IPM-GOLF 2020-23

Preliminary results from 2020 and spring 2021

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Karin Juul Hesselsøe et al. (full list in preface)
Department for Urban Greening and Vegetation Ecology

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FORFATTER(E)/AUTHOR(S)

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SAMMENDRAG/SUMMARY:

Denne rapporten oppsummerer foreløpige resultater fra 2020 i IPM-Golf-prosjektet: 'Integrated Management of Important Turfgrass Diseases and Insect Pests on European Golf Courses'. Feltforsøk på Microdochium flekk ble utført i Landvik, Norge og Bingley, Storbritannia. På Landvik viste resultatene at rulling ved lav N og sitronsyre, tilført fra aug.-okt. kan redusere Microdochium flekk til en viss grad blant de ikke-kjemiske behandlingene. Høy N resulterte i mer Mikrodochium flekk, men mindre antraknose. På Bingley viste resultatene at behandlingene som inneholder jernsulfat spesielt høyt jern, lyktes med å kontrollere sykdommen, men effekten varte ikke gjennom vinteren. Feltforsøkene ved Kjøpenhavns Golf Club viste at rulling to ganger i uken forbedret kvaliteten på greens gjennom vekstsesongen og at reduksjon av Microdochium flekk ble oppnådd ved å rulle fra august til desember. Feltforsøkene med UV-C-stråling ved Osnabrück Golf Club viste at denne metoden kunne kontrollere, men ikke bekjempe fullstendig dollar spot. Litteraturgjennomgangen om myrstankelbein og hageoldenborre viste at problemene varierer sterkt mellom år og de ulike landene.

GODKJENT /APPROVED	PROSJEKTLEDER /PROJECT LEADER
HÅKON BORCH	KARIN JUUL HESSELSØE

NIBIO

NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

Preface

The R&D project 'IPM-Golf: 'Integrated Management of Important Turfgrass Diseases and Insect Pests on European Golf Courses' was initiated by Norwegian Institute of Bioeconomy Research (NIBIO) and collaborators in 2019. This project is a concerted effort by researchers and greenkeepers from the Nordic countries, Germany, Portugal, the UK, Finland and Russia, suppliers from ICL, Syngenta, Suståne and Aqua-Yield. The project received funding from the Scandinavian Turfgrass and Environment Research Foundation (STERF) and the R&A in January 2020 and match funding from Netherlands Golf Federation, German Golf Association, and the Danish Environmental Protection Agency. The companies: Botaniska Analysgruppen (Sweden), Aqua-yield (USA), ICL (The Netherlands), Syngenta (UK), Suståne (UK, USA) and Xema (Finland) also contributed to the match funding.

The project has three subprojects/work packages: WP1 on microdochium patch, WP2 on dollar spot and WP3 on the insect pests – leather jackets and chafer grubs.

Contributors to this report and their affiliations:

Karin Juul Hesselsøe[1], Tatsiana Espevig[1], Trond O. Pettersen[1], Atle Beisland[1], Kristine Sundsdal[1], Erik Lysøe[1], Christian Spring[2], Mark Ferguson[2], Matthew Clark[2], Martin Nilsson[3], Wolfgang Pramässing[4], Jan Rosenbusch[4], Lukas Borrink[4], Daniel R. Hunt[4], Karin Normann[5], Marina Usoltseva[6], Kate Entwistle[7], Carlos Guerrero[8], Sabine Braitmaier[9], Yuri Lebedin[10], Anna Antropova[10], Tatiana Gagkaeva[11] and Ingeborg Mentzler-Hokkanen[12]

[1] NIBIO - Norwegian Institute of Bioeconomy Research, Norway

[2] STRI - Sports Turf Research Institute, UK

[3] Copenhagen Golf Club, Denmark

[4] University of Applied Sciences, Osnabrück, Germany

[5] Asbjørn Nyholt ApS, Denmark

[6] Botaniska Analysgruppen, Sweden

[7] The Turf Disease Centre, UK

[8] University of Algarve, Portugal

[9] ProSementis GmbH, Germany

[10] Xema, Finlands

[11] VIZR, Russia

[12] University of Eastern Finland

Landvik, 23.05.22

Karin Juul Hesselsøe

Content

Summary

This report summarises preliminary results from 2020 in the IPM-Golf project: 'Integrated Management of Important Turfgrass Diseases and Insect Pests on European Golf Courses'.

Field trials on microdochium patch were conducted at Landvik, Norway and Bingley, UK. At Landvik the results showed that trt. 15 (Rolling, low N) and trt.7 (Citric acid, Aug.-Oct.) could decrease microdochium patch to some extend among the non-fungicide treatments. High N resulted in more microdochium patch, but less antracnose. Low N resulted in less microdochium patch, but more antracnose. The experiments continue in the same form in 2021, though with a higher N-rate due to reestablishment after winter damages. At Bingley the results showed that fungicides were effective at controlling microdochium patch, even when the disease developed late in the season. Treatments containing iron sulphate particularly trt. 9 (High iron), were successful at controlling disease however the effect did not last through the winter. Application of organic fertiliser did not help with the initial infection but did help the turf cope with disease during the late winter spike. The experiment at Bingley continues in the same form in 2021. The field trials at Copenhagen Golf Club showed that rolling twice pr week improved turfgrass quality through the growing season and that reductions of microdochium patch was achived by rolling from August to December.

The field trials with UV-C radiation at Osnabrück Golf Club showed a tendency to reduce dollar spot development on greens with a higher radiation dosage around 80 mJ/cm². So, the UV-C radiation could provide an alternative physical method to control but not to combat completely dollar spot disease. At the same experimental green, the effect of organic slow-release fertiliser from Suståne 5-2-4 +Fe showed that there is a tendency of reduced dollar spot development with an amount of 130 kg N/ha of this product compared to the lower amount of 70 kg N/ha.

The Syngenta field trial to reduce microdochium patch and improving plant health at the experimental green in Bingley showed that the three alternative treatments were all successful in controlling microdochium patch, and that significant differences in disease control were not observed among the three treatments. Regarding turf colour significant differences between treatment 1 and trt 2, 3 and 4 were found from September and throughout the autumn and winter. The parallel experiment at Landvik showed that microdochium patch was higher in treatment 4 compared to trt. 2 which had a significantly higher turf quality than the other treatments. In March trt. 2 and 3 had significantly higher turf quality than the control and trt. 4.

Effects of alternative products on dollar spot incidence on red fescue dominant low input golf greens were tested at Bingley. Significant differences in dollar spot were observed on three out of six assessment dates. On these dates treatments 2, 3, 4 and 7 significantly reduced dollar spot levels when compared with untreated plots. Treatments 5 and 6 significantly reduced dollar spot levels when compared with untreated plots on one assessment date (7 DAT 7), however this was not observed consistently throughout the trial period.

In 2020, NIBIO Landvik received 40 turfgrass samples with DS symptoms from Denmark, Sweden, Norway, the UK, Portugal, and Germany. Dollar spot fungi were recovered from 15 turfgrass samples, and *Clarireedia* species will be identified using PCR in winter-spring 2022.

For immunoassay and identification of *Microdochium nivale* in plant tissue, the immunizations of animals by fungal extracts were completed and preliminary validation of ELISA prototype for *M. nivale* is going on in Finland and Russia. The same will be done for *Clarireedia* species.

The literature review on chafer grubs and leather jackets on golf courses in the Nordic countries showed that the problems differ strongly between years and the different countries.

Introduction

Integrated Pest Management (IPM) refers to the integration of all available techniques for control of diseases, harmful insects, and weeds, and it has for many years been one of STERF's highest research priorities.

The IPM Golf project 2020-2023 creates new knowledge on the challenges of diseases and insect pests comprising the effort by researchers, greenkeepers and suppliers representing alternative products, cultural practices and technologies in the Nordic countries, UK, Germany, Russia, and Portugal. Focus is on managing important diseases namely microdochium patch and dollar spot with no or strongly reduced pesticide inputs, to investigate causal species and to find testing methods for dollar spot and to review the management of insect pests – namely chafer grubs and leather jackets. This report summarises first year's results from the project.

Microdochium patch, caused by the fungus *Microdochium nivale*, is the economically most important disease on turfgrass in the Nordic countries (Melbye, 2019; Kvalbein et al., 2017). Effective prevention of microdochium patch is 'a long-running process' but can be successfully achieved by 'integrated turfgrass management' without use of fungicides (Bechelet and Owen, 2019).

Dollar spot, caused by four species of fungi in the genus *Clarireedia* is the disease with the strongest impact on playing quality on golf courses in North America, Central and Southern Europe. STERF projects recently confirmed that dollar spot has got a foothold even in Scandinavia (Espevig et al., 2015, 2017).

Chafer grubs and leather jackets are the insect pests that in some years cause a lot of damage on golf courses in Northern Europe. As the use of insecticides is restricted all over Europe, there is a need to look for alternatives.

Chapter 1 to 7 describes preliminary results of the experiments with alternative products and methods against microdochium patch and dollar spot. Experimental greens were established in spring 2020 at NIBIO Turfgrass Research Centre in southern Norway and at STRI's research station in Bingley, UK. Two golf clubs – Copenhagen Golf Club, Denmark and Osnabrück Golf Club, Germany are hosting experiments at selected greens. Products to be tested are fertilisers, iron sulphate, citric acid and other alternatives in different combinations, dosages, and timings. Methods to be tested are rolling with greens roller against microdochium patch, and UV-C radiation against both microdochium patch and dollar spot - a technology to kill germs which has been used increasingly to control fungal diseases on sports lawns. At the experimental greens at NIBIO and STRI the effect of the alternative products and methods are compared to standard and reduced fungicide treatments. Further details on the treatments are described in the individual chapters.

For dollar spot there is a need for more accurate identification of the pathogen species causing disease in various parts of Europe as some isolates of *Clarireedia* species cause more damage than others. Chapter 8 and 9 gives a summary on first year's results on the causal species of dollar spot in Europe and the testing methods for rapid tests for dollar spot and microdochium patch.

Chapter 10 describes first year's results on the review on insect pests.

Abbrevations used through the report: MP (Micordochium patch, *Microdochium nivale*), DS (Dollar spot, *Clarireedi*a sp.), WP (working package).

1 Alternative products, field trial on MP at NIBIO, Landvik (WP 1)

- Tatsiana Espevig, Trond Pettersen and Karin Juul Hesselsøe, NIBIO (Norway)

The objective of the trial was to investigate the effects of alternative products to prevent and control microdochium patch on golf greens.

1.1 Materials and methods

Project period, experimental site and plan:

May 2020 – May 2022. Two USGA annual meadow-grass golf greens (Photo 1) at NIBIO Turfgrass Research Centre Landvik, Grimstad, SE Norway (58°34'N, 8°52'E, 10 m a.s.l.). Poa Niblick with a rootzone mixture of 90% sand and 10% sphagnum peat (v/v) and Poa North with a rootzone mixture of 88% sand and 12% sphagnum peat. Further data from soil analyses taken prior to start of experiment are shown in Table 1. Soil bulk density and loss on ignition reflected a typical USGA-rootzone with P-AL and K-AL in the low range at Poa North and in the middle range at Poa Niblick.

Randomized complete block, 4 reps (blocks): 2 reps per green and 15 plots per block. Total plot size (treatment) = 3 m2 (1.5 m x 2 m) and registration plot area = 1.5 m2 (1 m x 1.5 m).

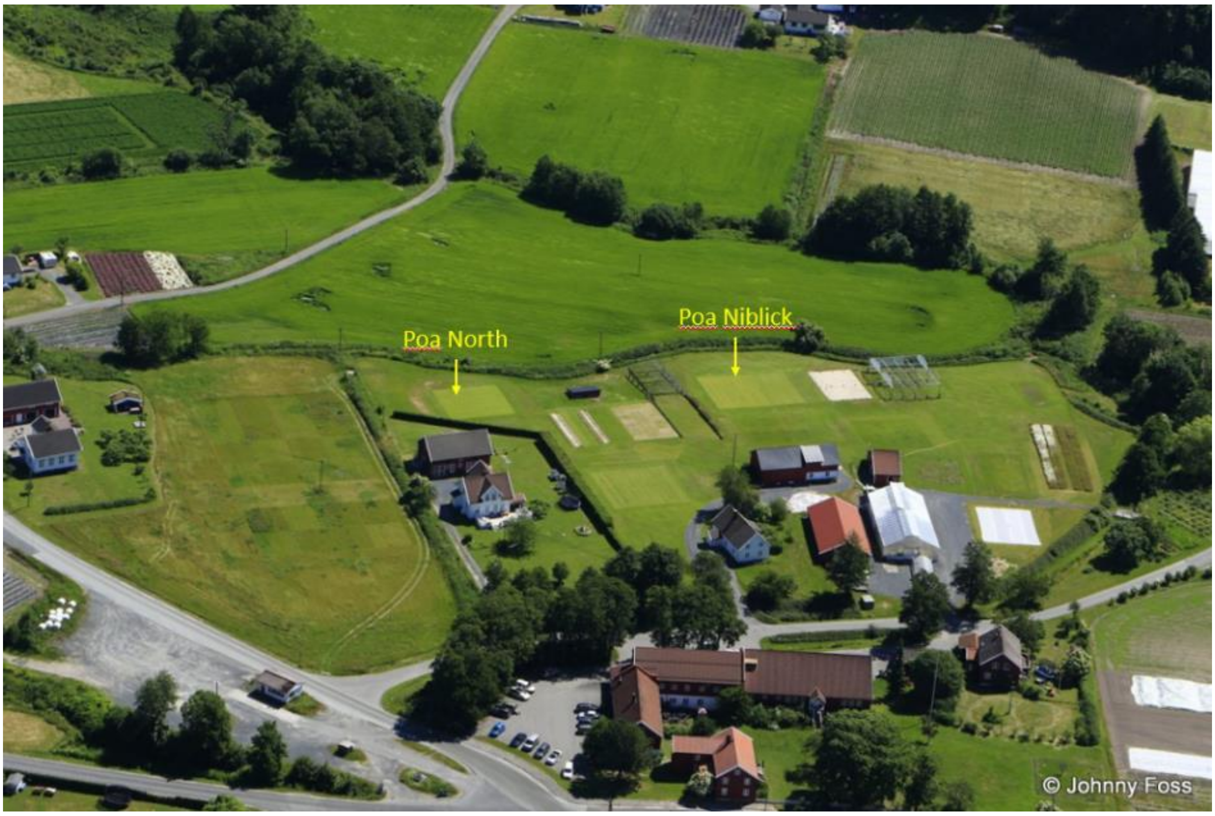


Photo 1: The experimental area with Poa Niblick and Poa North on 27 June 2020.

Photo: Johnny Foss.

Table 1: Soil bulk density, loss on ignition, P, K, Mg and pH in the experimental greens at the start of the trial.

Experimental green	Soil bulk density	Loss on ignition[1]	P-AL[2]	K-AL[2]	Mg-AL[2]	pH[3]
	g cm $^{-3}$	%	mg (kg dry soil) $^{-1}$	mg (kg dry soil) $^{-1}$	mg (kg dry soil) $^{-1}$	-
Poa North	1.4	1.8	31	45	37	6.0
Poa Niblick	1.5	1.4	55	66	45	6.4

[1] Method: EN 15935 (S33): 2012-11
[2] Method: DIN EN ISO 11885:2009-09
[3] Method: ISO 10390: 2005-12

Weather conditions during the growing season and winter 2020-21:

In late June/beginning of July 2020 there was a period with increased air temperatures (Figure 1). The hot weather led to an outbreak of anthracnose in the beginning of July especially at the low input plots on the 'Niblick green'. To reduce anthracnose the N-rate was increased with approximately 40 kg N in all treatments at this green. In 2020 precipitation was lower in May but doubled in June and July compared to the 30 years average. In August to October precipitation was slightly lower than the average.

The weather during the winter 2020-21 revealed a mild December, and after that soil was frozen until the beginning of April. In the end of February, the soil was frozen to 50-60 cm depth. There was also approx. 1-month ice formation under the snow due to rain just before snow from the end of January.

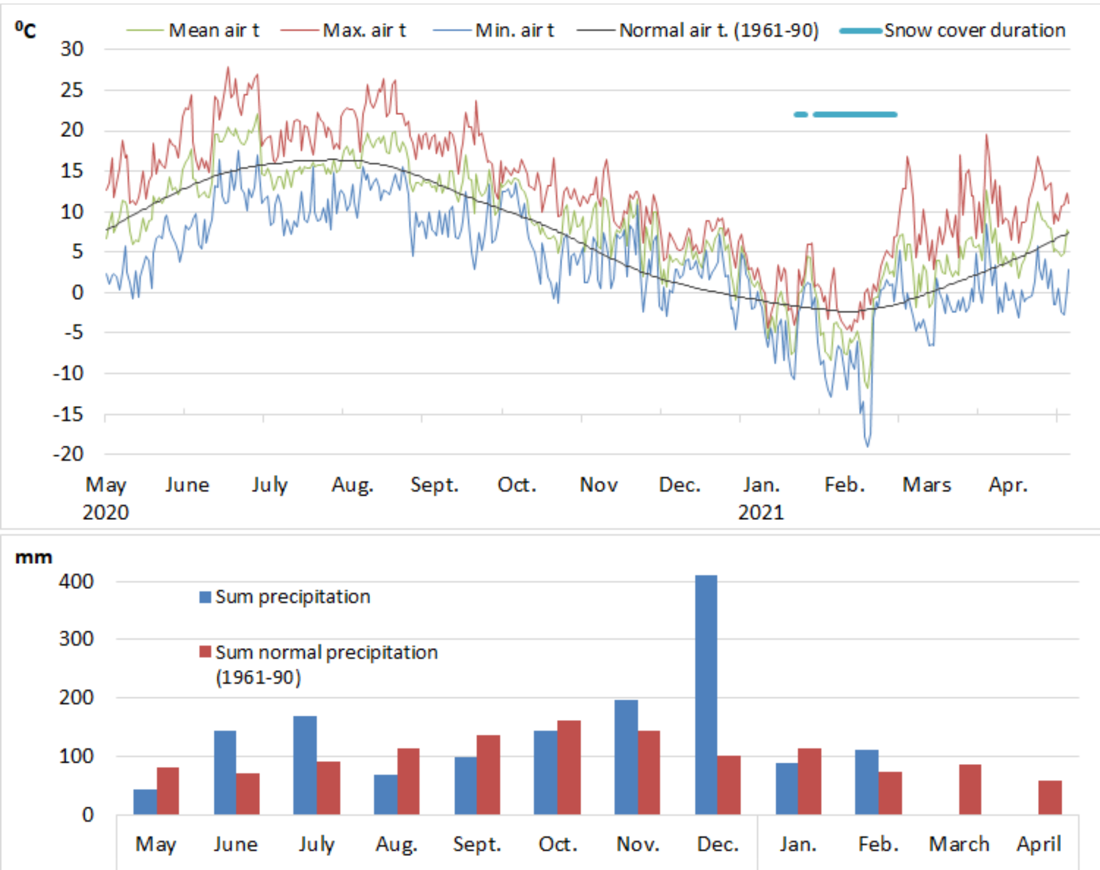


Figure 1: Mean, max. and min. air temperatures and precipitation from 1 May 2020 to 1 May 2021 from Landvik weather station compared with average temperatures and precipitation from 1961-90.

Treatments and fertilizer plans:

Due to high annual rainfall at Landvik 250 kg N/ha is the optimal N rate for annual meadow-grass greens at this site, and therefore this N rate was set in the original plan for the experiment. The reduced N rates in treatments 11-13 and 15 were adjusted to that optimum. Because of the outbreak of anthracnose on Poa Niblick in the beginning of July it was decided to increase the N rate at both experimental greens. Numbers in brackets in Table 2 is the average of the real N-amount given at both greens. See Table 3 for details.

Table 2: Treatments and N-rates in the original plan. N-rates in brackets are the average N-rates given at both greens.

