differences in control of microdochium patch by the fungicides Headway and Medallion were not significant except when applied at 'GREENCAST medium risk warning', but there was a tendency to higher overall impression after use of Medallion than after use of Headway at the application criteria 'Profylactic', 'GREENCAST high risk warning' and 'First sign of disease'. Significantly higher green speed after use of Headway than after use of Medallion was measured on one occasion.

As a preliminary conclusion, the GREENCAST High Risk criterion seems to offer the potential for reduction in fungicide use while maintaining adequate control of microdochium patch in autumn. The consequences for occurrence of pinks snow mold in spring remains to be elucidated as the experimental green used in this experiment died during the winter due to the combination of ice encasement and low freezing temperatures.

2. Introduction

According to EU-Directive 2009/128 (EU commission 2009a), the development and implementation of Integrated Pest Management (IPM) is a requirement for continued use of pesticides in Europe. Although the highest consumption of pesticides takes place in agriculture, EU-Regulation 1107/2009 (EU commission 2009b) specifically calls for a reduction in pesticide use in high-risk areas such as public parks and gardens and sports and recreation grounds that are open to the general public. The Scandinavian Turfgrass and Environment Research Foundation (STERF) has defined IPM as one of four prioritized areas of research (STERF 2011).

Three of the major principles of IPM are (1) that forecasting and early warning methods should be used whenever available, (2) that the most target-specific pesticide should be selected and (3) that the success of the pest management measure should be monitored and documented (EU Commission 2009a).

On an area basis, herbicides are the most widely used pesticides in turfgrass management in the Nordic countries. However, for the approximately 900 golf courses in Finland, Sweden, Denmark, Norway and Iceland, fungicides are probably more important as they are primarily used on the greens by which the quality of the entire golf course is usually evaluated. The fungus causing most problems on Nordic golf courses is *Microcohium nivale* ((Fries) Samuels and Hallett) which results in both microdochium patch (previsously often referred to as fusarium patch) during the growing season and pink snow mold under snow cover.

Syngenta's web-based GREENCAST warning system for turfgrass diseases was first developed in United States and has later been implemented and modified for use in UK and Ireland. The risk for attack for various diseases is predicted from local weather forecasts based on models first developed by Professor Karl Danneberger of Ohio State University.

The objective of the research presented in this report was to carry out a first evaluation of fungicide applications according to the GREENCAST predictions for *M.nivale* in the Nordic counties. Our hypothesis was that total fungicide use would be reduced by GREENCAST predictions compared with prophylactic applications without sacrificing control of *M.nivale*.

The project was funded by Syngenta and carried out by Bioforsk Turfgrass Research Group on contract with STERF.

Photo 1. Trond Pettersen spraying fungicides in GREENCAST trial at Landvik on 17 Nov. 2013. Photo: Trygve S. Aamlid.

3. Materials and methods

3.1 Experimental site and maintenance

The experiment was carried out from 5 Oct. 2012 to 1 June 2013 on an experimental USGA-spec. green at the Bioforsk Turfgrass Research Center Landvik, Grimstad, SE Norway (58°34'N, 8°52'E, 10 m a.s.l.). The green was constructed in Nov. 2004 with 12% (v/v) peat as organic amendment to the sand root zone. In summer 2010, velvet bentgrass (*Agostis canina*) used in an earlier project was deturfed, 3 cm of new root zone material added (also with 12% (v/v) peat) and a new turf cover of *Poa annua* established, partly using plugs from Kjekstad golf course, Drammen, SE Norway, and partly unspecified seed of *Poa annua* from the Norwegian seed dealer Felleskjøpet Agri. From 2011 to 2013, the green was used in a project for Syngenta evaluating the combined effect of the plant growth regulator Primo MAXX on infection of *M.nivale* and turfgrass winter survival (Aamlid et. 2011, 2012).

The fertilizer program for 2012 is shown in Table 1. We used a combination of liquid (Arena Crystal, Arena Calcium, Greenmaster liquid) and solid products (Arena Green Plus, Arena Start, Greenmaster 14-0-10). Soil samples taken on 22 Oct. 2012 from the 20 cm topsoil layer indicated a pH(H_2O) of 6.1, an ignition loss of 1.3% and plant available contents of P, K, Ca and Mg of 2.2, 5.2, 14 and 2.2 mg (100 g dry soil)$^{-1}$, respectively.

Table 1. Fertilization of Poa annua *experimental green during 2012.*

		kg per 100 m^2								
Date	**Fertilizer type**	**Fertilizer**	**N**	**P**	**K**	**Mg**	**S**	**Ca**	**Fe**	**Mn**
20 Mar.	Arena Calcium	1.00	0.000	0.000	0.000	0.000	0.160	0.210	0.000	0.000
20 Mar.	Arena Crystal 19-2-15	0.60	0.114	0.011	0.090	0.014	0.022	0.000	0.001	0.000
11 Apr.	Arena Green Plus 10-1-10	1.50	0.150	0.012	0.150	0.008	0.116	0.000	0.015	0.006
27 Apr.	Arena Start 22-3-10	0.68	0.149	0.020	0.068	0.000	0.027	0.000	0.000	0.000
11 May	Arena Green Plus 10-1-10	1.95	0.195	0.016	0.195	0.010	0.150	0.000	0.020	0.008
22 May	Arena Start 22-3-10	1.00	0.220	0.030	0.100	0.000	0.040	0.000	0.000	0.000
6 Jun.	Arena Start 22-3-10	1.00	0.220	0.030	0.100	0.000	0.040	0.000	0.000	0.000
20 Jun.	Greenmaster liq. 10-0-10	2.80	0.280	0.000	0.230	0.000	0.000	0.000	0.000	0.000
3 Jul.	Arena Start 22-3-10	0.75	0.165	0.023	0.075	0.000	0.030	0.000	0.000	0.000
17 Jul.	Arena Green Plus 10-1-10	1.65	0.165	0.013	0.165	0.009	0.128	0.000	0.017	0.007
24 Jul.	Arena Green Plus 10-1-10	1.65	0.165	0.013	0.165	0.009	0.128	0.000	0.017	0.007
14 Aug.	Arena Start 22-3-10	0.60	0.132	0.018	0.060	0.000	0.024	0.000	0.000	0.000
29 Aug.	Arena Crystal 19-2-15	0.60	0.114	0.011	0.090	0.014	0.022	0.000	0.001	0.000
29 Aug.	Arena Calcium	0.75	0.000	0.000	0.000	0.000	0.120	0.158	0.000	0.000
11 Sep.	Arena Start 22-3-10	0.45	0.099	0.014	0.045	0.000	0.018	0.000	0.000	0.000
26 Sep.	Greenmaster 14-0-10	0.64	0.090	0.000	0.053	0.012	0.000	0.000	0.006	0.000
2 Oct.	Arena Crystal 19-2-15	0.50	0.095	0.010	0.075	0.012	0.019	0.000	0.001	0.000
9 Oct.	Arena Crystal 19-2-15	0.45	0.086	0.009	0.068	0.010	0.017	0.000	0.001	0.000
23 Oct.	Arena Crystal 19-2-15	0.40	0.076	0.008	0.060	0.009	0.015	0.000	0.001	0.000
7 Nov.	Arena Crystal 19-2-15	0.30	0.057	0.006	0.045	0.007	0.011	0.000	0.001	0.000
Sum			2.572	0.244	1.834	0.114	1.087	0.368	0.080	0.028

During the growing season 2012 the green was cut with a single walk-behind green's mower every Monday, Wednesday and Friday and exposed to artificial wear using a friction wear roller with soft spikes for a total of 30 times corresponding to 10.000 rounds of golf. Mowing started at 9 mm on 26 March and was gradually lowered to the standard height of 3 mm on 18 May, at which it was maintained until late September. The mowing height was raised to 4 mm from 26 Sep. and to 5 mm at the last mowing on 31 Oct. 2012.