Treatment	Nitrogen (kg N/ha/year)	Short description
1	250 (276)	Negative control (untreated) - spoon feeding, every week, optimal annual N
2	as trt 1	Standard fungicide approach: 2 applications of fungicides (100% recommended dosage)
3	as trt 1	Reduced fungicide approach: 2 applications of fungicides (60% of recommended dosage)
4	as trt 1	Reduced fungicide approach: 2 applications of fungicides (60% of recommended dosage) + NanoPro
5	as trt 1	Non-frequent nutrition (every 2 week), optimal annual N
6	as trt 1	N 250 kg/ha/yr + citric acid in June-Oct. (pH as trt 8)
7	as trt 1	N 250 kg/ha/yr + citric acid in Aug.-Oct. (pH as trt 8)
8	as trt 1	N 250 kg/ha/yr + iron sulfate (FeSO4, 4 kg/ha x 6, Aug.-Oct.)
9	as trt 1	N 250 kg/ha/yr + iron sulfate (FeSO4, 8 kg/ha x 6, Aug.-Oct.)
10	as trt 1 + 9 LAN	Late-autumn nutrition (LAN)
11	180 (213)	Low maintenance: Nutrition every week, but 72% of trt 1
12	220 (253)	Organic slow-release nutrition, Suståne 5-2-4+Fe
13	220 (253)	The same annual N as in trt 12 with products and frequency as trt 1
14	as trt 1	rolling x 2 per week in October at N 250 kg/ha/yr
15	as trt 11	rolling x 2 per week in October at N 180 kg/ha/yr

Table 3: Fertilizer plan for Poa North and Poa Niblick. N-rates in kg N/100 m2. Yellow row indicates the originally planned N-rates, green row the increased N-rates on each green due to anthracnose and the blue row the average N-rates.

Poa North				Suståne		LAN
	250	250	180	220	220	250
	trt 1	trt 5	trt 11	trt 12	trt 13	trt 10
Week			**Kg N pr 100 m2**			
14	0.060	0.060	0.060	0.060	0.060	0.06
15	0.068	0.068	0.068	0.068	0.068	0.07
16	0.075	0.075	0.075	0.075	0.075	0.08
17	0.090	0.090	0.090	0.090	0.090	0.09
18	0.105	0.105	0.105	0.105	0.105	0.11
19	0.098	0.098	0.098	0.098	0.098	0.10
20	0.092	0.092	0.092	0.092	0.092	0.09
21	0.105	0.215	0.074	0.225	0.093	0.10
22	0.111		0.078		0.099	0.11
23	0.117	0.240	0.083		0.104	0.12
24	0.123		0.087	0.225	0.110	0.12
25	0.123	0.246	0.087		0.110	0.12
26	0.123		0.087		0.110	0.12
27	0.117	0.228	0.083	0.225	0.104	0.12
28	0.111		0.078		0.099	0.111
29	0.105	0.203	0.074		0.093	0.10
30	0.098		0.070	0.225	0.088	0.10
31	0.092	0.178	0.065		0.082	0.09
32	0.086		0.061		0.077	0.09
33	0.086	0.172	0.061	0.225	0.077	0.09
34	0.086		0.061		0.077	0.09
35	0.080	0.154	0.057		0.071	0.08
36	0.074		0.052	0.225	0.066	0.07
37	0.068	0.129	0.048		0.060	0.07
38	0.062		0.044		0.055	0.06
39	0.055	0.105	0.039	0.225	0.049	0.06
40	0.049		0.035		0.044	0.05
41	0.043	0.080	0.030		0.038	0.04
42	0.037		0.026	0.225	0.033	0.04
43	0.037	0.074	0.026		0.033	0.04
44	0.037		0.026		0.033	0.04
45						0.030
46						0.025
47						0.020
48						0.015
SUM N weeks 14-44	**2.612**	**2.612**	**2.019**	**2.388**	**2.389**	**2.687**
SUM N weeks 21-44	**2.023**	**2.023**	**1.431**	**1.800**	**1.801**	**2.023**
						0.090

Poa Niblick					Suståne		LAN
		250	250	180	220	220	250
		trt 1	trt 5	trt 11	trt 12	trt 13	trt 10
	Week			**Kg N pr 100 m2**			
	14	0.060	0.060	0.060	0.060	0.060	0.060
	15	0.068	0.068	0.068	0.068	0.068	0.068
	16	0.075	0.075	0.075	0.075	0.075	0.075
	17	0.090	0.090	0.090	0.090	0.090	0.090
	18	0.105	0.105	0.105	0.105	0.105	0.105
	19	0.098	0.098	0.098	0.098	0.098	0.098
	20	0.092	0.092	0.092	0.092	0.092	0.092
	21	0.105	0.215	0.074	0.225	0.093	0.105
	22	0.111		0.078		0.099	0.111
	23	0.117	0.240	0.083		0.104	0.117
	24	0.123		0.087	0.225	0.110	0.123
	25	0.123	0.246	0.087		0.110	0.123
	26	0.123		0.087		0.110	0.123
	27	0.117	0.228	0.083	0.225	0.104	0.117
	28	0.111		0.078		0.099	0.111
1.40	29	0.146	0.284	0.104		0.130	0.146
1.40	30	0.138		0.097	0.315	0.123	0.138
1.35	31	0.125	0.241	0.088		0.111	0.125
1.35	32	0.116		0.082		0.103	0.116
1.30	33	0.112	0.224	0.079	0.315	0.100	0.112
1.30	34	0.112		0.079		0.100	0.112
1.20	35	0.096	0.185	0.068		0.085	0.096
1.20	36	0.089		0.063	0.259	0.079	0.089
1.20	37	0.081	0.155	0.057		0.072	0.081
1.20	38	0.074		0.052		0.066	0.074
1.20	39	0.066	0.125	0.047	0.259	0.059	0.066
1.20	40	0.059		0.042		0.053	0.059
1.20	41	0.052	0.096	0.037		0.046	0.052
1.20	42	0.044		0.031	0.259	0.039	0.044
1.20	43	0.044	0.089	0.031		0.039	0.044
1.20	44	0.044		0.031		0.039	0.044
	45						0.030
	46						0.025
	47						0.020
	48						0.015
SUM N weeks 14-44		**2.915**	**2.915**	**2.234**	**2.669**	**2.660**	**2.990**
SUM N weeks 21-44		**2.327**	**2.327**	**1.646**	**2.081**	**2.071**	**2.327**
							0.090
Average both N weeks 14-44		**2.76**	**2.76**	**2.13**	**2.53**	**2.52**	**2.84**
Average both N weeks 21-44		**2.18**	**2.18**	**1.54**	**1.94**	**1.94**	**2.18**

General maintenance of the greens:

The greens were maintained optimally and equally except for the treatments themselves.

Fertilization: Tuesday or Thursday from week 14 to week 44, ratio N:P:K~100:12:60 with products: Wallco liquid fertilizer 5-1-4 and Greenmaster cold start 11-5-5 and Greenmaster zero 14-0-10. Irrigation 5 mm after fertilization.

Mowing: 3 times per week (a day after fertilization Mon., Wed., Fri) using John Deere single mower. Initial mowing height 6 mm (Start 30th of March), from 4.5 to 3 mm in April, 4 mm from July, last mowing on 3rd of Nov.

Wear: Friction wear drum with golf spikes, 3 passes per week in 20 weeks from 8th of May to 15th of October (corresponding to 20000 rounds of golf per season if 20 weeks until 1 Oct.).

Irrigation: To field capacity every time soil moisture to 12-cm depth (TDR-measurements) is less than 12%.

Topdressing: Weekly 0.25 mm sand from 5th of June to 2nd of October, totally 5 mm of sand.

Vertical cutting: First in week 22, then every fourth week, each time after visual registrations.

Herbicides 22nd of April against *Sagina procumbens*: Ariane S (40 g fluroxypyr+ 20 g clopyralid+ 200 g MCPA/l)

Wetting agent: On 24th of April (H_2PRO, 20 g/m²) and on 9th of July (Revolution).

Registration and data collection:

Visual assessments were done monthly from May to November, always prior to fertilization, and one assessment in March 2021. The assessments included:

Visual turfgrass quality (overall impression), scale 1-9, 9 is very good, 1 is very poor. 5 is lowest acceptable. Density: (scale 1-9, 9 is very high, 1 is very low). Color intensity (scale 1-9)

Diseases (% of plot area): Anthracnose from July to October and MP – monthly from August to November, and one assessment in March 2021. For MP the area under disease progress curve (AUDPC) in the various treatments was calculated.

Statistical analyses:

ANOVA tests were done using one way ANOVA with differences among treatment means being identified using the Least Significant Difference method.

1.2 Results and discussion

Microdochium patch:

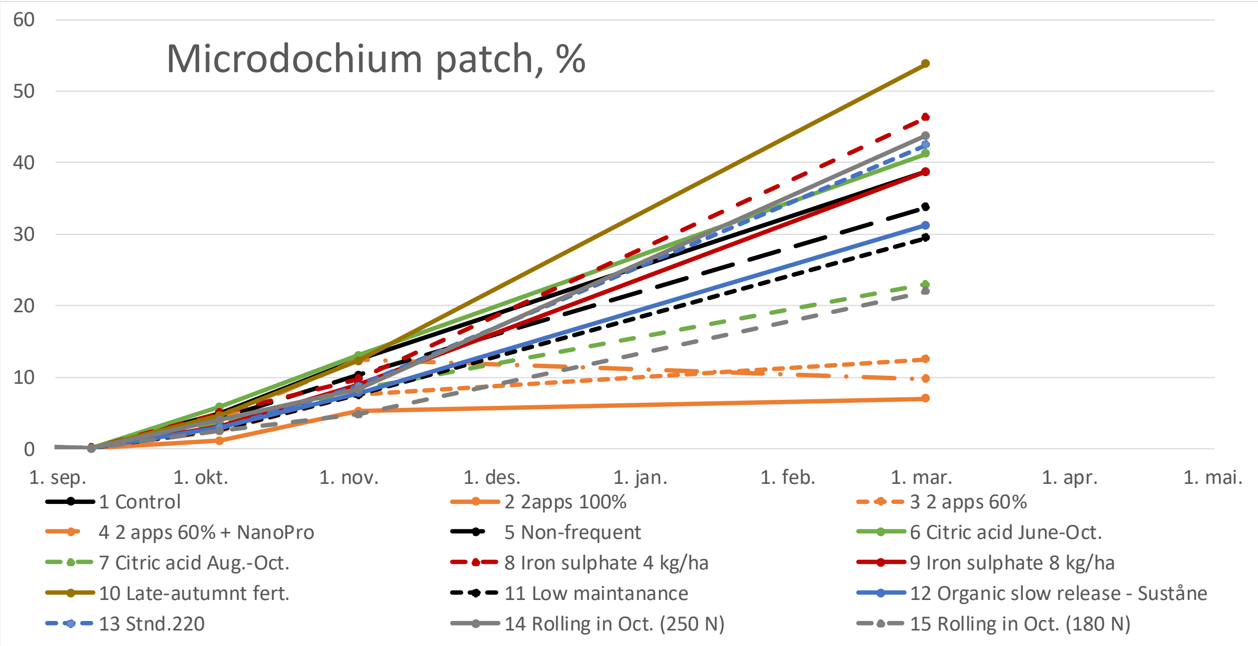


Figure 2: % of MP from October 2020 to March 2021.

After the second outbreak in September MP increased during the autumn and winter (Figure 2). At the registration 5th of October trt. 9 (High $FeSO_4$), trt. 11 (Low maintenance), trt. 12 (Organic slow release) and trt. 15 (Rolling, low N) had some effect on MP comparable to the 60 % fungicide trt. 3 (Table 4).

At the registration in November there were no significant differences between the treatments.

At the registration in the beginning of March 2021 trt. 7 (Citric acid, Aug.-Oct.) and trt. 15 (Rolling, low N) had 22 and 23 % of MP which were the lowest among the non-fungicide treatments (Table 4).

Table 4: % of MP on the registration dates in October, November 2020 and March 2021.

Treatment		N, kg/ha/yr	5. okt.		3. nov.	2. mar.	
1	Control	250	5.0	ab	12.5	38.8	abcd
2	2apps 100%	250	1.1	c	5.3	7.0	g
3	2 apps 60%	250	2.5	bc	7.5	12.5	efg
4	2 apps 60% + NanoPro	250	4.3	ab	12.5	9.8	fg
5	Non-frequent	250	4.1	ab	10.3	33.8	abcd
6	Citric acid June-Oct.	250	5.9	a	13.0	41.3	abcd
7	Citric acid Aug.-Oct.	250	3.6	abc	8.3	23.0	cdefg
8	Iron sulphate 4 kg/ha	250	5.0	ab	9.8	46.3	ab
9	Iron sulphate 8 kg/ha	250	3.1	bc	9.0	38.8	abcd
10	Late-autumnt fert.	250	4.6	ab	12.3	53.8	a
11	Low maintanance	180	2.6	bc	7.5	29.5	bcdef
12	Organic slow release	220	3.0	bc	7.8	31.3	bcde
13	Stnd.220	220	2.9	bc	8.8	42.5	abcd
14	Rolling in Oct.	250	4.0	ab	8.3	43.8	abc
15	Rolling in Oct.	180	2.5	bc	4.8	22.0	defg
		p ledd	*0.0739*		*0.1933*	*0.0004*	

Table 5: AUDPC (area under disease pressure curve) for MP from October to March.

Treatment		N, kg/ha/yr	AUDPC	
10	Late-autumnt fert.	250	3313	a
8	Iron sulphate 4 kg/ha	250	2839	ab
6	Citric acid June-Oct.	250	2824	ab
1	Control	250	2658	ab
14	Rolling in Oct.	250	2605	abc
13	Stnd.220	220	2547	abcd
9	Iron sulphate 8 kg/ha	250	2392	abcd
5	Non-frequent	250	2268	abcde
12	Organic slow release	220	1982	bcde
11	Low maintanance	180	1874	bcdef
7	Citric acid Aug.-Oct.	250	1646	bcdef
15	Rolling in Oct.	180	1363	cdef
4	2 apps fung., 60% + NanoPro	250	1318	def
3	2 apps fung., 60%	250	1091	ef
2	2 apps fung., 100%	250	668	f
		p	*0.004*	

Table 5 shows that trt. 10 (Late autumn fertilizer) had the highest AUDPC. Trt. 7, 11, 12 and 15 had the lowest AUDPC among the non-fungicide treatments.

Fungicides in trt. 2, 3 and 4 were applied at 16th Sep and 4th November, not programme applications. Trt. 2 (100 % dosage) had the lowest AUDPC followed by trt. 2 (60 % dosage) and trt. 3 (60 % dosage + NanoPro).

Overall impression:

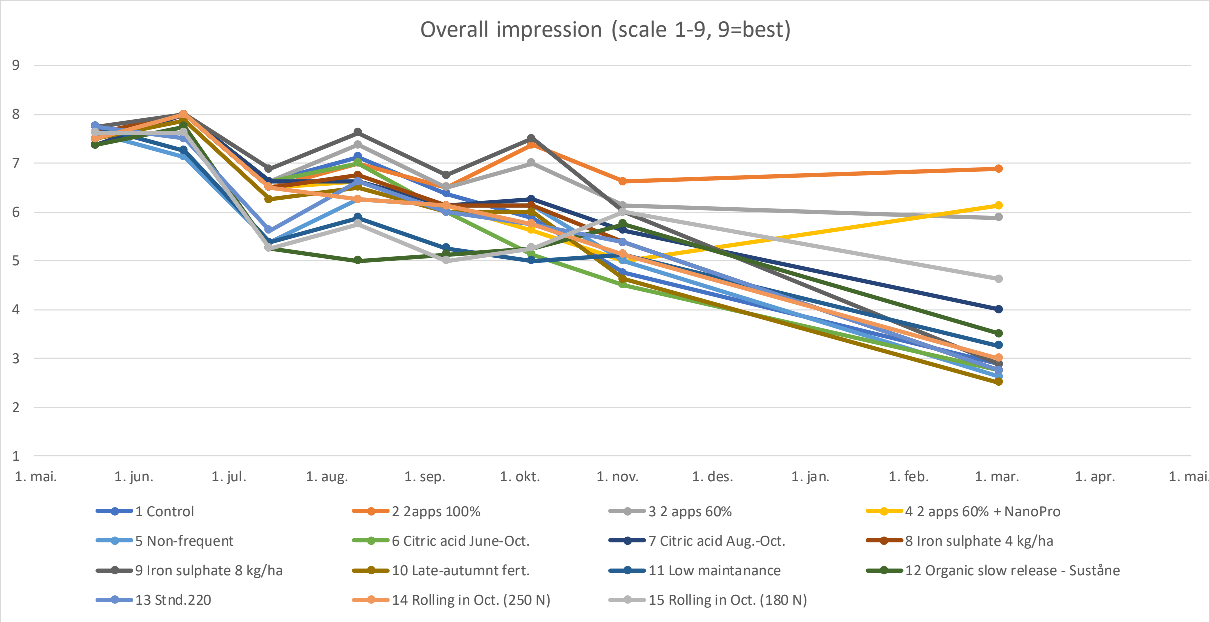


Figure 3: Overall impression on a scale from 1 to 9, where 9 is best.

Overall impression was very high and uniform (on average 7.5) in all treatments at the start of the experiment in May (Figure 3 and Table 6). Anthracnose decreased overall impression in mid-July to September especially in trt. 11, 12 and 15. The highest overall impression in 2020 was 7.2 in trt. 9 (Iron Sulphate, 8 kg/ha) very close to trt. 2 and 3. It could be due to a darker color in this treatment. In March 2021 overall impression in the non-fungicide treatments was decreased, trt. 2, 3 and 4 still obtained the highest overall impression (5.9-6.9), while trt. 9 was decreased to 2.9. Trt. 15 (Rolling in October, low N) was the non-fungicide treatment with the highest overall impression in March.

On average for 2020 and 2021 trt. 2 had the best overall impression, while trt. 9 was the non-fungicide treatment with the highest score in this period.

Table 6: Overall impression (Scale from 1 to 9) from May to November in 2020, in March 2021 and on average from 2020 and 2021.