During the growing season, the green was also verticut four times and topdressed (dusted) 17 times corresponding to a total rate of 3.7 mm of pure sand (0.2-0.7 mm, no organic amendment). Due to starting indications of soil water repellency, the experimental area was treated with Revolution (Aquatrols Inc., Paulsboro, NJ, USA) on 26 July (1.9 L per ha) and 6 August (2.5 L per ha) 2012.

By the start of the trial on 5 Oct. 2012, the botanical composition was 97% *Poa annua* and 3% *Agrostis stolonifera*.

3.2 Experimental plan and implementation

A randomized complete block experiment with four blocks (replicates) and the following treatments was laid out on 5 Oct. 2012:

Treat-ment	Criterion for application[1]	Fungicides used	Target Rate
1	Untreated control	-	-
2	GREENCAST medium risk warning [1]	Headway: azoxystrobin + propiconazole (acropetal penetrants[2])	3 L = 187.5 + 312 g a.i. per ha
3	GREENCAST medium risk warning [1]	Medallion TL: fludioxonil (contact)	3 L = 375 g a.i per ha
4	GREENCAST high risk warning [1]	Headway: azoxystrobin + propiconazole (acropetal penetrants[2])	3 L = 187.5 + 312 g a.i. per ha
5	GREENCAST high risk warning [1]	Medallion TL: fludioxonil (contact)	3 L = 375 g a.i. per ha
6	First sign of disease[1]	Headway: azoxystrobin + propiconazole (acropetal penetrants[2])	3 L = 187.5 + 312 g a.i. per ha
7	First sign of disease[1]	Medallion TL: fludioxonil (contact)	3 L = 375 g a.i per ha
8	Profylactic, every 3 weeks	Headway: azoxystrobin + propiconazole (acropetal penetrants[2])	3 L = 187.5 + 312 g a.i. per ha
9	Profylactic, every 3 weeks	Medallion TL: fludioxonil (contact)	3 L = 375 g a.i per ha

1) In treatments 2-7, the turf was considered to be protected for three weeks after each application. After three weeks, the next application was determined by the same criteria as for the first application (Appendix 1).
2) Terminology according to Latin (2011).

A web-based test version of GREENCAST was provided by Syngenta to determine fungicide applications in treatments 2-5. From the alternatives in the test version, we selected the location 'Grimstad, Aust-Agder county', the table 'DiseaseZA' and the disease 'Fusarium patch High Risk' (= Fusarium Patch on Parkland Courses). The output of the program (see cover page of this report) gave five risk levels for disease, but for the purpose of this experiment, 'low risk' and 'some risk' were pooled into 'low risk' while 'medium risk' and 'medium/high risk' were pooled into 'medium risk; thus leaving the three risk levels 'low', 'medium' and 'high'. Further instructions on how to use the program were provided in E-mails from Jérôme Tricand de la Goutte and Simon Watson of Syngenta (Appendix 1). In agreement with the suggestion in S. Watson's mail on 2 Oct., the turf in treatments 2-9 was considered protected for 21 days before deciding on reapplication according to the criteria in the protocol.

Applications were conducted according to the Norwegian 'Good Experimental Practise' Protocol. We used an experimental backpack plot sprayer (Oxford / LTI) working at 150-200 kPa pressure and with a 1 m wide boom with three nozzles (Teejet 11002) 50 cm apart (Photo 1). Screens on both sides of the boom prevented drift to neighbor plots. The procedure allowed full coverage of the central 1.0 m x 1.0 m of each plot which was always used for assessments. The spraying volume of fungicides was 250 L per ha. Actual application rates were recorded by weighing the tank before and after spraying.

Applications dates, realized rates and weather conditions at application are given in Table 2. Only in one case (Headway on 7 Nov.) was deviation between actual rate and target rate more than 10 % which is the limit recommended for GEP trials. The 'prophylactic' program (treatments 8 and 9); the 'GREENCAST medium risk warning' (treatments 2 and 3), and the 'first sign of disease' criterion (treatments 6 and 7) all resulted in three applications before winter. The only treatments that reduced number of applications in October and November from three to two were applications according to the 'GREENCAST high risk warning' (treatments 4 and 5).

Table 2. Application date and time of day, realized rates according to weighing before and after application, weather conditions at application and hours to first rainfall after application. Data from Landvik weather station.

Date (2012)	Treat-ment	Product applied	Spraying, time of day	Target rate, L ha^{-1}	Realized rate, L ha^{-1}	Weather at application			Hours before rainfall
						Air temp. °C	Rel.humi -dity, %	Wind, m s^{-1}	
05 Oct.	2	Headway	09:00-10:00	3.00	3.02	5.0	100	0.1	>12
	3	Medallion TL		3.00	3.04				
	8	Headway		3.00	3.05				
	9	Medallion TL		3.00	2.89				
12 Oct.	6	Headway	16:45-17:30	3.00	3.16	8.6	72	1.7	>12
	7	Medallion TL		3.00	3.14				
17 Oct.	4	Headway	09:30-10:10	3.00	3.07	6.9	97	0.4	9
	5	Medallion TL		3.00	3.07				
26 Oct.	8	Headway	14:15-15:00	3.00	3.26	6.4	33	1.7	>12
	9	Medallion TL		3.00	2.94				
30 Oct	2	Headway	14:00-14:30	3.00	3.20	3.5	56	0.4	4
	3	Medallion TL		3.00	3.20				
1 Nov.	6	Headway	08:20-08:50	3.00	3.26	8.2	82	1.5	7
	7	Medallion TL		3.00	3.14				
7 Nov.	4	Headway	12:00-12:40	3.00	3.33	4.9	73	2.3	>12
	5	Medallion TL		3.00	3.20				
16 Nov.	8	Headway	10:20-10:50	3.00	2.82	8.9	88	1.8	4
	9	Medallion TL		3.00	2.94				
24 Nov.	2	Headway	13:15-14:15	3.00	3.26	4.5	100	0.2	>12
	3	Medallion TL		3.00	2.94				
	6	Headway		3.00	3.26				
	7	Medallion TL		3.00	3.26				

3.3 Weather data and winter management

The average temperature for October 2012 was 0.9 °C lower, but the average for November 2012 1.6 °C higher than the 30 year normal values (Table 3). Precipitation exceeded normal values by 35 and 67% in October and November, respectively.

Temperatures below zero in the last week of November resulted in frost to 15-20 cm depth in the green root zone. Three days later, on 2 December, the green was covered by 20 cm of snow (Fig.1). December had an average temperature 3.5°C lower than the 30 year normal, and precipitation was very high, partly as snow and partly as rain (Table 3). During the last week of December there was a mild period resulting in a 10 cm layer of ice under the snow.

Table 3. Monthly values for temperature and precipitation at Landvik from 1 Sep. 2012 to 31 May 2013 and 30 year normal values (1961-1990).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Temperature, °C								
2012-2013	6.8	4.8	-3.3	-3.1	-2.1	-1.8	3.7	11.5
30 year normal	7.9	3.2	0.2	-1.6	-1.9	1.0	5.1	10.4
Precipitation, mm								
2012-2013	218	239	286	81	26	36	101	134
30 year normal	162	143	102	113	73	85	58	82

Based on earlier experiences showing poor tolerance to ice encasement in *Poa annua* (Aamlid et al. 2009, 2011) we decided to remove the ice from the experimental area as soon as possible. However, because of temperatures down to -20°C, there was no opportunity for ice removal until a mild period in the last week of January. At this stage, samples taken inside indicated that the turf was still alive. On 25 and 28 Jan. we were able to drive on the ice layer and remove 20-30 cm snow on the top of the ice layer (Photo 2). Then we dressed a thin layer of dark sand on the ice to enhance melting both from the top and from the bottom. Three days later there was a thin water film between the turf and the ice that allowed us to remove the ice without any damage to the turfgrass crown area (Photos 3-4). After ice removal on 31 January, the green was covered with an agryl tarp to protect the newly exposed turf from cold, as air temperatures the following night went down to -7.7 °C. On 2 February, the weather forecast predicted snow, so the tarp was removed and the green was covered with 5-10 cm of light snow for the following two weeks.

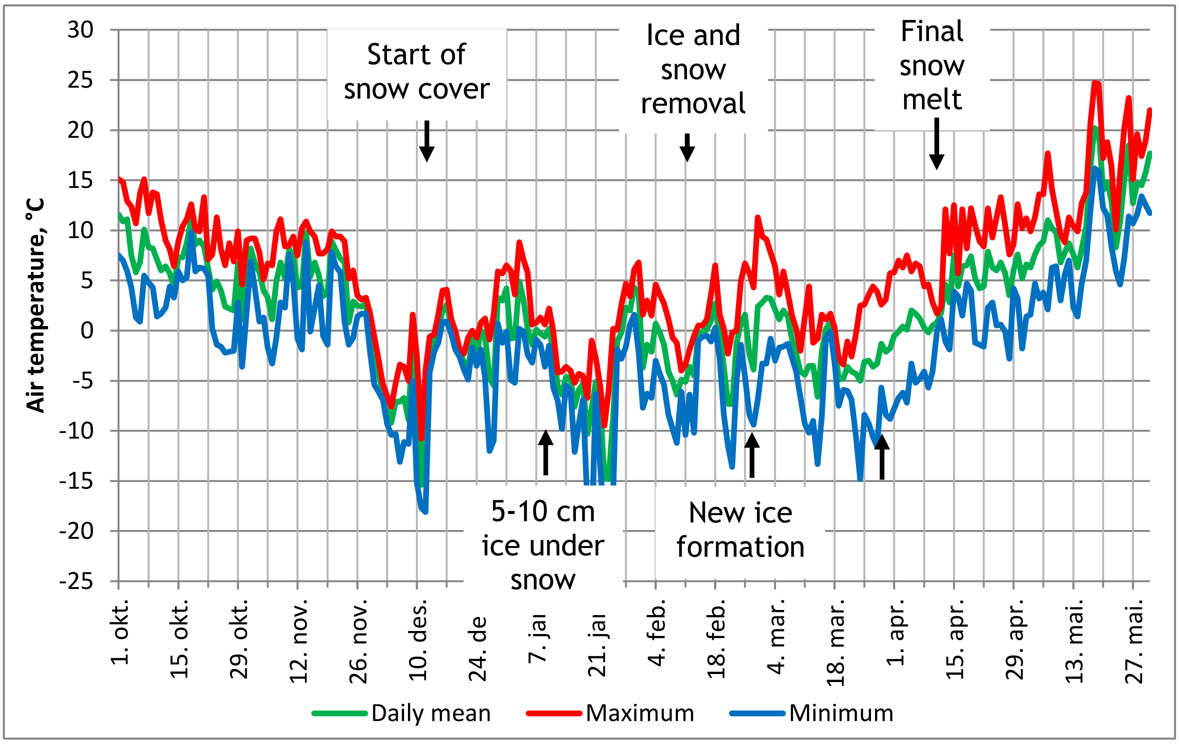

Figure 1. Official recordings of daily mean, maximum and minimum air temperatures at Landvik weather station from 1 Oct. 2012 to 1 June 2013. Duration of snow and ice cover has been indicated.

Photo 2. Driving on the 10 cm thick ice layer to remove snow on 25 January. Photo: Trond Pettersen.

Photo 3. Mechnical removal of ice on 31 January. Photo: Trond Pettersen.

Photo 4. After ice removal on 31 January. Photo: Trond Pettersen.

Photo 5. New ice formation in mid-February. Photo: Trond Pettersen.

Photo 6. Green temporarily without snow and ice cover in first week of March. Photo: Trygve S. Aamlid

In mid-February there was again a mild period causing ice to be formed on the green (Photo 5), but this only lasted for about two weeks. In late February, samples taken regularly into the growth chamber indicated that the turf was dead.

In the first week of March the snow and ice had melted (Photo 6), but from 15 March the green was again covered with snow until about 1 April. Both March and April were much colder than the 30 year normal values (Table 2). When the ice and snow finally thawed around 15 April, the turf appeared to be dead irrespective of treatments, and this was confirmed as no greenup occurred over the next three weeks. Consequently, the experiment could not be evaluated for attack of pink snow mold in sping.

3.4 Registrations and statistical analyses

Because of the ice encasement and/or subsequent freezing injury causing 100 % winter kill, registrations were limited to the period 5 October – 2 December 2012:

- Per cent of plot area infected with *M. nivale* was recorded at weekly intervals. As differentiation between active disease and old patches/scars was impossible, only the total area affected will be presented in tables/figures.
- Turfgrass overall impression (scale 1-9, where 9 is best quality) was also evaluated at weekly intervals.
- Green speed: Turfgrass ball roll distance was measured at start of the trial on 5 Oct. and on 19 Oct. We used a stimpmeter modified for research plots (Gaussion et al. 1995). The stimpmeter had its ball release notch 38 cm rather than 76 cm from the beveled end.