Treatment		N, kg/ha/yr	2020		2021		2020-21	
1	Control	250	6.6	bcde	2.9	de	6.1	def
2	2apps 100%	250	7.1	ab	6.9	a	7.0	a
3	2 apps 60%	250	7.0	abc	5.9	ab	6.9	ab
4	2 apps 60% + NanoPro	250	6.5	cde	6.1	a	6.4	bcd
5	Non-frequent	250	6.2	def	2.6	e	5.8	ef
6	Citric acid June-Oct.	250	6.4	def	2.8	de	6.0	def
7	Citric acid Aug.-Oct.	250	6.7	bcd	4.0	cd	6.3	cd
8	Iron sulphate 4 kg/ha	250	6.7	bcd	2.8	de	6.2	cde
9	Iron sulphate 8 kg/ha	250	7.2	a	2.9	de	6.7	abc
10	Late-autumnt fert.	250	6.4	def	2.5	e	5.9	def
11	Low maintanance	180	6.0	f	3.3	de	5.6	f
12	Organic slow release	220	5.9	f	3.5	cde	5.6	ef
13	Stnd.220	220	6.4	def	2.8	de	5.9	def
14	Rolling in Oct.	250	6.5	def	3.0	de	6.1	def
15	Rolling in Oct.	180	6.1	ef	4.6	bc	5.9	def
		p-value	0.00010		<.0001		<.0001	

Colour:

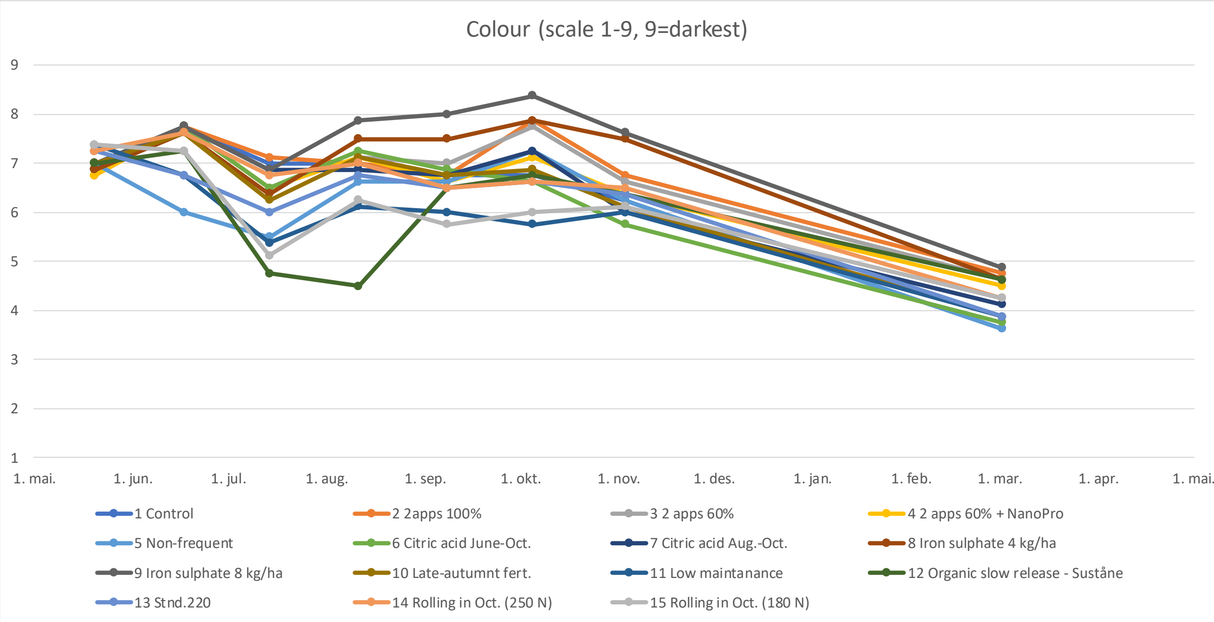


Figure 4: Color on a scale from 1 to 9, where 9 is darkest.

Colour was uniform (average 7.0) in all treatments at the start of the experiment in May (Figure 4 and Table 7). The treatments 8 and 9 receiving iron sulphate, 4 and 8 kg/ha from June to October became darker green from August to November, this effect could also be seen in March 21. Trt. 12 became lighter green from July to August due to anthracnose.

Table 7: Colour (Scale from 1 to 9) from May to November in 2020, in March 2021 and on average from 2020 and 2021.

Treatment		N, kg/ha/yr	2020		2021		2020-21	
1	Control	250	6.5	cde	3.6	d	6.5	h
2	2apps 100%	250	6.8	bc	4.8	ab	6.8	gh
3	2 apps 60%	250	6.8	bcd	4.6	ab	6.8	gh
4	2 apps 60% + NanoPro	250	6.6	bcde	4.5	abc	6.6	fgh
5	Non-frequent	250	6.1	fgh	3.6	d	6.1	efg
6	Citric acid June-Oct.	250	6.5	dfe	3.8	d	6.5	def
7	Citric acid Aug.-Oct.	250	6.6	cde	4.1	bcd	6.6	def
8	Iron sulphate 4 kg/ha	250	7.0	ab	4.6	ab	7.0	cde
9	Iron sulphate 8 kg/ha	250	7.3	a	4.9	a	7.3	cde
10	Late-autumnt fert.	250	6.5	def	3.9	cd	6.5	cde
11	Low maintanance	180	5.9	h	3.9	cd	5.9	bcde
12	Organic slow release	220	6.0	gh	4.6	ab	6.0	bcd
13	Stnd.220	220	6.3	efg	3.9	cd	6.3	bc
14	Rolling in Oct.	250	6.6	cde	4.3	abcd	6.6	ab
15	Rolling in Oct.	180	6.0	gh	4.3	abcd	6.0	a
			0.0001		0.0013		0.0001	

Rolling and N rates affect MP:

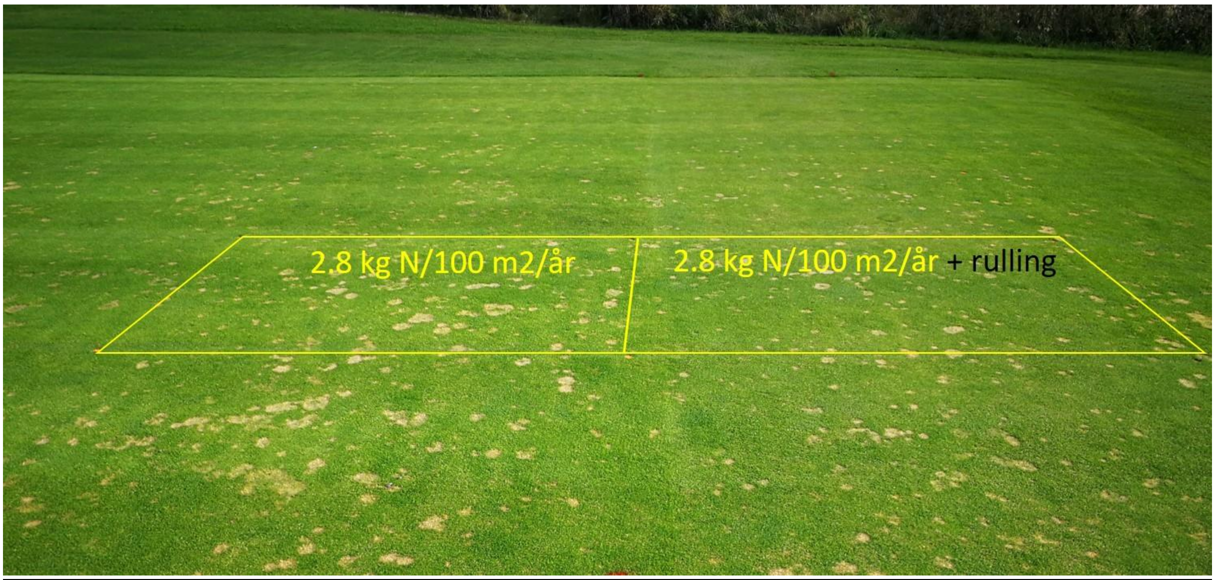


Photo 2: Less MP on 15th of October on plots rolled two times/wk, high N from 28th of September compared to the control.

Photo: Tatsiana Espevig.

Results from the first year showed that in the treatments with reduced N-rate attacks from MP almost halved, while anthracnose increased by 1.5 (Table 8). Rolling was done from 28th of September to 29th of October with a Smithco greens roller twice pr week. Plots rolled had less MP, but the differences disappeared in November.

Table 8: Effect of rolling and N rate on overall impression. Numbers that do not share a letter are significantly different. ** - 0.01, * - 0.05, (*) - 0.1 og NS – not significant.

Nitrogen	Rolling	Overall impression (scale 1-9, 9=best)					Antracnose, %			Mikrodochium patch, %				
kg/100 m2	Only Oktober	11. aug.	8. sep.	5. okt.	3. nov.	2. mar.	11. aug.	8. sep.	5. okt.	11. aug.	8. sep.	5. okt.	3. nov.	2. mar.
250 (control)		6.7 a	6.3 a	5.8	4.9	2.9	3.0	6.5	2.6	0.4	0.0	4.5 a	10.4	41.3
180		5.8 b	5.1 b	5.1	5.6	3.9	8.3	15.1	6.0	0.5	0.0	2.6 b	6.1	25.8
	no	6.5	5.8	5.4	4.9	3.1	4.9	12.5	4.9	0.4	0.0	3.8	10.0	34.1
	Rolling	6.0	5.6	5.5	5.6	3.8	6.4	9.1	3.8	0.4	0.0	3.3	6.5	32.9
	p N	**	**	(*)	NS	(*)	NS	(*)	(*)	NS	NS	*	NS	(*)
ANOVA	p Rolling	(*)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	p N*Rolling	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Anthracnose:

Photo 3: Anthracnose started at Poa Niblick in the beginning of July.

Photo: Tatsiana Espevig, August 2020.

The outbreak of anthracnose was mostly seen in the low input treatments (180-220 kg N/ha) at Niblick green with 14 to 25 % in the middle of July decreasing to 5 to 10 % in August (Figure 5). Especially in treatment 11 and 12 (Low maintenance and slow release) anthracnose increased to around 20 % in September before it disappeared in the autumn. The decision to increase the N-rate in July at Niblick green prevented further development of the disease. Calculations of AUDPC showed that treatment 12 had significantly more anthracnose than the other treatments.

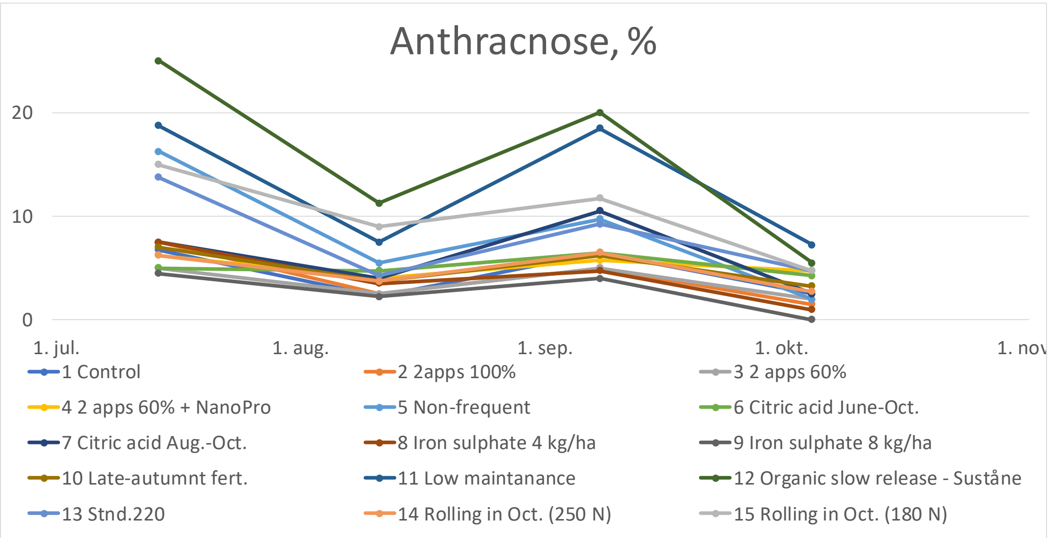


Figure 5: % of anthracnose in the different treatments from mid-July to beginning of October.

Conclusion:

Trt. 15 (Rolling, low N) and trt.7 (Citric acid, Aug.-Oct.) could decrease MP to some extend among the non-fungicide treatments. High N resulted in more MP, but less anthracnose. Low N resulted in less MP, but more anthracnose. The experiments will continue in the same form in 2021.

2 Alternative products, field trial on MP at STRI, Bingley (WP 1)

- Christian Spring, Mark Ferguson and Matthew Clark, STRI (UK)

The objective of the trial was to investigate the effects of alternative products to prevent and control microdochium patch on golf greens.

2.1 Materials and methods

Project period, experimental site and experimental plan:

May 2020 – May 2022. This trial was laid out on a natural soil golf green (native sandy soil) at STRI's research station in Bingley, West Yorkshire (UK). The area had thatchy golf green turf that was prone to microdochium patch disease, which typically occurs in autumn and winter months. The turf had 40% of annual meadow-grass and 60% of browntop bent (*Agrostis capillaris*).

The trial was laid out as a randomised complete block design with treatments replicated 4 times. Plot size was 2 m x 1 m with the full plot treated, but the area assessed was 1.9 m x 0.9 m (leaving a 5 cm border around each edge of the plot that was not be included during assessments to counter edge effects). The treatments were similar to those in microdochium patch trial at Landvik, but N-rates were optimal for Bingley site and corresponded to 122 kg N per ha per year for standard treatments, 149 kg N per ha per year for treatments receiving late autumn nutrition and 88 kg N per ha per year in 'low-maintenance program' (TRT11, 72% of TRT1) (Table 9). The realized N rates are shown in Table 10. After a maintenance application of fertiliser in Spring 2020 to aid with winter recovery, the trial fertilization treatments were started on 5th of June 2020 and lasted until February 2021.

A composite soil sample was taken from the area for pH, P and K analysis. Soil analyses showed a pH of 6.5, organic matter content in the top 20 mm of 6.4% (loss on ignition), phosphate of 23 mg/l and potash of 94 mg/l.

Table 9: Treatments and planned N rate.

Treatment	Nitrogen (kg/ha/yr)	Short description
1	122	Negative control (untreated) - spoon feeding, every wk, opt. annual N
2	122	Standard fungicide approach: 2 apps of fungicides (100%, recom. dosage)
3	122	2 apps of fungicides 40% reduction (60% of recom.dosage)
4	122	2 apps of fungicides 40% reduction (60% of recom.dosage) + NanoPro
5	122	Non-frequent nutrition (every 2 wks), optimal annual N
6	122	Citric acid in June-Oct. (pH as trt 8)
7	122	Citric acid in Aug.-Oct. (pH as trt 8)
8	122	Iron sulfate (FeSO4, 4 kg/ha x 6, Aug.-Oct.)
9	122	Iron sulfate (FeSO4, 8 kg/ha x 6, Aug.-Oct.)
10	149	Standard nutrition (122 kg N) + Late-autumn nutrition (LAN) (27 kg N)
11	88	Low maintenance: nutrition every week but 72% of trt 1
12	149	Organic slow release nutrition, Suståne 5-2-4+Fe

Table 10: Realized fertiliser plan in kg N/100 m2 at microdochium patch trial at STRI.

		trt 1	trt 5	trt 11	trt 10	trt 12
						Suståne
		122	122	88	122+LAN	122+LAN
Week	Month	Kg N pr 100 m2				
15	Apr					
16	Apr					
17	Apr					
18	Apr/May					
19	May	0.017	0.017	0.017	0.017	0.017
20	May					
21	May					
22	May					
23	June	0.050	0.100	0.036	0.050	0.150
24	June	0.050		0.036	0.050	
25	June	0.050	0.100	0.036	0.050	
26	June	0.050		0.036	0.050	0.150
27	June/July	0.050	0.100	0.036	0.050	
28	July	0.050		0.036	0.050	
29	July	0.050	0.100	0.036	0.050	0.150
30	July	0.050		0.036	0.050	
31	July	0.050	0.100	0.036	0.050	
32	Aug	0.050		0.036	0.050	0.150
33	Aug	0.050	0.100	0.036	0.050	
34	Aug	0.050		0.036	0.050	
35	Aug	0.050	0.100	0.036	0.050	0.150
36	Sept	0.050		0.036	0.050	
37	Sept	0.050	0.100	0.036	0.050	
38	Sept	0.050		0.036	0.050	0.150
39	Sept	0.050	0.100	0.036	0.050	
40	Sept/Oct	0.050		0.036	0.050	
41	Oct	0.050	0.100	0.036	0.050	0.150
42	Oct	0.050		0.036	0.050	
43	Oct	0.050	0.100	0.036	0.050	
44	Oct	0.050		0.036	0.050	0.150
45	Nov	0.050	0.100	0.036	0.050	
46	Nov	0.050		0.036	0.050	
47	Nov				0.023	0.069
48	Nov				0.023	
49	Des				0.023	
50	Des				0.023	0.069
51	Des				0.023	
52	Des				0.023	
53	Des/Jan				0.023	0.069
1	Jan				0.023	
2	Jan				0.023	
3	Jan				0.023	0.069
4	Jan				0.023	
5	Feb				0.023	
6	Feb					
SUM N weeks	15-46	1.22	1.22	0.88	1.22	1.22
SUM N weeks	15-22	0.02	0.02	0.02	0.02	0.02
SUM N weeks	23-46	1.20	1.20	0.86	1.20	1.20
LAN SUM N weeks	47-6	0	0	0	0.276	0.276

Maintenance:

The trial was maintained as a golf green but with the overall objective to encourage natural outbreaks of microdochium patch disease during conducive conditions. The trial area had a standard maintenance program:

Mowing: The trial was mown 3 times a week during the growing season and less frequently outside of the growing season. The mower was benchset at 5 mm during the growing season giving an effective height of cut of between 3.75 – 4.25 mm depending on ground conditions. Outside of the growing season the height of cut was lifted to a benchset of 6 mm.

Fertiliser: Fertiliser according to the nutrient application plan. On mowing days, fertiliser applications were done after mowing.

Irrigation: Irrigation was applied as required to maintain plant health. After fertiliser application turf was irrigated to wash excess nutrients off the leaf surface ready for root uptake.

Aeration and other cultural operations (such as verticutting): These maintenance operations were carried out to meet turf requirements, but not in a way that affected treatment effects. No wear was done at the experimental green.

Registration and data collection:

The following visual assessments was done monthly throughout the trial and always prior to fertiliser application:

- Visual turfgrass quality (scale 1-9, 9 is very good, 1 is very poor)
- Turf density (scale 1-9, 9 is very high, 1 is very low)
- Turf colour (scale 1-9)
- Diseases (% of plot area). From these data, the area under disease progress curve (AUDPC) in the various treatments were calculated.
- Photos in the start of the experiment and then at least monthly. Photos of all plots in October, November-December and April-May.

Weather during the growing season and winter 2020-21:

Weather data from STRI (Figure 6) during the trial period was strongly influenced by a dry spring in April-May 2020 and then a relatively wet autumn and winter. Air temperatures remained relatively high until early winter resulting in extended grass growth period.

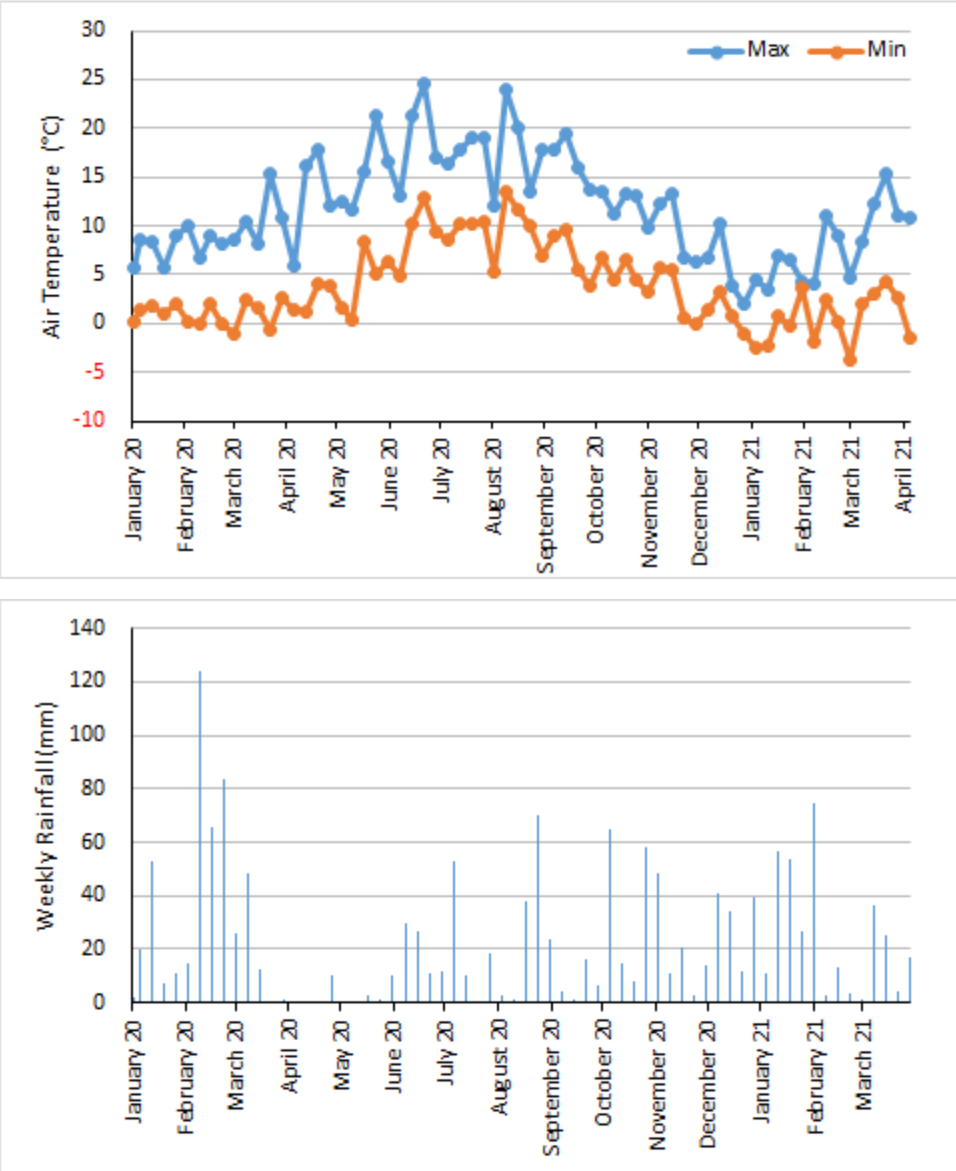


Figure 6: Weekly average minimum and maximum air temperatures and rainfall data from STRI.

All data was collated and analysed statistically using one way ANOVA with differences among treatment means being identified using the Least Significant Difference method.

2.2 Results and discussion

<u>Microdochium patch:</u>

First fungicide application was on 4th September and the second was on 6th November 2020. The fungicide treatments (Trt. 2, trt. 3, and trt. 4) were all effective in controlling MP including a spike in MP in January and February 2021. The fungicide treatments, particularly trt. 4 containing Nano-Pro retained good turf quality throughout. The application of organic fertiliser did not help with disease infection rate through the main disease season but did provide benefit during the late disease spike in January and February 2021.

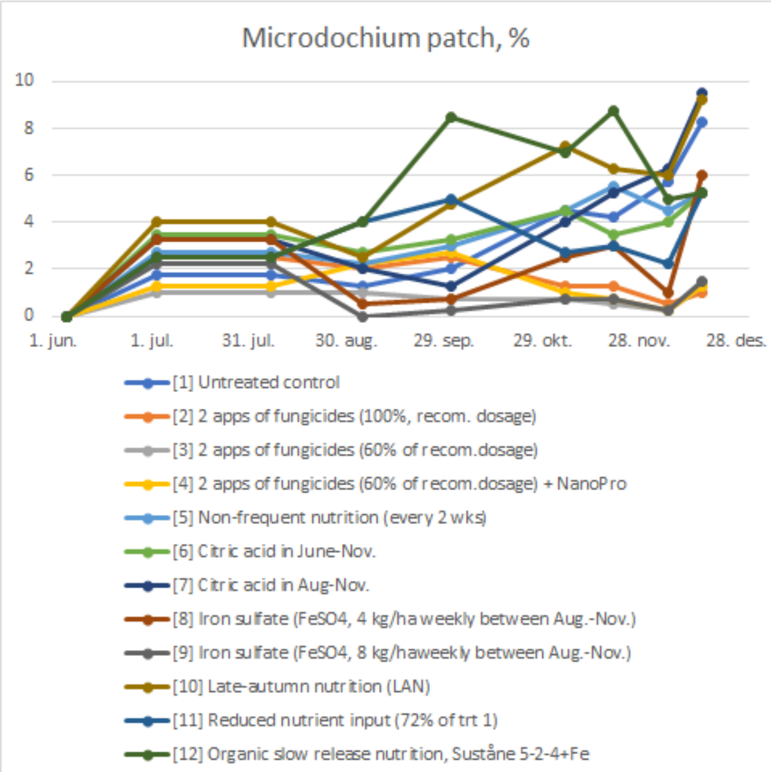


Figure 7: Microdochium patch development in 2020 in the STRI experiment.

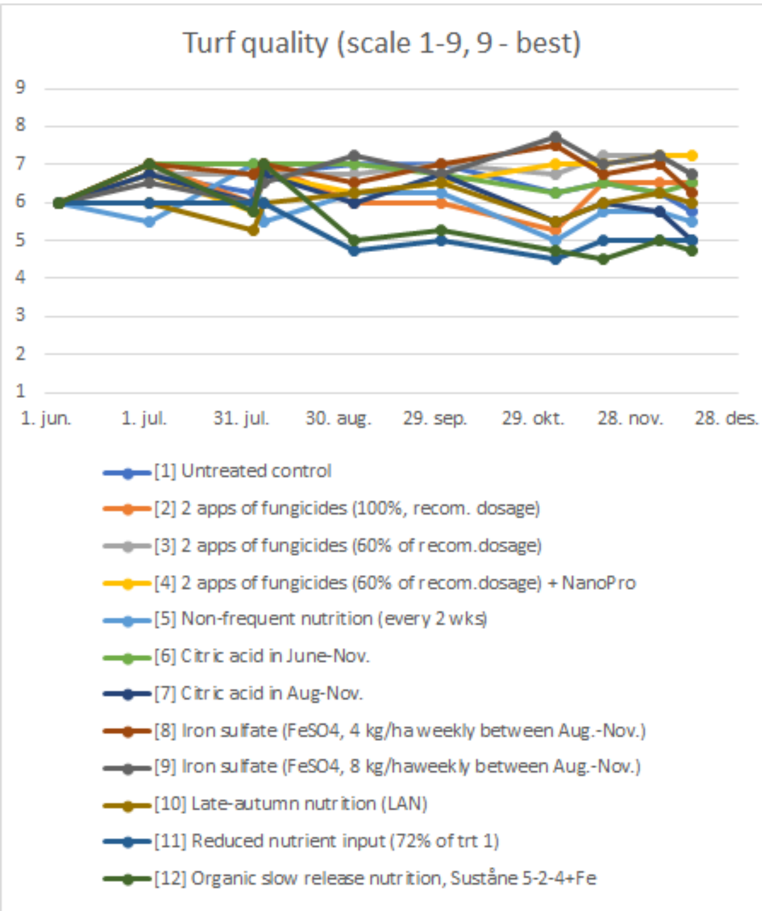


Figure 8: Turf quality in the STRI experiment in 2020.

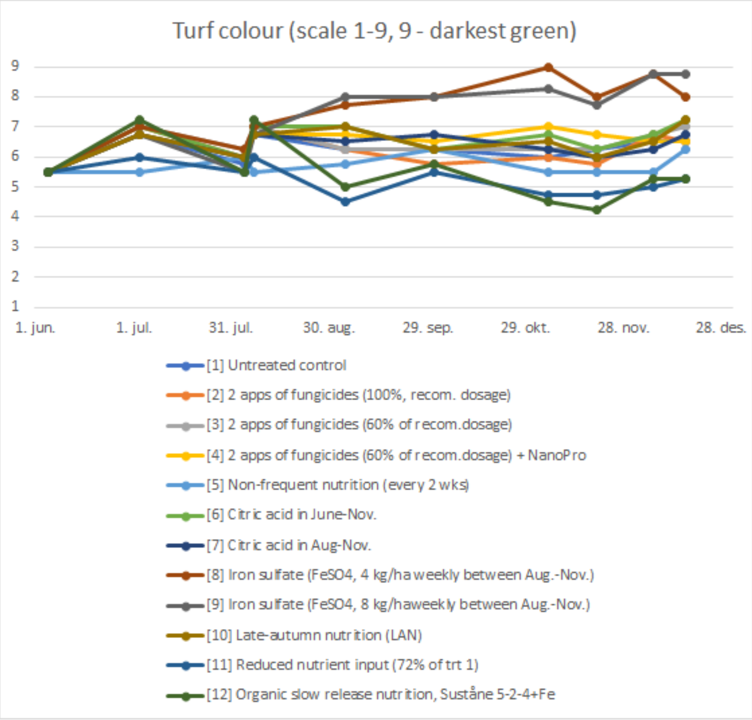


Figure 9: Turf colour in STRI experiment 2020.

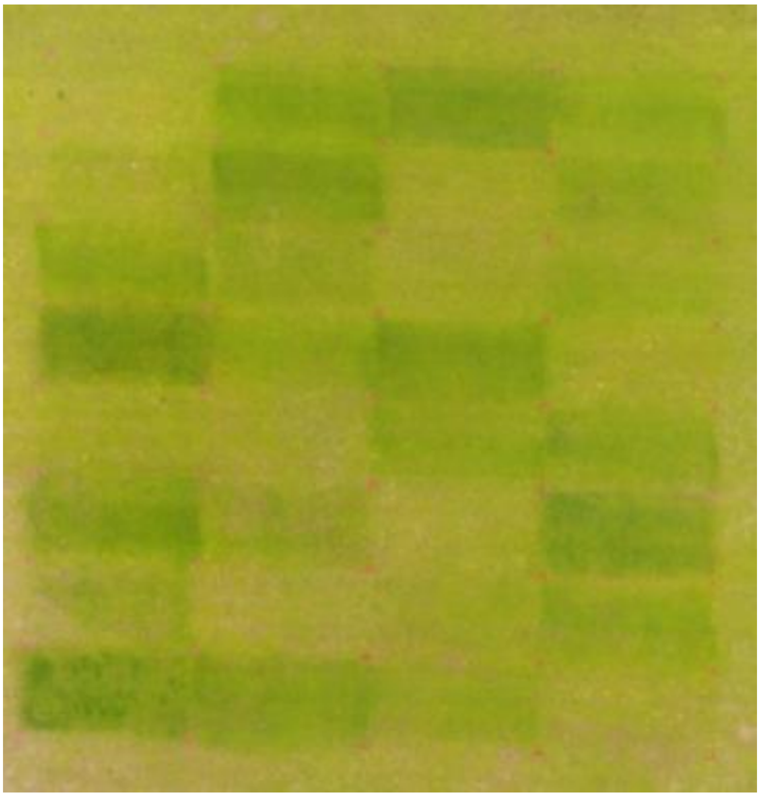


Photo 4: 1st of Sep. Nutrient treatments and plant health effects evident

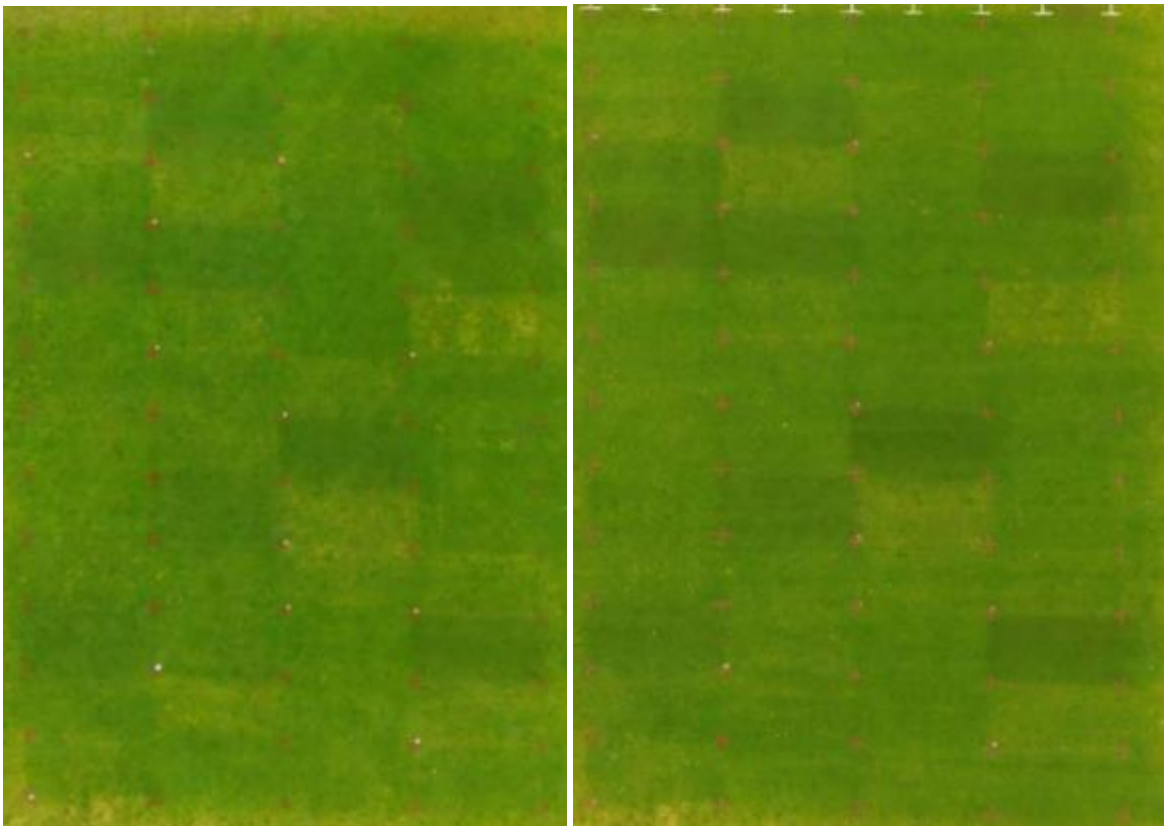


Photo 5: to the left, 23th of Oct and to the right, 11th of Nov. Nutrient and iron effects evident.

The non-fungicide treatments (Trt. 8 and 9 containing iron, Photo 6), also retained good turf quality and darker green colour. These treatments (particularly treatment 9 with 8 kg iron sulphate/ha) were successful at controlling disease (Figure 7). However, this did not last into 2021. Trt. 7 (Citric Acid, Aug.-Oct.) suffered a significant spike in MP in January/February 21. In the 1-5 cm topsoil the pH in the Citric acid/FeSO4-plots was 5.4.

Photo 6: To the left showing the low iron, in the middle showing the high iron and to the right showing the control at 10th November 2020.

<u>Conclusion:</u>

Fungicides were effective at controlling microdochium patch, even when the disease developed late in the season. Treatments containing iron sulphate particularly trt. 9 the high iron, were successful at controlling disease however the effect did not last through the winter. Application of organic fertiliser did not help with the initial infection but did help the turf cope with disease during the late winter spike.

The experiments will continue in the same form in 2021.

3 Effect of rolling on MP, field trial at Copenhagen Golf Club, Denmark (WP 1)

• Karin Juul Hesselsøe, NIBIO (Norway) and Martin Nilsson, Copenhagen Golf Club (Denmark)

The objective of the trial was to investigate the effects of rolling to prevent MP.

3.1 Materials and methods

The experiment was conducted on Copenhagen GC, Denmark on a red fescue/colonial bentgrass putting green from June-December 2020. We determined the effect of rolling frequencies (e.g. no rolling, rolling twice a week and rolling 4 times pr week) and timing (during the whole season from June to October vs. from August to October) on severity of microdochium patch.

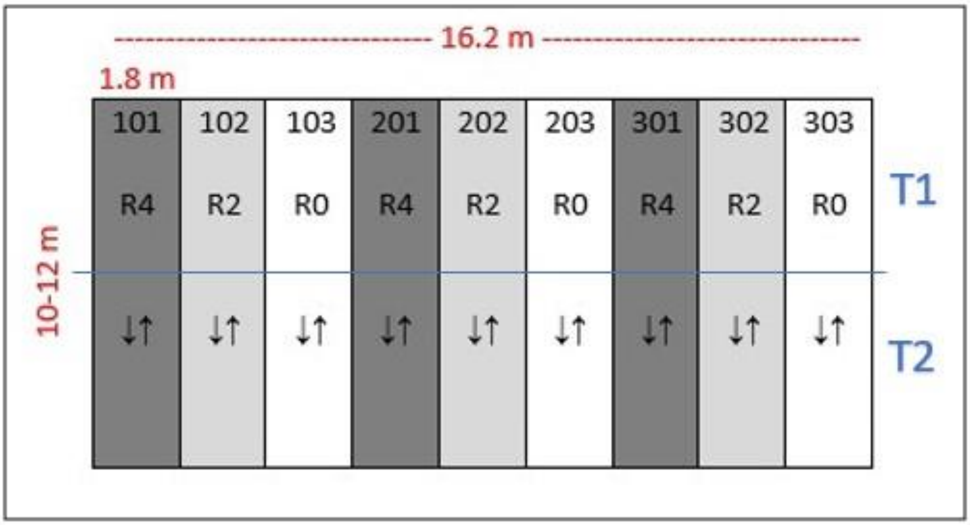


Figure 10: Field map of the experiment. R0=no rolling, R2=rolling twice a week, R4= rolling 4 times pr week. T1=Rolling from June to December, T2= Rolling from August to December. By start of the registrations the field map was changed so that: Plot 102, 202 and 302=R0. 103, 203 and 303=R2.

The experiment was laid out as a complete block design with 3 reps (Figure 10). The area pr. treatment=one plot was approx. 6 m2. Corners of each plot was marked with grass marking tufts and spray in different colours, and they were maintained throughout the season (Photo 7). Visual assessments (turfgrass quality and colour on a scale from 1 to 9) and % of disease were done monthly from June to December. Soil moisture was measured monthly with a TDR in 7.5 cm depth three measurements/plot. All assessments and measurements were done by course manager Martin Nilsson.

Photo 7: The trial at Copenhagen Golf Club, December 2020. Blue: Rolled four times pr week, yellow: No rolling, red: Rolled twice a week.

Photo: Martin Nilsson.

Rolling was done with a Smithco greensroller (Photo 8) 91 cm wide. Two rollings pr plot back and forth. The area of the green was approx. 370 m2. Initially a push up green with a 7 cm of 'Greenmix light' from Solum un top. Soil pH from the start of the experiment was 6.8.

Photo 8: Rolling with Smithco greensroller at Copenhagen GC.

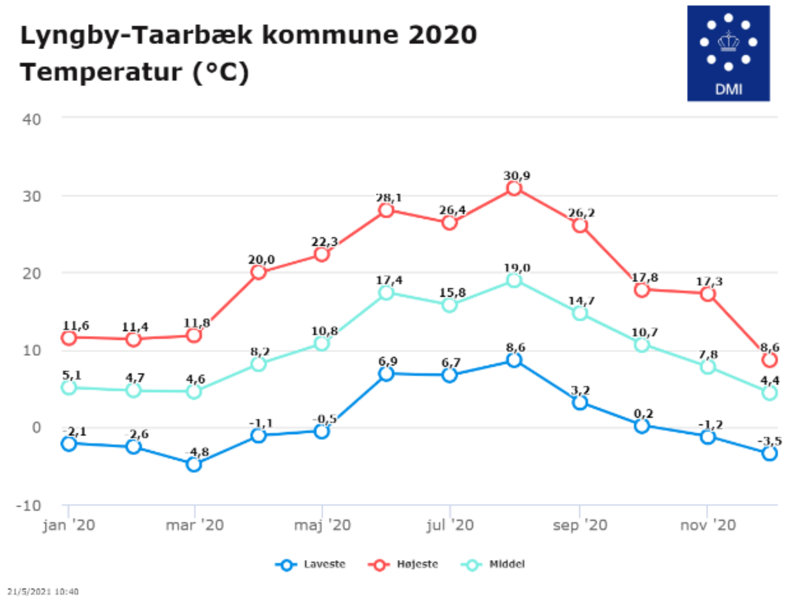
Photo: Karin J. Hesselsøe

Statistical analyses:

All data was collated and analysed statistically using ANOVA mixed effects model.

Maintenance and weather data:

Maintenance of the green followed the same program as for the other greens on the course. No fungicides were applied during the experiment. Air temperature and precipitation on a monthly basis from the nearest weather station (DMI, 2021) is shown in Figure 11. Fertilisation was: N: 50 kg/ha, P: 0 kg/ha, K: 0 kg/ha (3 applications/year), mowing height was 4.2 mm, topdressing 3 times/year, vertidrain once a year and one aeration with solid tines/year. The irrigation programme was deficit irrigation.