All experimental data were subjected to analyses of variance using the SAS procedure PROC ANOVA. After converting the risk levels 'low', 'medium' and 'high' to the numeric values 1,2 and 3, respectively, we also conducted a simple correlation analysis (PROC CORR) and a stepwise regression analysis (PROC REG) to relate GRRENCAST predictions to the local weather observations at Landvik.

In the text and tables, significance levels in the ranges <0.001, 0.001-0.01, 0.01-0.05, 0.05-0.1 and >0.1 have been indicated by ***, **, *, (*), and ns, respectively. The term 'significant' in the text always refer to P<0.05, whereas P-values in the range 0.05-0.10 have been referred to as 'tendencies'. Fisher's protected least significant difference at P<0.05 have been used to indicate significant differences in figures.

4. Results

4.1 GREENCAST warnings and anticipated protection by fungicides

GREENCAST warnings showed a broad relationship with daily values for temperature, precipitation and relative humidity at the local weather station Landvik (Table 4). According to the forecast, 30 of the 59 days from 5 October to 2 December, most of them in November, had a high risk for development of *M.nivale*. After conversion of the risk levels 'Low', 'Medium' and 'High' into the numeric values 1,2 and 3, respectively, there was a strong positive correlation between risk for infection and average daily humidity (r= 0.59***). The correlations with between risk for infection and daily maximum temperature, daily minimum temperature, daily mean temperature and preciptitation were also positive, but much weaker (r=0.20ns, r=0.23(*), r=0.28* and r=0.24(*), respectively. Because of intercorrelation among the weather variables, the stepwise multiple regression procedure selected no other variable than relative humidity to explain the risk for disease.

Based on an anticipated protection period of three weeks for both fungicides, Table 4 shows that the turf be protected during most of October and November regardless of treatment. The most notable exception were the four days 20-23 Nov., which according to GREENCAST had a High Risk for disease, but where the effect of former fungicide treatments was considered insufficient in treatments 2 and 3, and on the two latter days even in treatments 6 and 7. The reason why fungicides in these treatments could not be reapplied until 24 November was the almost continuous rainfall on 20 and 21 November, followed by many unpredictable showers on 22 and 23 November.

Table 4. Daily values for temperature, precipitation and relative humidity at Landvik weather station, GREENCAST prediction for spread of M.nivale*, and anticipated protection from fungicides applied according to the criteria 'GREENCAST Medium Risk', 'GREENCAST High Risk', 'First sign of disease' and 'Profylactic' from the start of the experiment on 5 Oct. to snow covered the green on 2 Dec. 2012. (Black cells indicate application dates and white cells days without fungicide protection).*

Week-day	Date	Air temperature, °C			Precipi-tation, mm	Relative humidity, %	Risk for spread of *M.nivale* (Greencast)	Anticipated protection from fungicide application			
		Min.	Max.	Mean				Treatm. 2&3 Medium Risk	Treatm. 4&5 High risk	Treatm. 6&7: First Sign	Treatm. 8&9 Profyl-actic
Fri	5-Oct	1.3	10.7	5.8	0.1	91.7	Medium				
Sat	6-Oct	0.9	13.7	6.8	0.1	73.8	Medium				
Sun	7-Oct	5.5	15.1	10.1	0	63	Medium				
Mon	8-Oct	4.8	11.7	8.3	0	51.7	Medium				
Tue	9-Oct	4.3	13.8	8.2	0	42.7	Low				
Wed	10-Oct	1.4	13.6	7.1	0	67.5	Low				
Thu	11-Oct	1.7	11	6.0	0	78.6	Low				
Fri	12-Oct	2.3	9.0	6.4	0.3	79.5	Low				
Sat	13-Oct	4.4	8.1	5.7	8.8	78.6	Low				
Sun	14-Oct	3.3	6.4	4.4	4.8	77.2	Low				
Mon	15-Oct	5.9	8.9	7.3	25.6	87.7	Low				
Tue	16-Oct	5.0	10.4	7.3	27.7	91.6	High				
Wed	17-Oct	5.3	11.1	8.7	10.0	89.1	Medium				
Thu	18-Oct	9.8	12.6	11.1	18.5	95.2	Medium				
Fri	19-Oct	5.9	10.1	8.6	12.4	95.5	Medium				
Sat	20-Oct	6.3	9.9	9.0	24.7	96.9	Medium				
Sun	21-Oct	6.2	13.3	8.4	0.3	92.1	High				
Mon	22-Oct	5.5	7.1	6.2	0	92.2	High				
Tue	23-Oct	0.2	7.6	4.1	0	90.9	High				
Wed	24-Oct	-1.4	11.3	4.9	0.1	88.1	High				
Thu	25-Oct	-1.6	8.1	4.0	0.1	59.1	High				

Table 4 continued

Week-day	Date	Air temperature, °C Min.	Max.	Mean	Precipi-tation, mm	Relative humidity, %	Risk for spread of *M.nivale* (Greencast)	Anticipated protection from fungicide application: Treatm. 2&3 Medium Risk	Treatm. 4&5 High risk	Treatm. 6&7: First Sign	Treatm. 8&9 Profyl-actic
Fri	26-Oct	-2.2	6.5	2.4	0.1	53.5	Low				
Sat	27-Oct	-2.1	8.7	2.2	0	53.1	Low				
Sun	28-Oct	-2	6.9	2.0	10.2	72.4	Low				
Mon	29-Oct	2.8	9.9	6.6	8.7	91.5	Low				
Tue	30-Oct	-3.6	4.6	1.1	6.3	79.8	Medium				
Wed	31-Oct	1.8	9	5.7	27.4	93.4	High				
Thu	1-Nov	6.9	9.2	8.2	7	83.2	High				
Fri	2-Nov	4.2	9.2	6.7	19.5	89.7	High				
Sat	3-Nov	0.9	7.8	5.8	9.6	90.8	High				
Sun	4-Nov	1.3	5.1	4.0	37.5	97.1	High				
Mon	5-Nov	-1.7	6.7	3.3	0.9	88.1	Medium				
Tue	6-Nov	-3.3	6.5	1.1	1.0	95.4	High				
Wed	7-Nov	-0.7	9.9	4.9	0	78.2	High				
Thu	8-Nov	2.8	11.1	6.8	0	84.8	High				
Fri	9-Nov	2.3	8.4	5.2	5.2	89.6	High				
Sat	10-Nov	7.6	8.5	8.1	14.1	94.3	High				
Sun	11-Nov	4.8	9.4	7.5	9.3	88.8	High				
Mon	12-Nov	-0.8	7.5	4.3	0	70.4	High				
Tue	13-Nov	-1.9	10.2	4.4	4.9	95.4	High				
Wed	14-Nov	8.8	10.9	9.8	0	93.6	Medium				
Thu	15-Nov	-0.1	9.9	5.4	0	86.4	High				
Fri	16-Nov	2.3	9.4	6.8	1.8	92.5	High				
Sat	17-Nov	4.5	7.7	5.5	28.4	95.2	High				
Sun	18-Nov	-0.5	7.7	3.4	0.4	94.6	High				
Mon	19-Nov	-1.4	8.1	3.8	1.3	91.5	High				
Tue	20-Nov	7.8	9.9	8.9	28.9	97.8	High				
Wed	21-Nov	6.4	9.4	8.0	22.2	97.9	High				
Thu	22-Nov	5.8	9.4	7.2	8.8	97.3	High				
Fri	23-Nov	0.9	8.9	6.8	5.1	91.7	High				
Sat	24-Nov	-1.4	5.2	0.8	1.8	99.9	High				
Sun	25-Nov	-0.7	6.0	2.9	28.9	93.2	High				
Mon	26-Nov	1.4	3.5	2.5	3.8	87.8	Medium				
Tue	27-Nov	1.7	3.1	2.4	1.1	84.7	Medium				
Wed	28-Nov	1.7	3.3	2.7	0	75.5	Medium				
Thu	29-Nov	-2.2	1.7	-0.7	0.1	72.9	Low				
Fri	30-Nov	-5.4	-0.6	-2.8	0	64.1	Low				
Sat	1-Dec	-6.1	-2.8	-4.3	0	63.9	Low				
Sun	2-Dec	-6.9	-5.4	-6.2	4	74.4	Low				