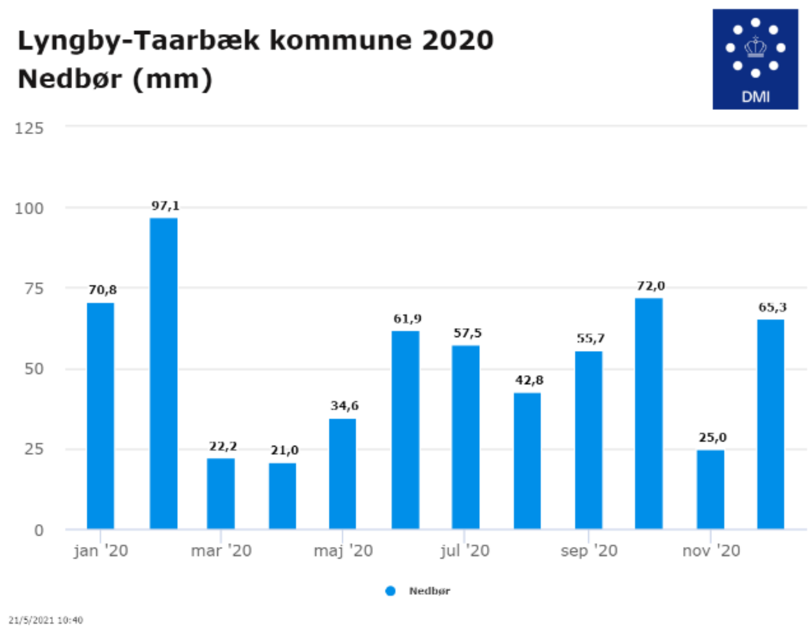


Figure 11: Weather data from 2020 from nearest weather station in Lyngby-Taarbæk.

3.2 Results and discussion

The first year of the trial at Copenhagen Golf Club was completed as planned with rolling and observations from June to December. Though observations of microdochium patch was done the whole season, attacks did not show up until the beginning of December.

Preliminary results from 2020 showed that rolling twice and four times pr week caused significantly lower attacks of microdochium patch in December than no rolling (Table 11).

Observations of overall impression showed that there was no difference between the treatments at the beginning of the trial in June. From August to December rolling twice and four times pr week improved the overall impression significantly compared to no rolling. This was mainly due to less moss and lower attacks from microdochium patch. On Photo 7 from December 2020 plots with no rolling looked darker green than plots with rolling which was due to more moss in these plots.

Rolling four times pr week did not improve the overall impression compared to twice a week. Neither did it affect the attacks from microdochium patch significantly. In December the overall impression on plots rolled four times pr week were lower than the plots rolled twice a week, but the difference was not significant. The course manager noted that plots rolled twice a week compared to 4 times pr week looked slightly less 'worn'.

Timing of rolling (June-December compared to August-December) showed no significant differences (results not shown).

In summary first year's results showed that rolling twice a week improved turfgrass quality through the growing season, and that reductions of microdochium patch was achived by rolling from August.

The trial continues in 2021.

Table 11: Overall impression and % of microdochium patch on plots rolled twice and four times pr week compared to no rolling.

	Overall impression Scale 1-9				% microdochium patch
	June	August	October	December	December
	Average of 6 reps.				
Rolling 2 times/week	5.0 a	7.0 a	7.0 a	6.5 a	2.0 a
Rolling 4 times/week	5.0 a	7.0 a	7.0 a	6.0 a	2.3 a
No rolling	5.0 a	5.0 b	5.0 b	4.0 b	5.0 b
p rolling (ANOVA mixed effects model)	0.000	0.004	0.004	0.004	0.003

4 Effect of UV-C-radiation on MP and DS at Osnabrück Golf Club

- Jan Rosenbusch, Lukas Borrink, Daniel R. Hunt and Wolfgang Pramässing, University of Applied Sciences (Germany)

The objective of this project was to test the effectiveness of UV-C radiation with SGL UVC 180 on a putting green to control dollar spot and microdochium patch.

4.1 Materials and methods

Project period, experimental site and plan:

The aim of the study was to compare 3 different dosages of UV-C radiation by using the UV-C unit SGL UVC 180 (Photo 10) applying 2 rsp. 3 different operating speeds in % of maximum speed rsp. 1 double application instead of 3rd operating speed. UV-C was applied from May (2020) and will continue to May (2022), between November and April depending on weather conditions in relation to occurrence of microdochium patch. The different dosages were specified by measuring UV-C radiation with UVpro Radiometer (Photo 11) at different operating speeds of SGL UVC 180 and/or multiple application. During application of UV-C radiation in trials, the dosage was set and controlled by the measuring device UVpro Radiometer (Photo 12).

Photo 9: Preparing experimental green at Osnabrück GC for UV-C trials.

Photo: W. Prämaßing.

The tests were realized on the grounds of the Golf Course Osnabrück Bissendorf – Jeggen, Am Golfplatz 3 in 49143 Bissendorf, Germany on a putting green constructed according to FLL with grass composition of creeping bentgrass (*Agrostis stolonifera*) and annual meadow grass.

The maintenance of the test area was carried out by the employees of the Osnabrück Golf Club. The mowing height of the test area was 4 mm. The experimental plan is showed in Table 13. Normalized Difference Vegetation Index (NDVI) was measured with a handheld Greenseeker (Trimble Inc.). The NDVI quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). A vital and green turf canopy does reflect only a very low amount of red light.

Weather during the growing season and winter 2020-21:

Table 12: Climate data during the trial period (Source: WetterKontor GmbH 2020; Meteorological station Osnabrueck-Belm).

Year	Month	average temperature in °C	amount of precipitation in l/m²
2020	May	12,15	16,3
2020	June	16,81	80,6
2020	July	16,78	60,9
2020	August	20,44	48,3
2020	September	14,80	42,5
2020	October	11,01	83,8
2020	November	7,86	32,7

Statistical analyses:

Statistical analyses were done using Tukey-HSD, Dunnett-T3 und Games-Howell, $p \leq 0{,}05$.

Table 13: Experimental plan of the UV-C radiation trial.

Trial	**SGL UV – C 180**
Design	randomized complete block design
Replications on Putting green	3
Plotsize	6 m² (2 m x 3 m)
Treatments	1. Untreated control 2. UV-C dosage 1 (50% of speed 7-8 mJ/cm²) – 3 x per week 3. UV-C dosage 2 (10% of speed 35-40 mJ/cm²) – 3 x per week 4. UV-C dosage 3 (10% of speed x 2 times, 70-80 mJ/cm²) – 3 x per week
Data collection	Monthly from May to May always prior to fertilization
	Visual turfgrass quality (Scale 1 – 9; 9 is very good, 1 is very poor)
	Density (Scale 1 – 9; 9 is very high, 1 is very low)
	Colour intensity (Scale 1 – 9) and/or NDVI measurement
	Diseases (% of plot area)
	Dollar spot during summer
	Microdochium patch monthly from September to May
	Anthracnose in the spring

Photo 10: SGL UVC 180 radiation unit operating on experimental green.

Photo: W. Prämaßing.

Photo 11: SGL UVC 180 unit operating on trial plot, dosage controlled by device.

Photo: W. Prämaßing.

Photo 12: Device to control dosage.

4.2 Results and discussion

Turf quality:

Figure 12 shows the turf quality of the UV-C trial from May 2020 to November 2020. The highest rating marks of all 4 variants was achieved from June to August. From August the turf quality decreased in all four variants and reached the lowest values in November. Overall, UV-C dosages 2 and 3 achieved on trend a better turf quality than the untreated control over the complete test period.

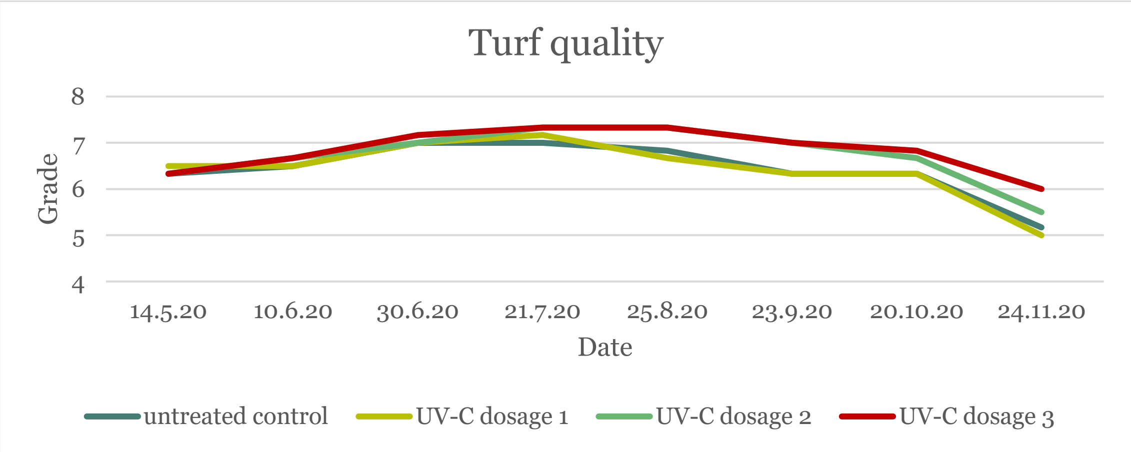


Figure 12: Turf quality of the UV-C trial (1)

Figure 13 shows the arithmetic mean and the mean variation of each treatment of the UV-C trial. The mean value of the turf quality of the variants UV-C dosage 2 and UV-C dosage 3 is higher on trend than in the two other treatments untreated control and UV-C dosage 1. All in all the variants do not differ significantly in turf quality.

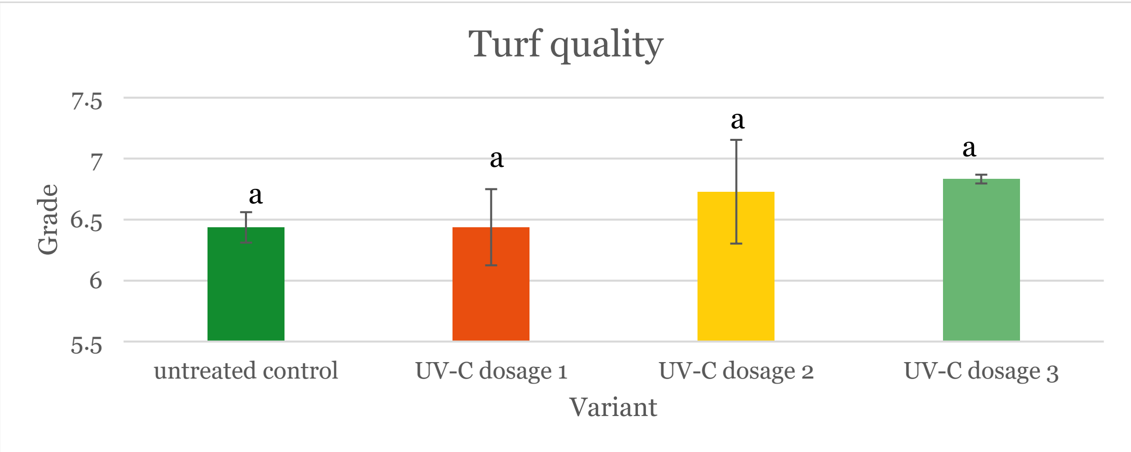


Figure 13: Turf quality of the UV-C trial (2): Means followed by the same letter within a column were not significantly different ($p \leq 0{,}05$).

Tiller density:

Figure 14 shows the tiller density of the UV-C trial from May 2020 to November 2020. As can be seen from the figure, the tiller density increased for all variants until June 30th. Until October 20th, the tiller density remained almost constant with low fluctuations in all treatments. On November 24th, the UV-C dosage 1 had the lowest tiller density rating (5.17) and the UV-C dosage 3 the highest (6.33).

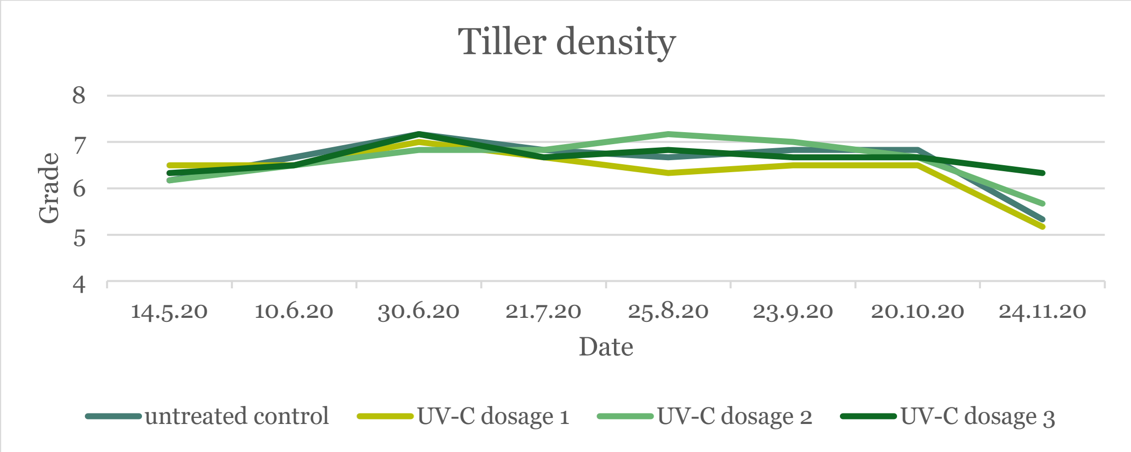


Figure 14: Tiller density of the UV-C trial (1).

Figure 15 show the arithmetic mean and the mean variation of each treatment of the UV-C trial. The mean value of the tiller density of the variant untreated control was 6.60, of the UV-C dosage 1 6.40, of the UV-C dosage 2 6.61 and of the UV-C dosage 3 6.65. Thus, the variants did not differ significantly from each other.

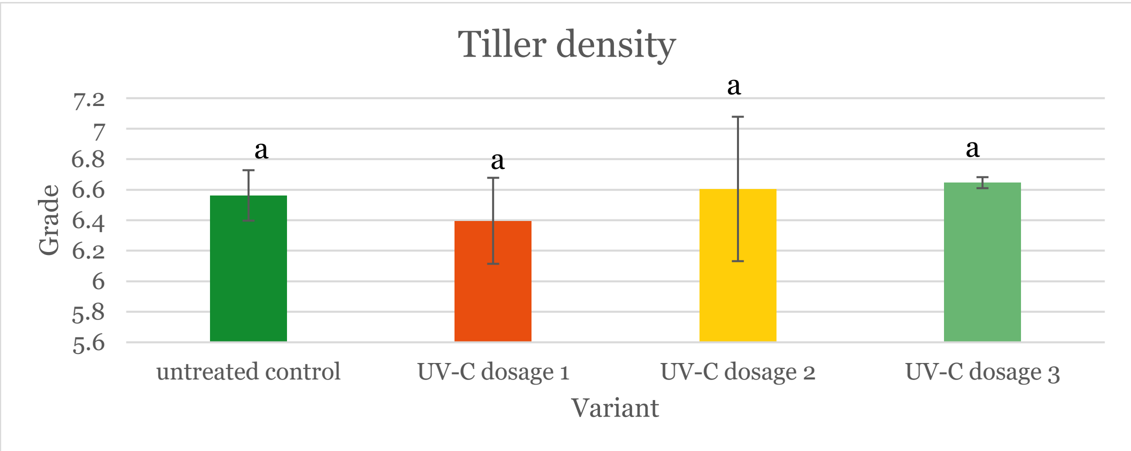


Figure 15: Tiller density of the UV-C trial (2). Means followed by the same letter within a column were not significantly different ($p \leq 0,05$).

<u>Colour:</u>

Figure 16 show the colour of the putting green from May to November 2020. The highest NDVI values (0.78) were achieved by the variant untreated control on June 30th and by the variants UV-C dosage 1 and UV-C dosage 2 on September 23rd. As can be seen the colour was subject to fluctuations. The lowest NDVI (0.68) was generated on November 24th by the variant UV-C dosage 3.

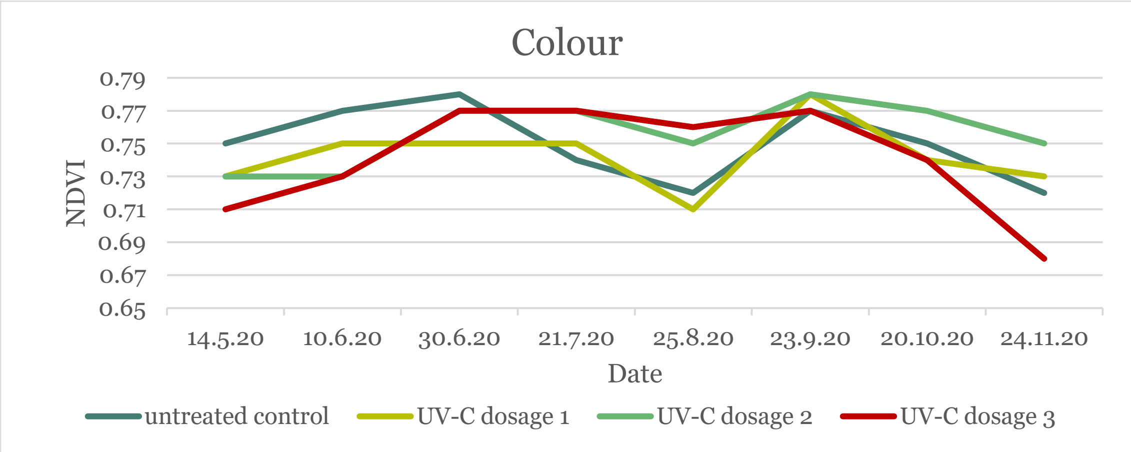


Figure 16: Normalized Difference Vegetation Index (NDVI) of the UV-C trial (1).

Figure 17 show the range of the data from the turf colour of all four variants. The highest average NDVI had the UV-C dosage 2 (0.756) and the lowest the UV-C dosage 3 (0.741). Data do not differ significantly from each other.

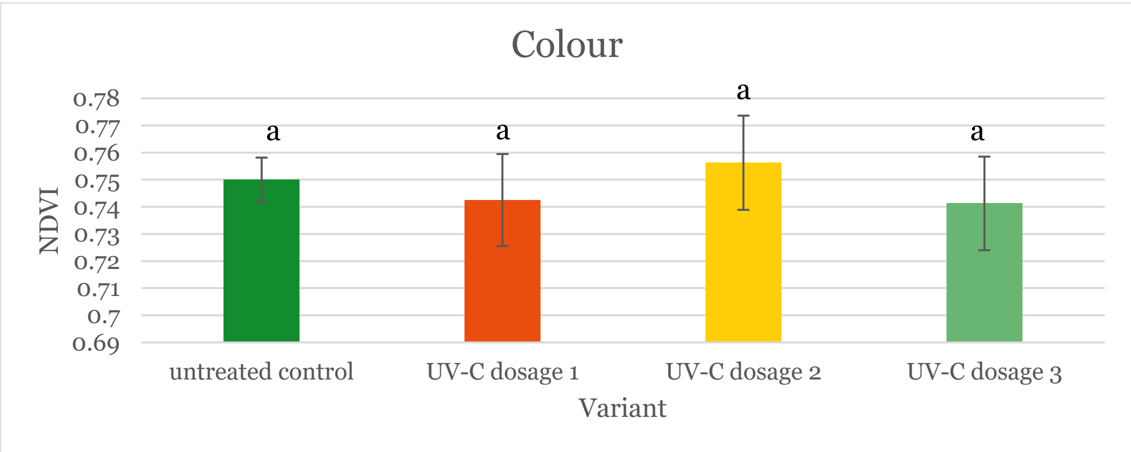


Figure 17: NDVI of the UV-C trial (2). Means followed by the same letter within a column were not significantly different ($p \leq 0,05$).

<u>Diseases (% of plot area):</u>

Figure 18 show the development of the average disease incidence from May to November of the UV-C trial. The highest percentage disease infection (4.5 %) was with the variant UV-C dosage 1 on October 20th, followed by the untreated control (4.3 %). At this point, the other two treatments UV-C dosage 2 and UV-C dosage 3 had an average disease coverage of 2.8 and 2.3 %.

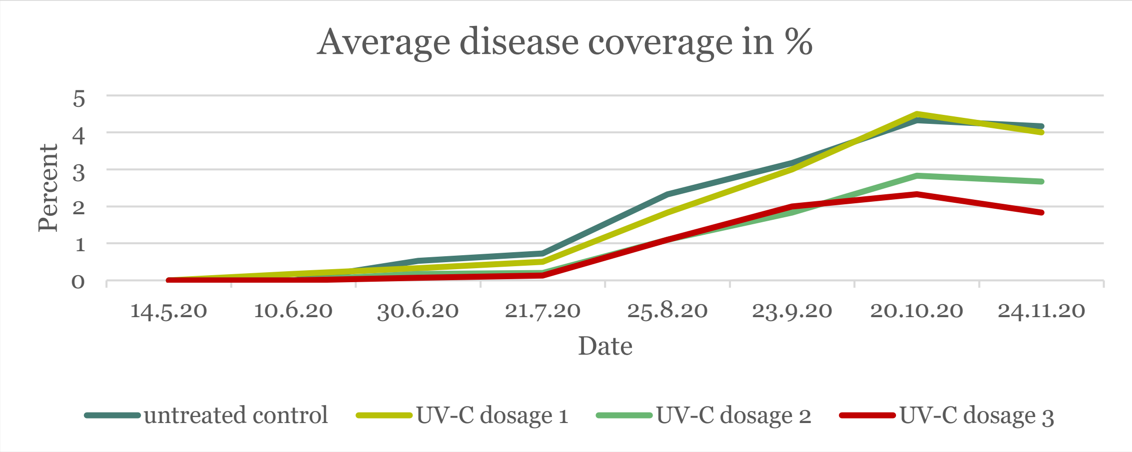


Figure 18: Average disease coverage in % of the UV-C trial (1).

Figure 19 show the average disease coverage in percent of the four treatments. The untreated control had the highest percentage disease coverage (1.91 %) and the treatment UV-C dosage 3 had the lowest incidence of disease (0.93 %). Nevertheless, the variability was very strong in all variants, but there were no significant differences in the treatments.

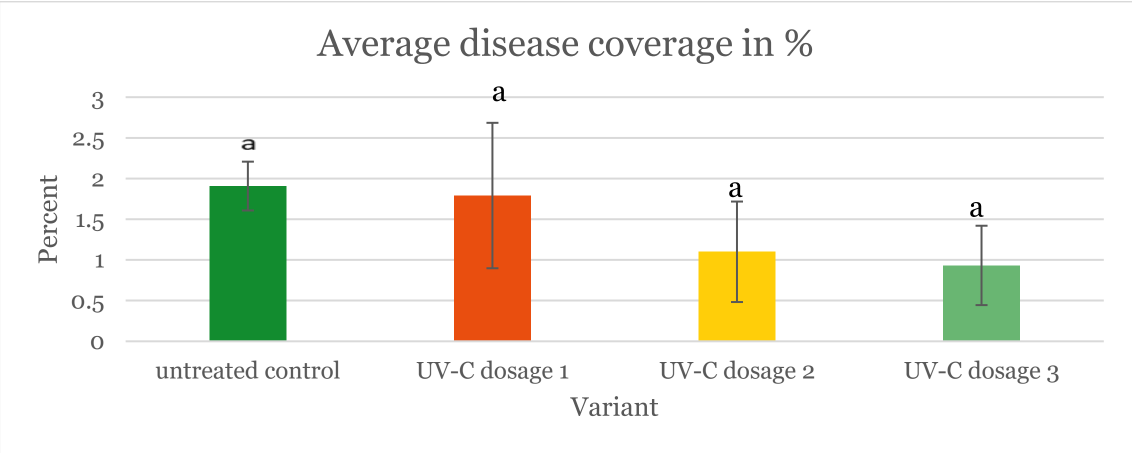


Figure 19: Average disease coverage in % of the UV-C trial (2). Means followed by the same letter within a column were not significantly different ($p \leq 0{,}05$).

<u>Conclusion:</u>

The UV-C radiation trial showed that there is a tendency to reduce dollar spot development on greens with a higher radiation dosage around 80 mJ/cm². So, the UV-C radiation could provide an alternative physical method to control but not to combat completely dollar spot disease.

5 Effect of organic slow-release nutrition Suståne on MP and DS, Osnabrück Golf Club

- Jan Rosenbusch, Lukas Borrink, Daniel R. Hunt and Wolfgang Pramässing, University of Applied Sciences (Germany)

The objective of this project was to test the use of organic slow-release nutrition as alternative product application with 'Sustane 5-2-4 +Fe Natural Fertilizer' on a putting green to control dollar spot and microdochium patch.

5.1 Materials and methods

<u>Project period, experimental site and plan:</u>

The trial was conducted with 2 different dosages of 'Sustane 5-2-4+Fe' on the same green as in chapter 4 in a separate trial layout (randomized complete block design). The used dosage of 'Sustane' was in agreement with the course managers fertiliser programme.

The trial was realized on the grounds of the Golf Course Osnabrück Bissendorf – Jeggen, Am Golfplatz 3 in 49143 Bissendorf, Germany. The maintenance of the test area was carried out by the employees of the Osnabrück Golf Club. The cutting height of the test area was 4 mm.

<u>Statistical analyses:</u>

Statistical analyses were done using Tukey-HSD, Dunnett-T3 und Games-Howell, $p \leq 0,05$. Table 14 show the experimental plan of the 'Sustane' trial.

Table 14: Experimental plan of the 'Sustane 5 - 2 - 4 + Fe' trial.

Trial	**Sustane 5 - 2 - 4 + Fe**
Design	randomized complete block design
Replications on Putting green	4
Plotsize	4 m^2 (2 m x 2 m)
Treatments	1. Control – greenkeeper fertiliser programme approx. 110 kg N/ha 2. Sustane 5-2-4, every 2 weeks, 130 kg N/ha/yr 3. Sustane 5-2-4, every 2 weeks, 70 kg N/ha/yr
Data collection	Monthly from May to November and in the spring for MP always prior to fertilisation
	Visual turfgrass quality (Scale 1 – 9; 9 is very good, 1 is very poor)
	Density (Scale 1 – 9; 9 is very high, 1 is very low)
	Colour intensity (Scale 1 – 9) and/ or NDVI measurement
	Diseases (% of plot area)
	Dollar spot during summer
	Microdochium patch monthly from September to May
	Anthracnose in the spring

Photo 13: Preparing experimental area for 'Sustane' trial.

Photo: W. Prämassing

5.2 Results and discussion

Turf quality:

Figure 20 show the turf quality of the 'Sustane' trial from 14th May to 24th November 2020. The turf quality of variant 'Sustane 5- 2- 4 + Fe'; 130 kg N/ha/yr was the best over the entire test period, followed by variant 'Sustane 5- 2- 4 + Fe'; 70 kg N/ha/yr. The best rankings were achieved from 30th June to 21st July and the lowest (5.13) in November.

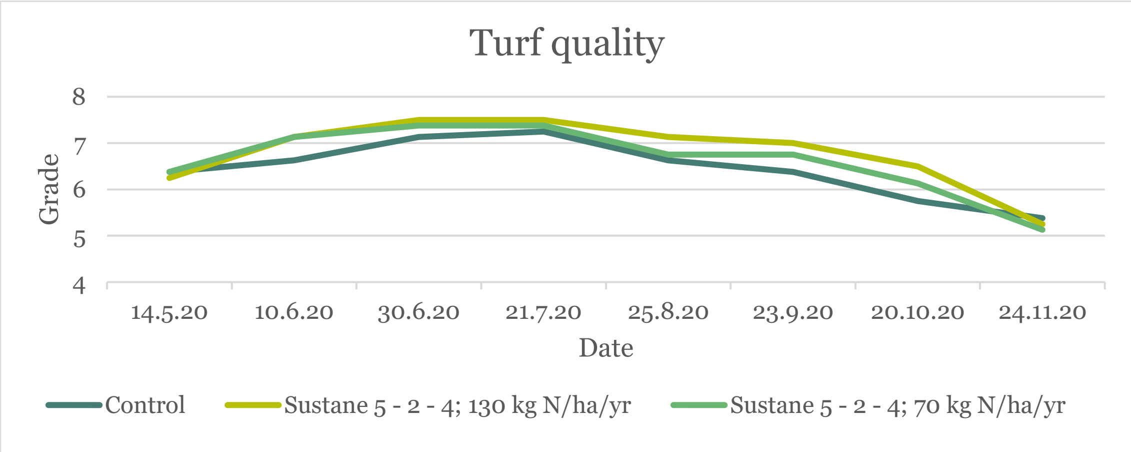


Figure 20: Turf quality of the Sustane (5- 2- 4 + Fe) trial (1)

Figure 21 show the mean variety of the turf quality of the 'Sustane trial'. The highest ranking (6.78) was achieved by the 'Sustane 5- 2- 4 + Fe'; 130 kg N/ha/yr treatment. And the lowest ranking was achieved by the control treatment (6.44). Overall, the values did not differ significantly from one another.

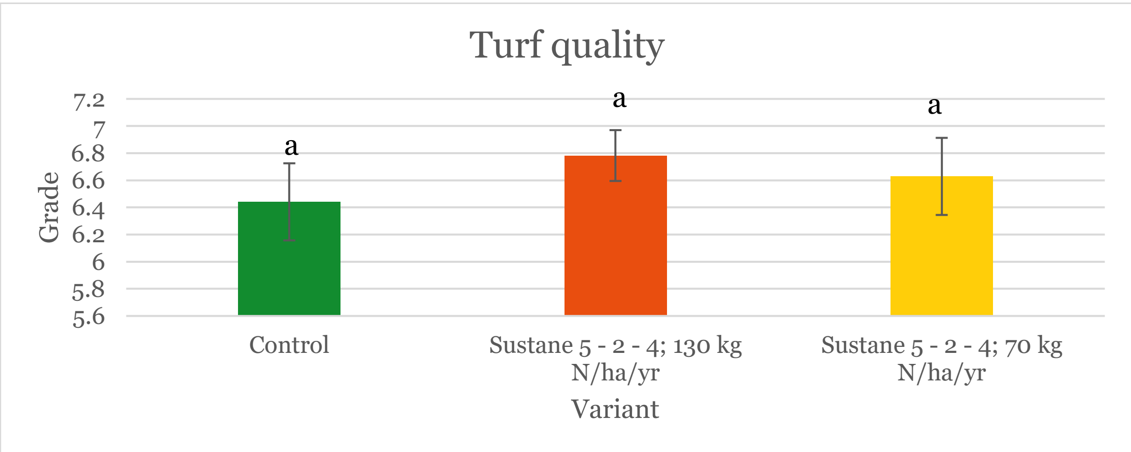


Figure 21: Turf quality of the 'Sustane 5- 2- 4 + Fe' trial (2); Means followed by the same letter within a column were not significantly different ($p \leq 0{,}05$).

Tiller density:

Figure 22 show the tiller density of the three treatments of the 'Sustane 5- 2- 4 + Fe' trial. As can be seen from the figure, the tiller density increased for all variants until July 27th. On November 24th, the 'Sustane 5- 2- 4 + Fe; 70 kg N/ha/yr' had the lowest tiller density rating (5.38) and the 'Sustane 5- 2- 4 + Fe; 130 kg N/ha/yr' the highest. The maximum tiller density rating (6.63) was reached in July from both 'Sustane' variants.

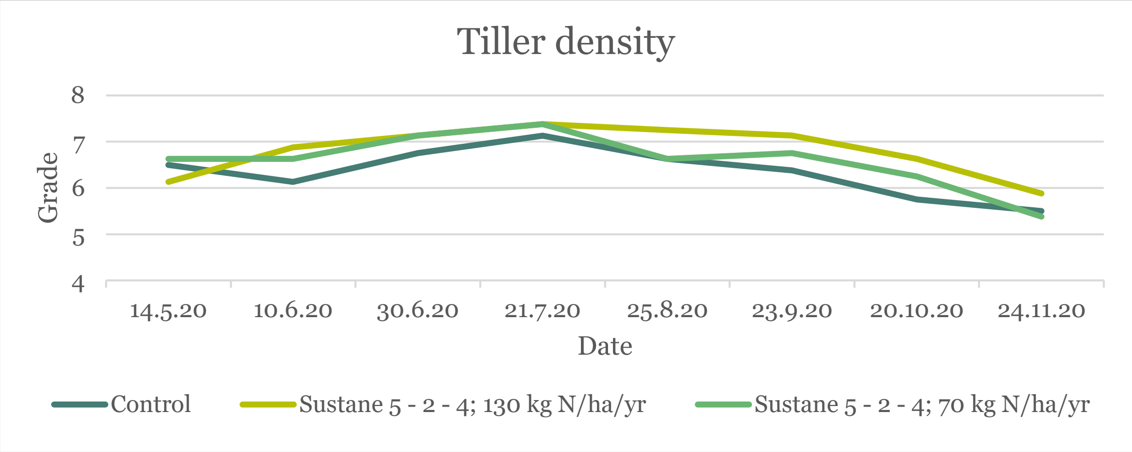


Figure 22: Tiller density of the 'Sustane 5- 2- 4 + Fe' trial (1).

Figure 23 show the arithmetic mean of the tiller density of the 'Sustane' trial. The highest rating had the 'Sustane 5- 2- 4 + Fe; 130 kg N/ha/yr' (6.80) and the lowest the control (6.35). However, it turned out that the control and 'Sustane 5- 2- 4 + Fe; 130 kg N/ha/yr' differed significantly from one another.

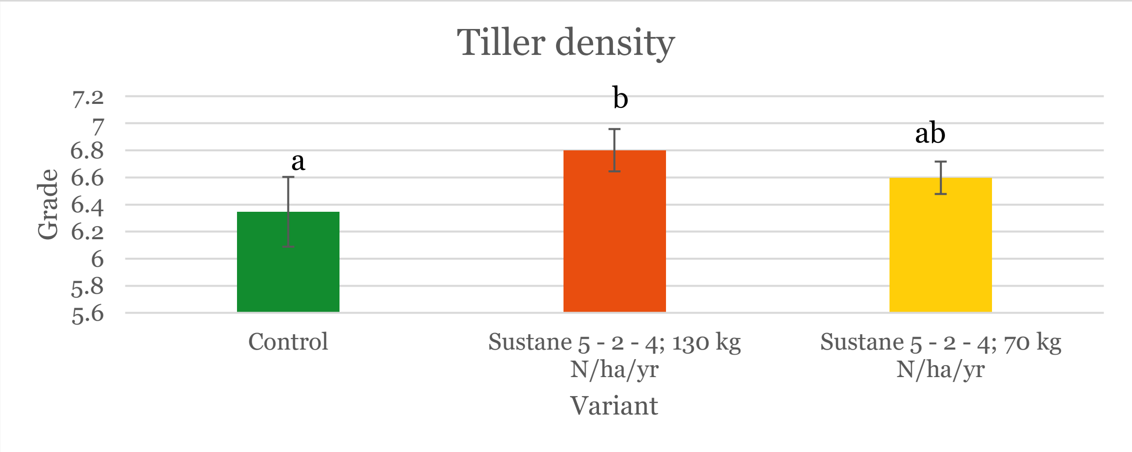


Figure 23: Tiller density of the 'Sustane 5- 2- 4 + Fe trial (2). Means followed by the same letter within a column were not significantly different ($p \leq 0{,}05$).

<u>Colour:</u>

Figure 24 show the NDVI development of all three variants from May to November 2020. The highest NDVI values (0.82) were achieved by the variant 'Sustane 5- 2- 4 + Fe; 130 kg N/ha/yr'. The minimum values (0.71) were reached by the control on 25th August.

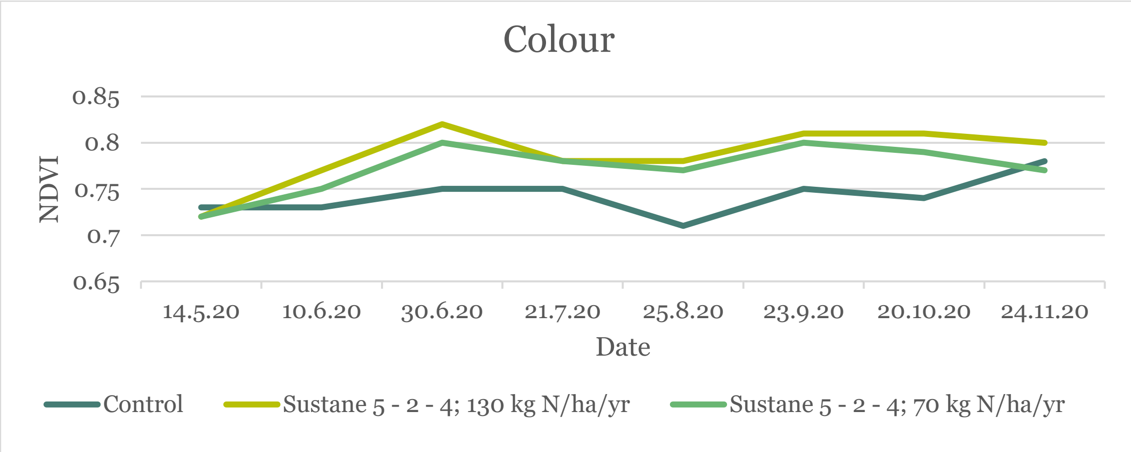


Figure 24: NDVI of the 'Sustane 5- 2- 4 + Fe' trial (1).

Figure 25 show the average NDVI of the 'Sustane trial' variants. The mean NDVI of the control variant was 0.74 of the variant 'Sustane 5- 2- 4 + Fe; 130 kg N/ha/yr' 0.79 and of the 'Sustane 5- 2- 4 + Fe; 70 kg N/ha/yr' variant 0.77. The NDVI differed significantly in all variants.

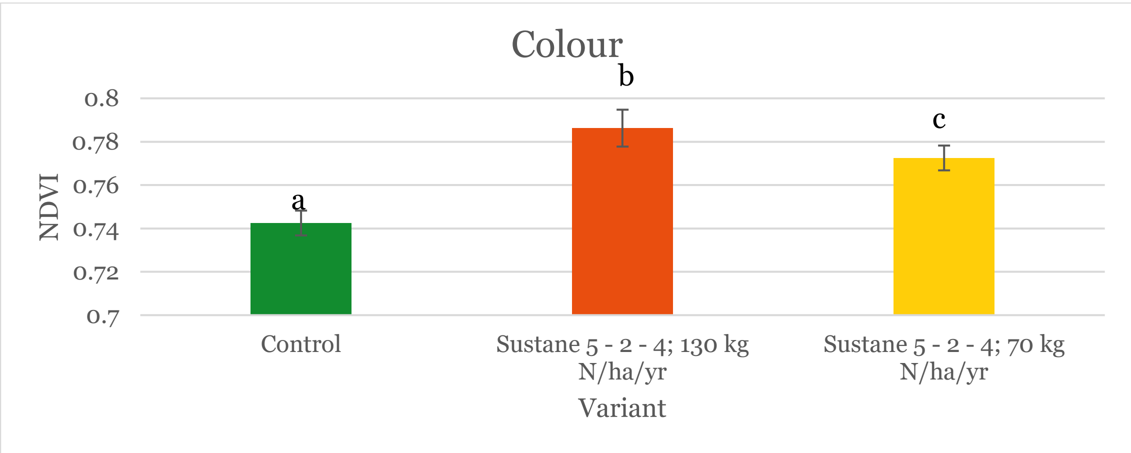


Figure 25: NDVI of the 'Sustane 5- 2- 4 + Fe' trial (2). Means followed by the same letter within a column were not significantly different ($p \leq 0,05$).

Photo 14: Sustane variant were darker in colour. Photo: W. Prämaßing, 20th Oct. 2020.