4.2 *Development of* M.nivale

The were no microdochium patches at the start of the experiment on 5 October 2012. The first patches were observed on 12 October and the disease continued to develop until 19 October, although at a reduced rate in treatments sprayed prophylactically with Medallion on 5 October or at the 'GREENCAST high risk warning' on 12 Oct (Fig. 2).

From 19 Oct. to 1 Nov. the level of disease either remained stable at 4-6 % of plot area in treatments 1 and 3, or decreased to 0-1 % of plot area in the other treatments (Fig. 2). Patches of *M.nivale* reappeared after 2 Nov., but were mostly controlled by fungicides after 9 Nov.

Except for the unexpected poor control by Medallion in treatment 3, there was no significant difference between Medallion and Headway in control of *M.nivale* at any application date. At the last assessment before snow fall, the unsprayed control treatment and the treatment receiving Medallion at 'GREENCAST medium risk warning' had significantly more *M.nivale* than the other treatments (Fig. 2). This was also the case on average for six observations from 12 Oct. through 23 Nov. (Table 5, see also Photo 7).

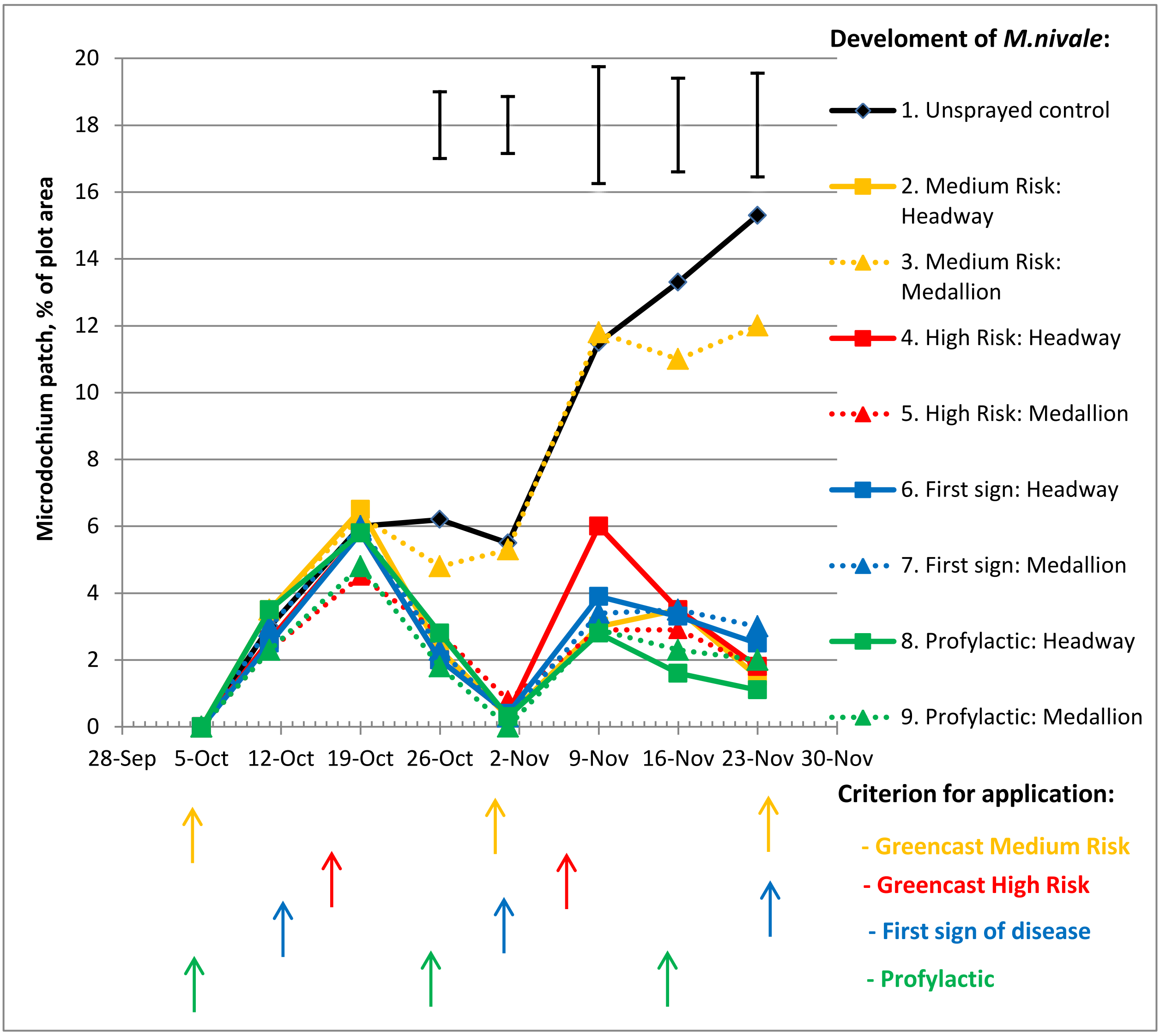

Figure 2. Application dates and development of microdochium patch in the various treatments. Bars indicate Fisher protected $LSD_{0.05}$.

Table 5. Average values for per cent of plot area affected by M.nivale and overall impression in October and November, along with vgolf ball roll distances measured on 19 Oct.