Diseases (% of plot area):

Figure 26 show the dollar spot development of the different 'Sustane' trial plots from 14th May until 24th November. As can be seen from the figure, the area covered by dollar spot increased for all plots until day 159 (20.10.2020) after start. The maximum dollar spot coverage was in plot 202-3 at day 194 after start.

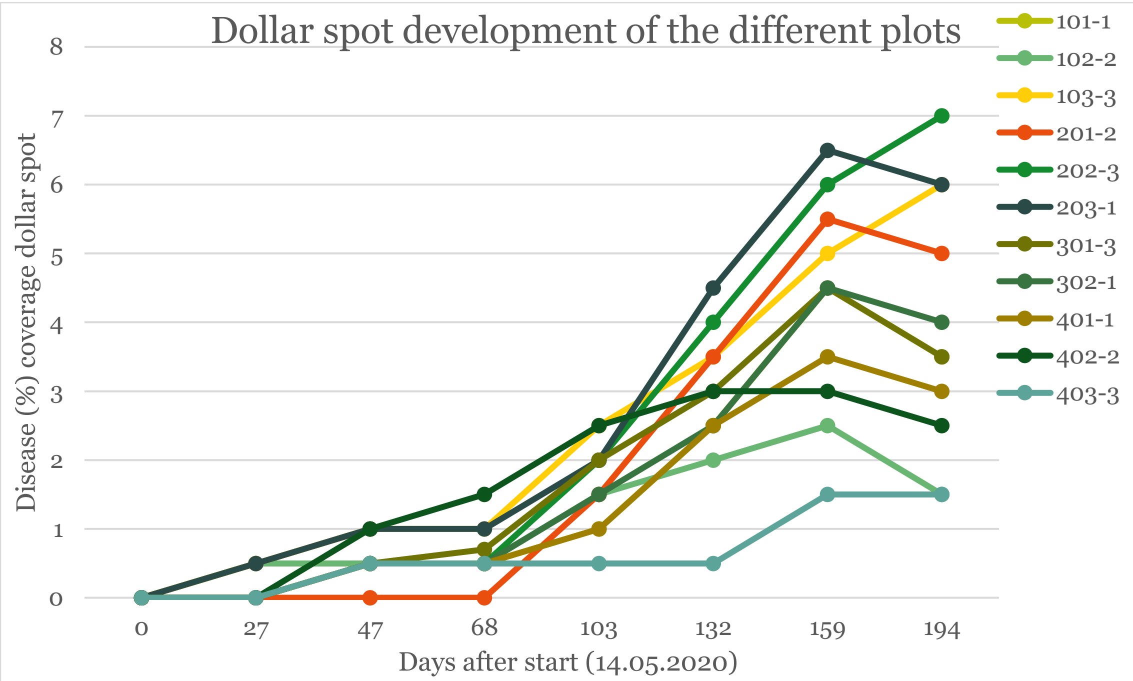


Figure 26: Dollar spot development of the different 'Sustane 5- 2- 4 + Fe' trial plots.

Figure 27 show the average dollar spot coverage in percent of the 'Sustane' trial over the time. As can be seen from the figure the maximum dollar spot coverage (4.75 %) was in the control plots at 20th of October. The other variants had on this date dollar spot coverages from 4.25 to 3.13 %.

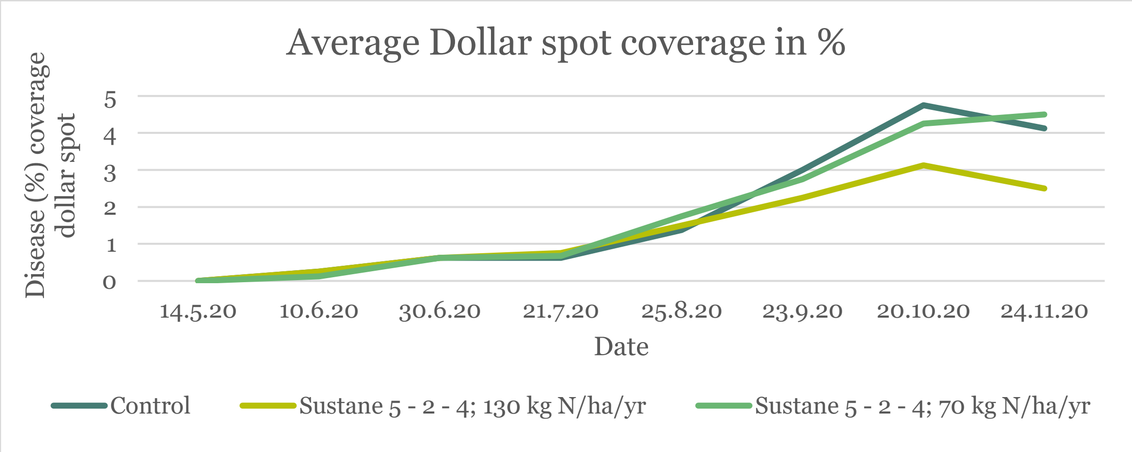


Figure 27: Average dollar spot coverage of the 'Sustane 5- 2- 4 + Fe' trial (1)

Figure 28 show the average dollar spot coverage in % of the 'Sustane' trial variants. The control showed an average dollar spot coverage of 1.84 %, the 'Sustane 5- 2- 4 + Fe; 130 kg N/ha/yr' 1.38 % and the 'Sustane 5- 2- 4 + Fe; 70 kg N/ha/yr' 1.83 %. The three variants did not differ in terms of their dollar spot coverage.

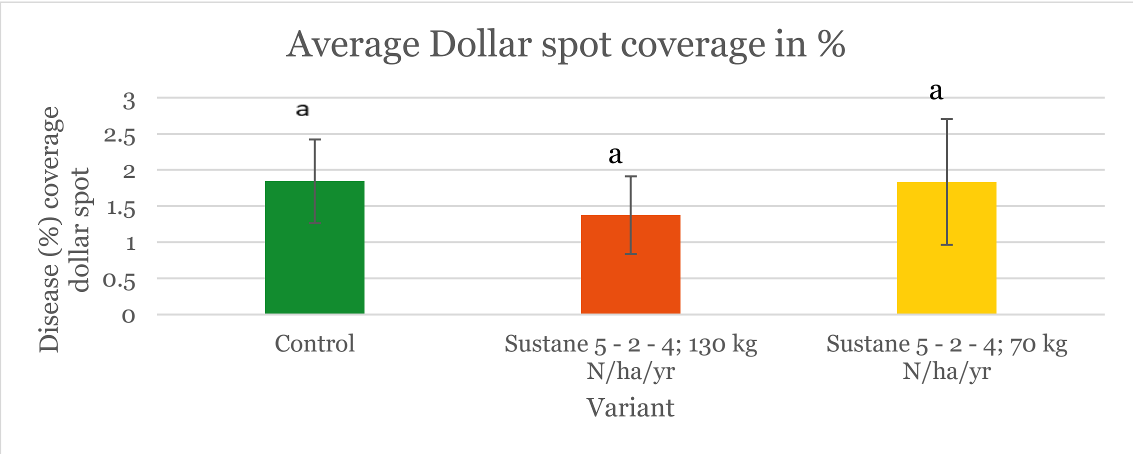


Figure 28: Average dollar spot coverage of the 'Sustane 5- 2- 4 + Fe' trial (2). Means followed by the same letter within a column were not significantly different ($p \leq 0,05$).

<u>Conclusion:</u>

The 'Sustane' trial showed that there is a tendency of reduced dollar spot development with an amount of 130 Kg N/ha compared to the lower amount of Sustane Natural Fertilizer 5-2-4 + Fe.

6 Syngenta field trial on MP at NIBIO and STRI, (WP 1)

- Christian Spring, STRI (UK)
- Trond Pettersen and Tatsiana Espevig, NIBIO (Norway)

The objective of this project was to evaluate different turf management programs including different numbers of fungicide applications and biostimulants to reduce MP and to improve overall plant health.

6.1 Materials and methods

<u>Project period, experimental site and plan:</u>

May 2020 – May 2022 at NIBIO Landvik, Norway and at STRI, Bingley, UK.

Landvik: USGA green with annual meadow-grass as predominant species (app. 95%). Rootzone 12:88 peat:sand by volume. Bingley: Sandy loam rootzone with bent/poa golf green turf. Randomized complete block, 4 reps (blocks).

Total plot size (treatment) = 2.25 m^2 (1.5 m x 1.5 m); registration plot area = 1 m^2 (1 m x 1 m)

<u>Treatments:</u>

Table 15: Treatments, products, and application rates at NIBIO, Landvik and STRI, Bingley.

Nr	Treatment	Products	Rate	Ryder	Water	Number of applications	NIBIO/STRI
1	Untreated control						
2	3 apps of fungicides, all tank mix with Ryder	A19188B1	3 L/ha	1 L/ha	250 L/ha	x1	Sept./Oct.
		A20323D	3 L/ha	1 L/ha	250 L/ha	x1	Oct./Nov.
		Medallion	3 L/ha	1 L/ha	250 L/ha	x1	Nov./Dec.
3	**Biostimulant** + 2 apps of fungicides, all tank mix with Ryder2	Hicure	20 L/ha	0.5 L/ha	250 L/ha	x5 every 2 wks	end of July-early August
		A20323D	3 L/ha	1 L/ha	250 L/ha	x1	Oct./Nov.
		Medallion TL	3 L/ha	1 L/ha	250 L/ha	x1	Nov./Dec.
4	**Biostimulant** + 1 app of fungicide, all tank mix with Ryder	Hicure	20 L/ha	0.5 L/ha	250 L/ha	x7 every 2 wks	end of July
		Medallion TL	3 L/ha	1 L/ha	250 L/ha	x1	Before snow cover/Dec.

[1] A19188B will be applied just prior first sign of microdochium patch

[2]Total dosage for Ryder is 3, 4.5 and 4.5 L/ha in trt 2, 3 and 4, respectively. No irrigation after application at least 4 h, ideally 24 h.

<u>General maintenance of the green:</u>

The greens were maintained optimally and equally except for the treatments themselves.

Fertilisation: Annual N was 261 kg ha^{-1} from wk 14 to wk 44 with Wallco liquid fertilizer 5-1-4 and Greenmaster cold start 11-5-5 and Greenmaster zero 14-0-10 at Landvik and 122 kg N ha^{-1} yr^{-1} with Aquatrols Complete and Aquatrols NK Special at STRI.

N rates were deducted by 11.7% in treatments 3 and 4 in weeks when Hicure was applied in order to give the same amount of N as in control treatment 1.

Mowing: 3 mm, 3 times per wk.

Wear: Friction wear drum with golf spikes, 3 passes per week in July-September at Landvik and Bingley.

Irrigation: To field capacity every time soil moisture to 12-cm depth (TDR-measurements) is less than 12%. Irrigation 5 mm after fertilization.

Vertical cutting: Every 2-4 weeks during peak flowering period for *Poa annua*, otherwise if needed.

Registration and data collection:

Visual assessments were done bi-weekly prior to first sign of MP (always prior to fertilization or treatments), then weekly until the last application of fungicides, then bi-weekly if no snow cover.

Visual turfgrass quality (scale 1-9, 9 is very good, 1 is very poor)

Density (scale 1-9, 9 is very high, 1 is very low)

Colour intensity (scale 1-9)

Diseases (% of plot area): anthracnose in July-August and MP from July to December, then in April-May. For MP the area under disease progress curve (AUDPC) in the various treatments was calculated.

Statistical analyses:

Data were analysed using ANOVA. At STRI, differences among treatment means were distinguished using least significant differences.

6.2 Results and discussion

Results from NIBIO Landvik:

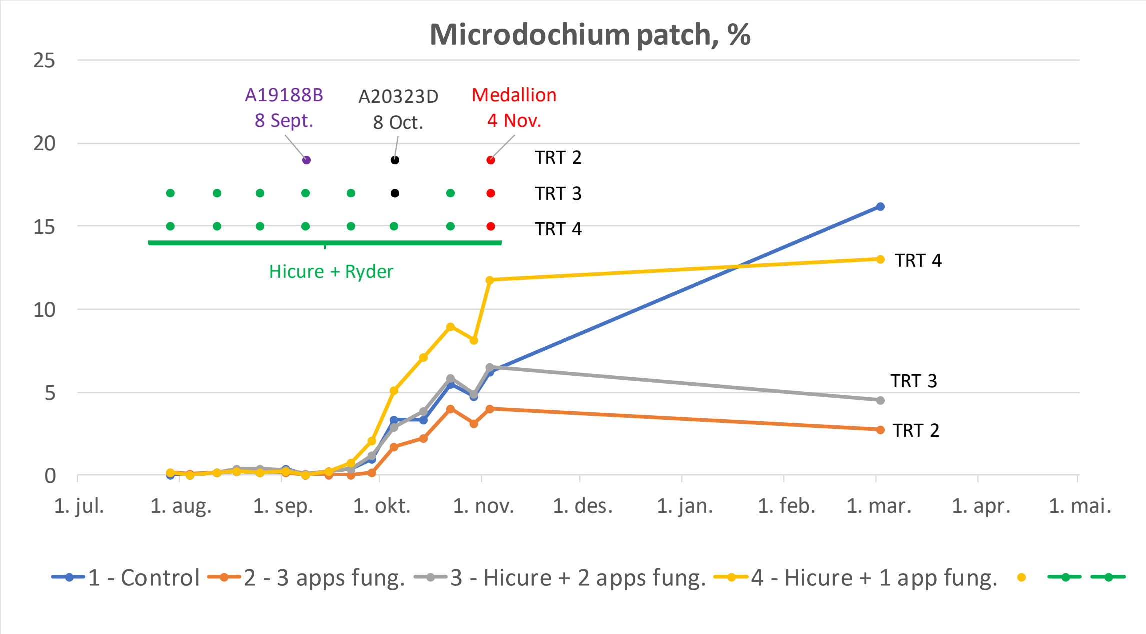


Figure 29: % of MP at Landvik in 2020 and in early spring 2021. Last assessment in early March.

MP (Figure 29) affected the trial area from the end of September to end of March. Disease cover increased in all treatments in the autumn until the last fungicide application 4th of November, where further development in trt. 2, 3 and 4 was stopped. At 22nd and 28th of September % of MP was significantly higher in trt. 4 compared to trt. 2. Treatment 1, the baseline fertiliser programme only, developed further MP with a peak of 16 % at the last assessment date in March. A that date there was a significant difference between the control and trt. 2 and 3.

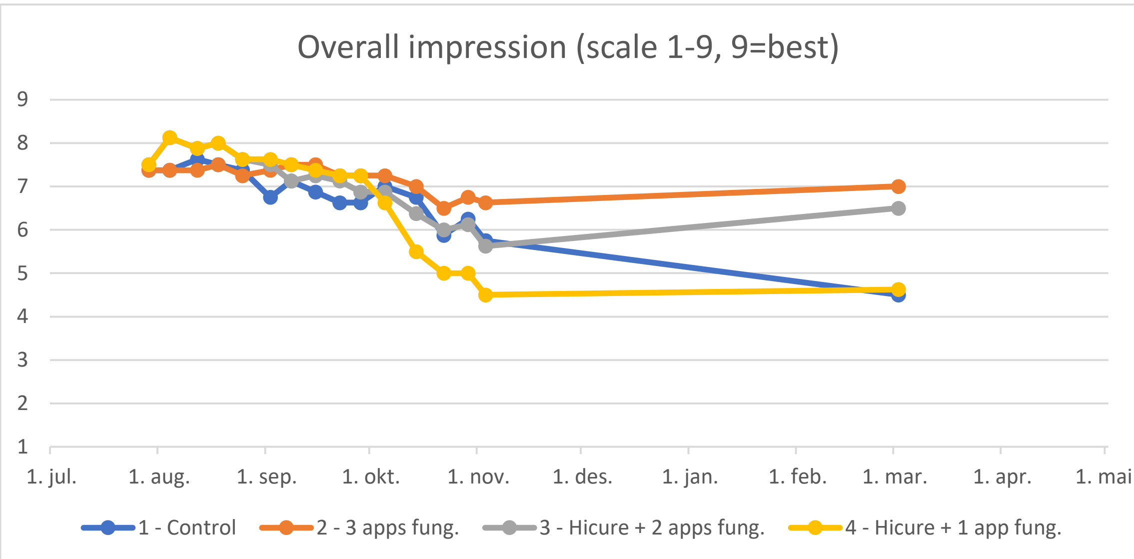


Figure 30: Overall impression (Scale 1-9) from August to March at Landvik.

Turf quality (overall impression, Figure 30Figure 30) showed no significant differences between the treatments except for one observation in early August, and the last observation in March 2021. In

August trt. 3 and 4 (both with Hicure) had a significantly higher turf quality than the other treatments. In March trt. 2 and 3 had significantly higher turf quality than the control and trt. 4.

Results from STRI, Bingley:

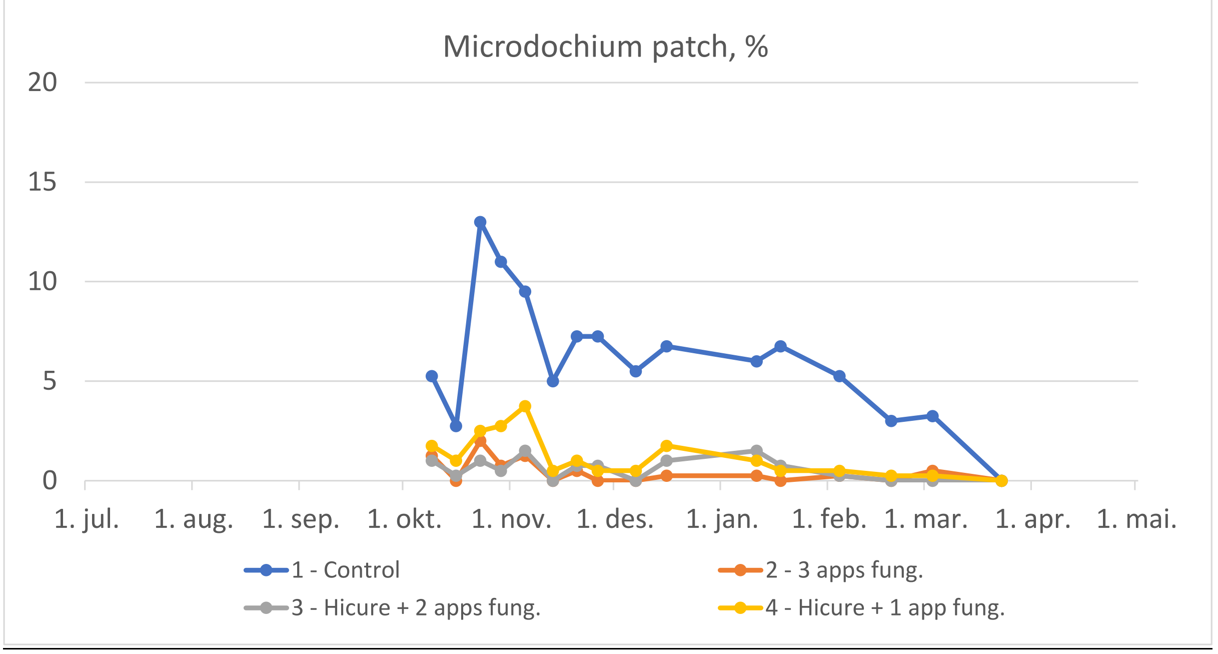


Figure 31: % of MP at Bingley from October 2020 to spring 2021. Last assessment in the end of March.

Microdochium patch affected the trial area from October through to February (Figure 31). Treatment 1, the baseline fertiliser programme only, was most affected by microdochium. Disease cover was approximately 10 % throughout autumn, peaking at 13 %. Treatments 2, 3 and 4 were all successful in controlling MP throughout the trial. Significant differences in disease control were not observed among trt 2, 3 and 4. All were equally effective.

Regarding turf colour significant differences between treatment 1 and trt 2, 3 and 4 were found from September and throughout the autumn and winter (Photo 15).