Treatment	% micro-dochium patch (mean of 6 obs.)	Overall impression (1-9) (mean of 7 obs.)	Turfgrass ball roll 19 Oct., cm
1. Unsprayed control	8.7	4.3	103
2. Medium Risk: Headway	2.9	5.9	114
3. Medium Risk: Medallion	7.8	4.7	105
4. High Risk: Headway	3.1	6.2	104
5. High Risk: Medallion	2.5	6.6	108
6. First sign. of disease: Headway	2.9	6.2	106
7. First sign. of disease: Medallion	3.1	6.4	104
8. Profylactic: Headway	2.5	6.3	109
9. Profylactic: Medallion	2.9	6.7	109
Significance	***	***	*
$LSD_{0.05}$	1.7	0.7	6

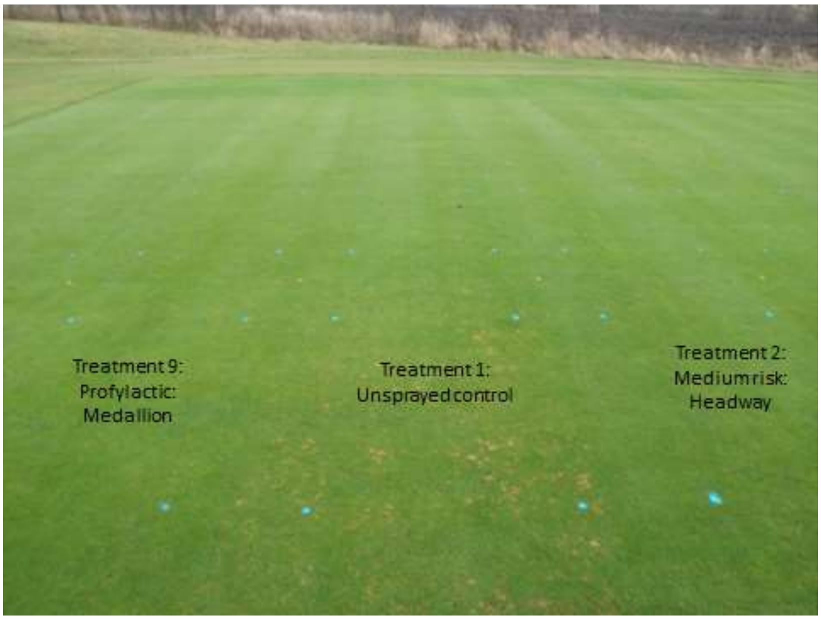

Photo 7. Both Headway applied at medium risk in treatment 2 and Medallion applied prophylactically in treatment 9 had significantly less microdochium patch than the unsprayed control treatment. Photo taken on 16 November by Trygve S. Aamlid.

4.3 Turfgrass overall impression

Differences in turfgrass overall impression among fungicide treatments were significant from 26 Oct. onwards (Fig. 3). As for infection with *M.nivale*, the unsprayed control treatment and treatment 3 had inferior quality compared with the other treatments. Except for treatment 3 and 4 receiving fungicides at the GREENCAST Medium Risk criterion, the mean values presented in Table 5 shows an insignificant trend for Medallion to produce more uniform turf with slightly better quality than Headway.

4.4 Turfgrass ball roll distance

Measurement of turfgrass ball roll on 19 Oct. showed higher green speed in treatment 2 receiving Headway according to the GREENCAST Medium Risk criterion than in the other treatments. Unsprayed control plots had the lowest green speed (Table 5).

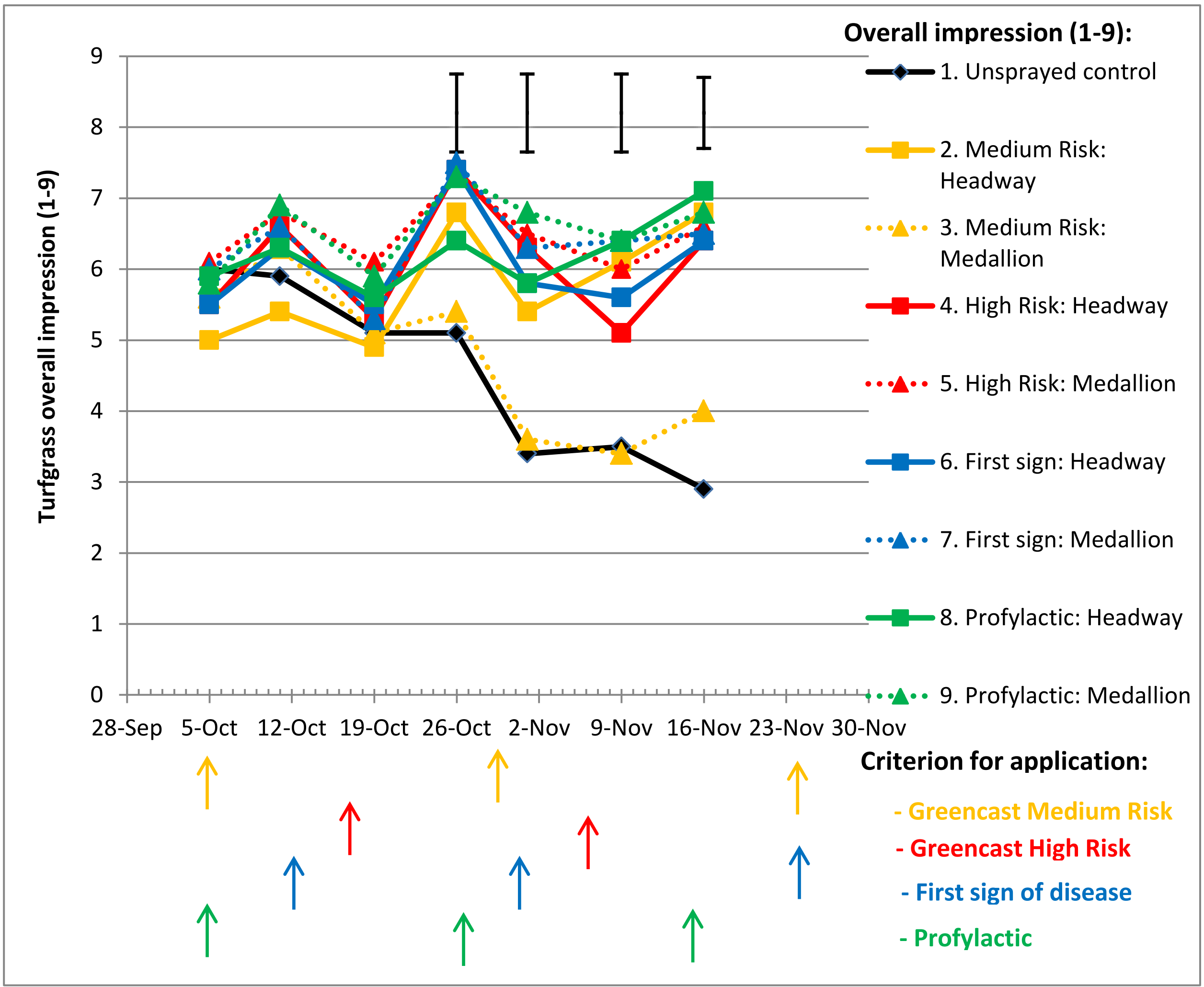

Figure 3. Application dates and turfgrass overall impression in the various treatments. Bars indicate Fisher protected $LSD_{0.05}$.

5. Discussion and conclusion

5.1 Development of M.nivale and precision of GREENCAST predictions

We have no exact information about weather conditions causing medium risk and high risk warnings for *M.nivale*, but correlation analysis based on Table 4 suggested that relative humidity was the most important variable. This is in agreement with Smith et al. (1989) who cited several reports showing *M.nivale* to be favoured by moist or wet weather in autumn. The fact that that the total area affected by *M.nivale* on unsprayed control plots did not increase from 19 to 26 October (Fig. 2) despite the high risk warnings of GREENCAST (Table 5) may, however, indicate that other variables should also be taken into account. One of them is temperature, as both Endo (1963, cited by Smith et al. 1989) and Årsvoll (1975) both found the optimal temperature for growth of *M.nivale* to be as high as 21ºC with little disease occurring at freezing temperatures.

The failure of GREENCAST the model to predict spread of M.nivale during certain periods may also be due to the fact that weather recordings were from different providers and included observations from Torungen, Nelaug and Kristiansand which are all located 20-50 km from the experimental site (J. Tricand de la Goutte, pers. comm, Appendix 1). Unfortunately, the data shown in Fig. 1 and Tables 3 and 4 from Bioforsk's / The Norwegian meteorological Institute's weather station Landvik, which is only 200 m from the experimental green, were not included. We don't know why Landvik data were not available, but as requested at the start of the project, direct use of weather data from Landvik into the GREENCAST model would most likely have made the evaluation of the model for Scandinavian conditions more accurate. Hopefully, this can be changed in the second evaluation year starting in August 2013.

In his textbook 'A practical guide to turfgrass fungicides', Latin (2011) referred to research showing rapidly declining protection of both acropetal penetrants and contact fungicides from 7 to 21 days after application. Most of the citations were from work with the summer-active pathogen dollar spot (*Sclerotinia homeocarpa*), and they are not confirmed by the present data for control of *M.nivale* at low temperatures. Our assessments in fact suggest that visible effect of fungicide applications often did not appear until one week after application, and that the effect of fungicides in enhancing repair of already existing patches was just as important as in preventing the outbreak of new ones. This suggest that preventative applications based on a prophylactic program or GREENCAST predictions will not necessarily result in less visible disease than application at 'first sign of disease'. Another implication is that the anticipated protection period from fungicide applications may perhaps be extended from three to four weeks, which is indeed practised when applying fungicides according to GREENCAST predictions in England (S. Watson, pers. comm, Appendix 1).

5.2 Headway vs. Medallion

Except for application of Medallion at the 'GREENCAST medium risk warning' (treatment 3) Headway and Medallion showed similar efficiency in controlling *M.nivale*. Syngenta usually recommends that Headway is applied when the turf is still growing, or at least one month before expected snowfall, as the two active ingredients are both absorbed into the leaf and that one of them, axoxystrobin requires about 10 ºC for optimal protection. Medallion (fludioxonil), on the other hand, is a contact fungicide that does not protect new growth and that should therefore be applied once growth has stopped in the late fall, preferably shortly before snowfall. The poor control by Medallion at the first application on 5 Oct. in treatment 3 ('GREENCAST medium risk warning') may at first glance confirm these recommendations, as the green continued to be mowed to 4-5 mm at approximately weekly intervals until the last mowing on 31 October. The poor performance of treatment 3 is, nevertheless, hard to understand, as prophylactic application of Medallion on the on the same date (treatment 9) showed excellent control. We have examined the GEP-spraying report for 5 Oct. but are not able to find a good explanation for this unexpected result. In comparison with the unsprayed control treatment, the second and third application of Medallion in treatment 3 seemed to have a certain effect on *M.nivale*, but this could by not compensate for the failure of the product at the first application.

One perhaps minor, but still interesting observation, was the significant increase in green speed after application of Headway on 5 October. Although this observation was only partly confirmed by the application in treatment 8, it may be speculated that the effect was due to a certain retarding effect of Headway on turfgrass leaf elongation. Growth-regulating effects of DMI-fungicides, e.g. propiconazole in Headway, have earlier ben documents in several grasses (e.g. Kane & Smiley 1983, Shell et al. 2012, Aamlid & Pettersen 2013). Except for of the rather odd difference between treatments 2 and 3, the fact that Medallion also tended to give slightly better scores for overall impression than Headway, may perhaps also be taken as an indication of a growth retarding effect only of the latter.

Although control of microdochium patch is important, the ultimate goal of fungicide applications in the late fall in Scandinavia is usually to protect the turf from pink snow mold and other winter diseases. It was therefore unfortunate that the physical winter conditions became so severe that the turf died irrespective of treatments. As *M.nivale* requires oxygen for respiration, it is not surprising that ice encasement masked the fungicidal effect on disease development. Given the number and timing of fungicide applications before snow cover on 2 December (Table 5), it would have been especially interesting to study differences in spring between treatments 4 and 5 that received only two fungicide applications and according to the anticipated three week protection period were unprotected when snow came on 2 Dec. (treatments 4 and 5); and the other treatments that received three fungicide applications. In last year's fungicide trials at Landvik, per cent of plot area infected by *M.nivale* was slightly lower and turfgrass overall impression in spring slightly higher with three than with two fungicide applications in October and November, but the differences were not statistically significant (Aamlid et al. 2012).

5.3 Conclusion

The first year results presented in this report confirmed the hypothesis in that applications according to 'GREENCAST's high risk warning' reduced the number of applications from three to two as compared with the prophylactic fungicide program. By contrast, applications according to' GREENCAST's medium risk warning' neither increased nor decreased the number of applications. Our preliminary data also support the current recommendation of using Headway for the first application in autumn and Medallion for subsequent application(s).

As the evaluation of GREENCAST continues for at least one more year, there is scope for improvements by using data from the local weather station and perhaps also for refinements of the temperature, relative humidity and rainfall criteria eliciting medium and high risk warnings. In agreement with the current practise in UK and Ireland, it may further be considered if the anticipated protection period from fungicide application should be extended from three to four weeks. Given EU directive 2009/128's requirement for Integrated Pest Management, the alternative to using GREENCAST is not prophylactic applications at predetermined time intervals, but application the at the first sign of disease, which is also an important criterion for fungicide application in this project.

6. References

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7. Appendix: Correspondence regarding use of GREENCAST test version

Hi Trygve,

It will be fine to use last year's fungicide. We had a missing MSDS for one of the fungicides that has delayed shipment of the trial material until today. I had confirmation of shipment earlier today and have requested it go the quickest way as you specified.

In terms of the other treatments the protocol should have specified:

Applications made when the Greencast model predicts medium risk are applied. The Greencast model is then reviewed 28 days later and a further application made when the model predicted medium risk or higher.

Applications made when Greencast predicts high risk are applied. The Greencast model id then reviewed 28 days later and a further application made when the model predicted high risk.

Applications made at the first sign of disease are applied and reviewed 28 days later and a further application made at the first sign of disease returning.

This is what we did in the UK and I think you should be at least monitoring things more frequently than 28 days. It might be in the Nordics that we look at things every 21 days? Not sure what do you think? Of course we have the snow cover to also think about which might well shorten the interval. Hopefully GreenCast weather will give us some idea of significant snow fall.

I agree that you green is equivalent to a parkland situation.

I hope this helps but if you have any questions get back to me

Regards
Simon

Simon Watson
Technical Manager EAME
Turf & Landscape

From: Trygve S. Aamlid [mailto:Trygve.Aamlid@bioforsk.no]
Sent: 02 October 2012 13:46
To: Tricand de la Goutte Jerome CHBS; Watson Simon GBFB
Cc: Trond Olav Pettersen
Subject: SV: Greencast Landvik

Dear Jerome,
Thanks for your response. Your link did not work for me, but don't bother. I can enter the location data whenever I start the program.

Simon:
We have put out the plots on our Poa annua experimental green and there are no signs of disease so far.
We are making our first prophylactic applications of Headway and Medallion (treatments 8 and 9) tomorrow.
(In case we do not receive your shipment this afternoon, we will use Medallion and Headway that is left from last year's trial.)

For tomorrow, Greencast says ‘some risk’ for Fusarium on links courses and ‘medium risk’ on parkland courses.
I suppose that our Poa annua green is comparable to a parkland course, in other words treatments 2 & 3 should also be applied tomorrow. Correct ?

I look forward to your answer to my question no 4 below.

Thanks,
Trygve

Fra: jerome.tricand_de_la_goutte@syngenta.com [mailto:jerome.tricand_de_la_goutte@syngenta.com]
Sendt: 2. oktober 2012 10:08
Til: Trygve S. Aamlid; simon.watson@syngenta.com
Kopi: Trond Olav Pettersen
Emne: RE: Greencast Landvik

Dear Trygve

1) Using this page (http://service.syngenta-ais.com/svc-rendering?servicePage=greencast/gcse/pages-fav/weather-fav&client=greencast&internaluser=Trygve), you will be able to store your locations as favorites :
a. On the weather page, you have a start “Add to favourite” to store the location you are currently looking at as a favorite
b. If you click on “Change location” on the top, You have a tab named “My Favourites” that shows you and let you select your favorites
2) This page is only showing one single weather forecast content + disease risk table.
3) The risk level is always an output of the models.
We have received the models from an external university, the diseases have been renamed (maybe to have them more understandable to the greenkeepers, who knows). Unfortunately, I’m not a specialist of turf diseases so I can’t really give you any more information, except what are the names of the models we have received, and how they are “translated” in the webpage:
a. The model name of what is written “Fusarium Patch High Risk” is “fusarium Patch Parkland”
b. The model name of what is written “Fusarium Patch Risk” is “Fusarium Patch Links”
4) @Simon, can you reply on this one?

5) Regarding your weather station, unfortunately, we cannot use it directly :
a) To calculate the results of the model for the future days, we need a weather forecast data, which is not provided by a physical weather station. Having a physical weather station could be used for model using only past weather conditions and not future. We are buying our weather forecast from a provider, but we are not controlling how and on top of which observed weather data he is running his weather forecast models.
b) We are also buying observed weather information from another provider. Unfortunately, the data we are receiving don’t have the right time scale to run the models, even for past days, as we are receiving some 6-hourly data, and some models require hourly data. For past days, we are forced to use the forecast data for past days to run the models
c) However we are regularly running some comparison between the observed weather information and the forecast we have received in the past, to check the quality of our weather forecast. The results are very acceptable.
Precisely, in your area, we are buying data for Torungen, Nelaug and Kristiansand

Please, remember that this page is not the production environment, and it is just a back door we are opening on our system to allow you to see the results of the models. The quality of the rendering has, then, to be considered as such.
The results of the models are correct, but there may be some bugs on the whole interface.
Do not hesitate to contact me if you are facing an issue stopping you in your work.

regards

Jérôme Tricand de la Goutte

From: Trygve S. Aamlid [mailto:Trygve.Aamlid@bioforsk.no]
Sent: 29 September 2012 19:39
To: Tricand de la Goutte Jerome CHBS; Watson Simon GBFB
Cc: Trond Olav Pettersen
Subject: SV: Greencast Landvik

Dear Jerome and Simon,

Following your instructions, I have now had my first lesson with Greencast.
To be able to use the program correctly and efficiently, I need some help from you.

1. The program found Norge (=Norway) and Grimstad, which is the nearest town to Landvik Research Centre. This is fine, but I had expected a username and password in order that the program would be able to recognize me and know my location next time I log on. Is it correct that I have to enter location data each time I open the program ?

2. After selecting Grimstad, the program automatically came up with a table called gc_diseaseriskindextitle which gave information about seedhead formation in Poa annua and many diseases but not M.nivale. This defalt setting is confusing and I wonder how to change it ?

3. When selecting diseaseZA, there was still no information about M.nivale, however, I understand that the program is using the old name Fusarium (please confirm). For Fusarium there were two alternatives, namely gc_FusariumPatchHighRisk and gc_FusariumPatchRisk, in both cases with colors indicating either no risk, some risk, medium risk etc. for the next 5 days. It seems confusing that 'risk level' is both a premise (input) and a result of model calculations (output) of the model. Which of the two premises should be used in the validation trial at Landvik ? Please explain.

4. Treatments 2&3 and 4&5 in the protocol for the trial at Landvik prescribes application at medium and high risk, respectively. Is this supposed to be only one application during the whole (5 month) trial period ? As far as I understand, I am not supposed to 'tell' the model that I have been spraying with one of your fungicides in order that the model can include this information when predicting when a second application is needed ?

When responding to these question, please copy my technician Trond Pettersen who shall be responsible for the daily management of the trial at Landvik.

Thanks and kind regards,

Trygve

Trygve S. Aamlid (Ph.D.)
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Fra: jerome.tricand_de_la_goutte@syngenta.com [mailto:jerome.tricand_de_la_goutte@syngenta.com]
Sendt: 27. september 2012 14:29
Til: simon.watson@syngenta.com
Kopi: Trygve S. Aamlid
Emne: RE: Greencast

Hi Simon and Trygve,

To access the model results, you can go on http://agri-cast.syngenta.com/pub/greencast/default.aspx.
Once you have defined your location, select the "{diseaseZA}" tab.

Regards

Jérôme Tricand de la Goutte

From: Watson Simon GBFB
Sent: 27 September 2012 14:17
To: Tricand de la Goutte Jerome CHBS
Cc: trygve.aamlid@bioforsk.no
Subject: Greencast

Hi Jerome,
Please can you arrange for Trygve to have access to the GreenCast model/forecasting system for Microdochium. He will be starting a validation trial for us in Norway next week and
If you need me to do anything then please let me know.

Cheers
Simon

Simon Watson
Technical Manager EAME
Turf & Landscape