Photo 15: Drone photo of the Syngenta trial area at STRI and the four treatments. Significant differences in colour between treatment 1 and trt 2, 3 and 4 were found from Sep. and throughout the autumn and winter. Date of photo: 11th November 2020.

7 Alternative products, field trial on DS at STRI, Bingley (WP 2)

• Mark Ferguson, Matthew Clark and Christian Spring, STRI (UK)

The aim of the trial was to investigate the effects of alternative products on dollar spot incidence on red fescue dominant low input golf greens, typical of those associated with Links golf courses where the majority of UK dollar spot tends to be observed.

7.1 Materials and methods

The trial was set up as a complete block randomised trial on a high fescue content area of golf green turf with a history of dollar spot. To boost slender creeping red fescue content (a highly dollar spot susceptible species) the area was oversown in April 2020 with a seed mix contained 100% slender creeping red fescue (three different varieties). Fescue content of the area was around 40%, with the rest of the grasses being made up of browntop bent and annual meadow-grass.

Turf was inoculated at the beginning of July with dollar spot to help ensure the pathogen population was boosted ready for infection.

The area received essential maintenance such as irrigation (as needed) and mowing at 4 mm three to four times a week, as determined by growing conditions. No applications of nutrient or other turf products were made, other than those used as part of the trial.

Table 16: Treatments and N rates.

Treatment	Nitrogen (kg/ha/yr)	Short description
1	0	Untreated control (no nitrogen applied)
2	86	Nutrients (NPK) only at low rate (liquids applied fortnightly)
3	128	N and K only at N rate to match ICL programme (liquids applied fortnightly)
4	137	Nutrients (NPK) only at high rate (liquids applied fortnightly)
5	86	Sustane 5-2-4+Fe (NPK) fortnightly at low rate
6	137	Sustane 5-2-4+Fe (NPK) fortnightly at high rate
7	128	ICL (NK) dollar spot programme

An additional application of Greenmaster K-Step (6-0-27) was applied at 25 g/m² to T7 at ICL's request once the trial was running. This increased the N application rate from the original 110 kg N/ha/yr to 128 Kg N/ha/yr. The positive control for the ICL programme (T3) also had application rates increased over the last five applications of the trial to give the same dose of N as the ICL programme.

The following assessments were made monthly throughout the trial prior to fertiliser applications scheduled:

• Visual turfgrass quality (scale 1-9, 9 is very good, 1 is very poor)

- Turf density (scale 1-9, 9 is very high, 1 is very low)
- Turf colour (scale 1-9)
- Diseases (% of plot area).

7.2 Results and discussion

Turf Quality:

Significant differences in turf quality were observed on three out of eight assessment dates. On these dates treatments 2, 3, 4 and 7 significantly improved turf quality when compared with untreated plots. On one assessment date, treatment 5 significantly improved turf quality when compared with untreated plots, however this was not observed consistently throughout the trial period.

Turf Colour:

Significant differences in turf colour were observed on seven out of eight assessment dates. On these dates, treatment 7 significantly improved turf colour when compared with untreated plots and some other treatments. On six out of eight assessment dates (from 7 days after treatment (DAT) 2) treatments 3 and 4 improved turf colour when compared with untreated plots. Treatments 2, 5 and 6 improved turf quality on five out of eight assessment dates (from 14 DAT 3) when compared with untreated plots. All treatment effects were still observed on the final assessment date (29 DAT 14).

Turf Density:

Significant differences in turf density were observed on four out of eight assessment dates. On these dates (from 7 DAT 2) treatment 7 consistently improved turf density when compared with untreated plots. On three out of eight assessment dates (from 14 DAT 3), treatments 3 and 4 significantly improved turf density when compared with untreated plots. Treatment 2 significantly improved turf density when compared with untreated plots on two out of eight assessment dates (from 7 DAT 4). Treatment 5 significantly improved turf density when compared with untreated plots on one out of eight assessment dates (7 DAT 4) but this was not observed consistently throughout the trial period.

Dollar spot:

Significant differences in dollar spot were observed on three out of six assessment dates. On these dates treatments 2, 3, 4 and 7 significantly reduced dollar spot levels when compared with untreated plots. Treatments 5 and 6 significantly reduced dollar spot levels when compared with untreated plots on one assessment date (7 DAT 7), however this was not observed consistently throughout the trial period.

Microdochium Patch:

Significant differences in microdochium patch were observed on one out of six assessment dates. On this date (7 DAT 7) all treatments had significantly lower microdochium levels when compared with untreated plots. However, this was not observed consistently throughout the trial period.

Red thread:

Significantly differences in red thread were observed on one out of eight assessment dates. On this date (7 DAT 7) treatments 2 – 5 and 7 had significantly lower red thread levels when compared with untreated plots. However, this was not observed consistently throughout the trial period.

8 Causal species for DS in Europe

- Karin Normann, Asbjørn Nyholt ApS (Denmark)
- Marina Usoltseva, Botaniska Analysgruppen (Sweden)
- Kate Entwistle, The Turf Disease Centre (UK)
- Carlos Guerrero, University of Algarve (Portugal)
- Sabine Braitmaier, ProSementis GmbH (Germany)
- Kristine Sundsdal, Erik Lysøe and Tatsiana Espevig, NIBIO (Norway)

The objective of this WP is to find out which *Clarireedia* species we have in Europe.

8.1 Update

In June-November 2020 NIBIO Landvik received 45 turfgrass samples from the following countries: Denmark (3), Sweden (4), Norway (4), UK (4), Germany (22), Portugal (3) and Spain (1) and two pure cultures (1- from Portugal and 1-from Germany). Dollar spot fungi were isolated from 16 turfgrass samples. Some other pathogenic fungi were isolated from 8 turfgrass samples with dollar spot symptoms. The pure cultures of the isolates were sent for molecular identification to NIBIO Ås. So far using ITS-region primer, *Clarireedia* spp. was confirmed in 16 turfgrass samples: 4 – from Sweden, 11 – from Germany, 1 – from Portugal, 1 – from Spain. Of other fungi, *Fusarium* spp., *Rhyzoctonia* spp., *Limonomyces roseipellis* and *Waitea circinate* were confirmed. The data is analysed in winter 2021-22.

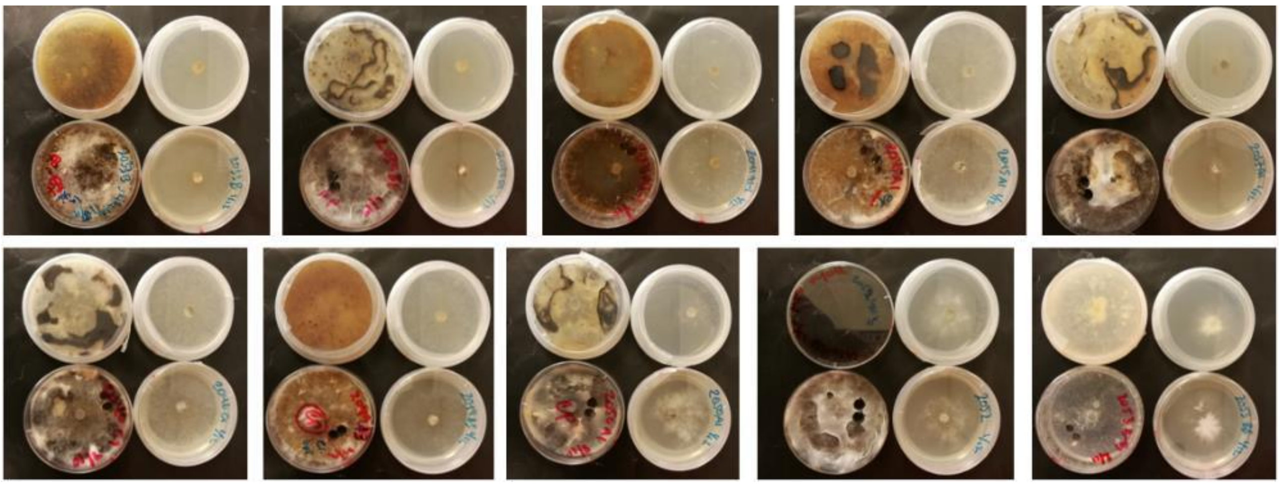


Photo 16: Pure cultures of some Clarireedia *spp. collected and isolated from turfgrass samples from different countries in 2020.*

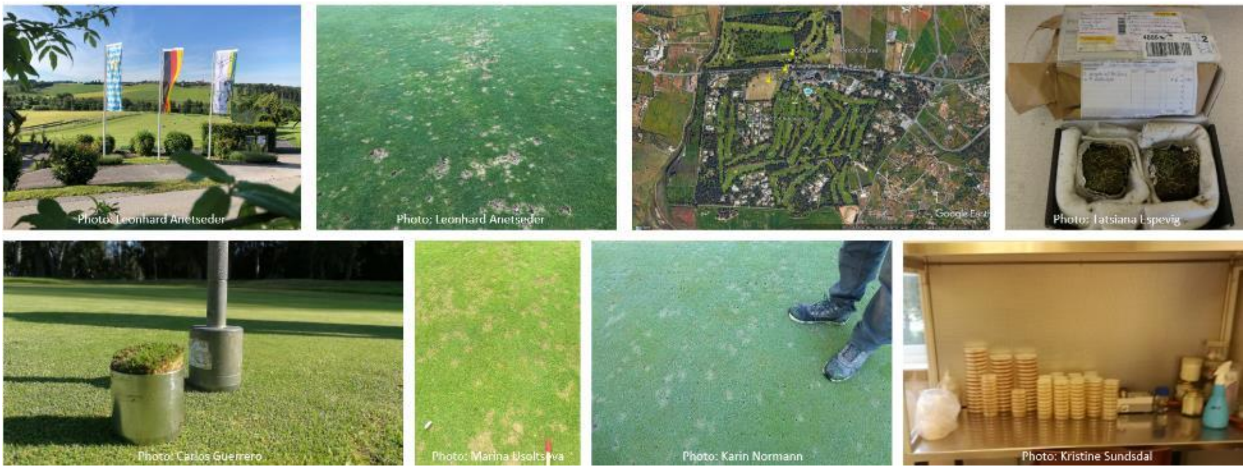


Photo 17: Dollar spot damage on golf courses in summer 2020, sampling and isolation of the fungi at NIBIO Landvik.

9 Rapid tests for DS and MP

- Yuri Lebedin and Anna Antropova, Xema (Finland)
- Tatiana Gagkaeva, VIZR (Russia)
- Marina Usoltseva, Botaniska Analysgruppen (Sweden)
- Tatsiana Espevig, NIBIO (Norway)

The objective of this WP was to investigate immunoassay for identification of *Clarireedia* spp. and *Microdochium nivale* in plant tissue and *Clarireedia* spp. in commercial seeds.

9.1 Materials and methods

Starting material (fungal strains)

M.nivale	VIZR #60432 VIZR #60214
M.bolleyi	VIZR #60517 VIZR #60509
M.majus	VIZR #60127

Growth of fungal cultures:

The fungi for immunization were cultured on malt broth for 21 days at room temperature.

Preparation of fungal extracts:

Mycelial masses and conditioned media from each species were collected for processing. Both types of materials of each species were pooled.

Conditioned media: the pools were treated by repeated ultrafiltration against 0.1 M phosphate buffered saline and concentrated into minimal volume.

Mycelial masses were homogenized and extracted by 1 M NaCl, cleared by centrifugation, then buffer was changed for 0.1 M phosphate buffered saline.

Total protein was determined by Lowrie, the range was 1.8-11.2 mg/ml in different preparations.

Immunizations:

Six extracts (mycelial and culture fluid preps from three species) were mixed on equal total protein weight basis into an immunogen mixture. Three rabbits and three mice were immunized by immunogen mixture. The immune response of the animals was controlled by solid phase ELISA.

Growing and inoculation of the grasses for further immunoassay:

Inoculation of *Poa pratensis* cut leaves with *Microdochium nivale*:

The fragments of leaves of *Poa pratensis* "Geronimo" grown from seeds in pots were placed in Petri dishes with filter paper moistened with sterile distilled water. The plugs of *M.nivale* 60214 cultures grown on potato dextrose agar (PDA) were placed on the leaves surfaces. The experiments were carried out in 3 replicates. The leaf fragments in the control were inoculated with pure PDA plugs. Petri dishes were placed in a plastic bag to prevent drying out and were incubated at room temperature. The bag was opened once a week for 5-10 min to get oxygen into the bag. 13-day cultures were frozen at -20C for further immunoassay.

Photo 18: Poa pratensis leaves 5 (to the right), 6 (in the middle) and 13 (to the left) days after inoculation.

Inoculation of *Poa pratensis* and *Festuca rubra* with *Microdochium nivale:*

Poa pratensis "Geronimo" and *Festuca rubra* "Maxima" were used. The seeds were treated with 70% ethanol for 30 sec, followed by three times washing in sterile distilled water. The soil was autoclaved twice (115C 30 min). Sowing rates were approximately 0.4 g per 49 cm^2. The grass was illuminated with a phytolamp for 12 hours a day. Incubation temperature was about 20C.

Inoculation procedure:

The grasses were inoculated with PDA plugs containing *M.nivale* 60214 by placing the plugs on leaves close to grass crowns but not on the soil (5-10 mm above the soil). Pot area was 49 cm^2 and 10 plugs (5×5 cm approximately) per each pot were used for inoculation. The grasses in control pots were not inoculated with *M.nivale*. The pots were placed in plastic bags individually. The bags were opened once a week for 5-10 min to get oxygen into them. The experiments were carried out in 2 replicates. Well-infected grasses were cut and frozen at -20C for further immunoassay.

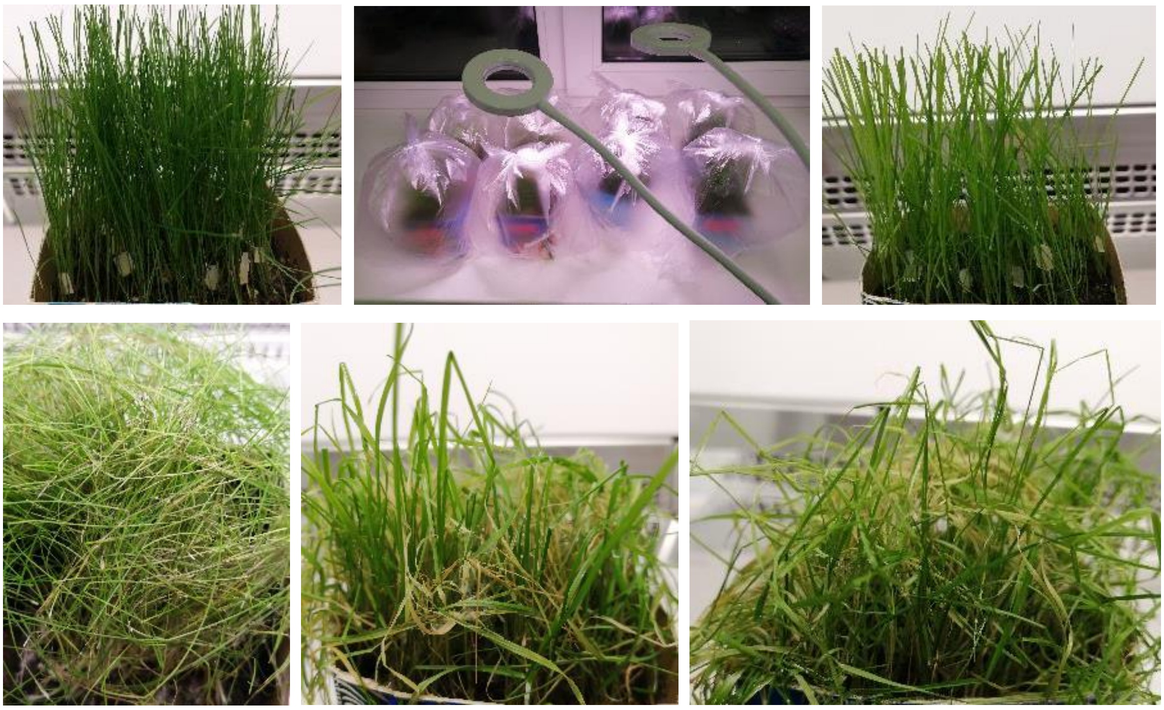


Photo 19: Inoculation and cultivation (top), infected grass (bottom).

9.2 Results and discussion

Rabbit antibodies:

After 3 months of immunization, ca 180 ml of hyperimmune serum was collected from rabbits. Hundred milligrams of fungal extract mixture identical to immunogen mixture was immobilized on agarose matrix to produce 5.0 ml of antigen affinity adsorbent. Approx. 15 mg of rabbit purified antibodies were obtained by affinity chromatography runs, 1 mg was labeled by horseradish peroxidase (HRP). Resulting affinity antibodies and their HRP-conjugate shown high reactivity to all three species extracts in solid phase ELISA.

Two site (sandwich) poly-poly ELISA prototype v0.1 with non-exhausted affinity antibodies.

Primary (non-exhausted) rabbit affinity antibodies were coated onto polystyrene microplates at 2 ug/ml, blocked by hydrolyzed casein and dried. Serial dilutions of three species extracts were incubated in the microwells simultaneously (1 step) or consequently (2 steps) with working dilution of the same primary rabbit antibodies labeled by HRP (conjugate) for total time 1 hour at 37 ^{o}C. After washing of microplate, the remaining HRP activity resulting from Ab-Ag-Ab* sandwich formation was detected by chromogenic substrate, and measured on microplate reader

The data shown preferential recognition of *M.nivale* and *M.bollei* species compared to *M.majus* preparation.

In preliminary specificity studies, the prototype v0.1 shown negative reaction on phytotron derived cereal extracts and moderate cross-reactivity with selected *Fusarium* species extracts (*F.langsethiae, F.chlamydosporum, F.fujikuroi, F.oxysporum, F.sambucinum)* as well as with other genera (*Botrytis, Rhizomucor pusillus, Trichosporon asahii)*

Exhaustion of primary antibodies and two site (sandwich) poly-poly ELISA prototype v0.2 with exhausted antibodies:

To exhaust cross-reactive antibodies, ca 14 mg of primary antibodies were applied on sequential antigen adsorbents containing mixed antigen extracts of *Fusarium sp*, *Mucor/Rhizomucor/Rhizopus* mix, *Trichosporon asahii*. The yield of exhausted (absorbed) antibody was 11.7 mg (83,5%)

ELISA prototype v 0.2 with exhausted antibodies was performed by the protocol shown in previous paragraph.

The results shown that after exhaustion, there is only weak recognition of species *majus*.

No cross-reactivity to *Fusarium sp*. and *Trichosporon asahii* emained, the exhaustion was successful.

However, the cross-reactivity remained with a single preparation of *Rhizomucor pusillus*

Immediate plans: primary validation of the assay on three types of grass material

1. Obviously infected grass, preferably with all three species
2. Obviously NON infected grass, or grass infected with nonrelevant pathogens
3. Study of antigen accumulation/degradation kinetics by model infection of grass

10 Review on chafer grubs and leather jacktes

- Karin Juul Hesselsøe, NIBIO (Norway)
- Ingeborg Mentzler-Hokkanen, University of Eastern (Finland)

The objective of this project was to compile a review of the management and potential innovation options of monitoring, warning, and control of chafer grubs (*Phyllopherta horticola*) and leather jackets (*Tiphula paludosa*) on golf courses in the Nordic countries. In some years, these pests cause a lot of damage on golf courses in Denmark and other North European countries. As the use of insecticides have been strongly decreased all over Europe, there is a need to look for alternatives. Scattered experiments with entomopathogenic nematodes and other control agents have been conducted in some of the countries and many practitioners (course managers and greenkeepers) have experienced those cultural measures such as irrigation can control the pests to some extent. There is a need to compile this information into a review article that can serve as basis for future innovations to control chafer grubs and leather jackets on golf courses.

The review will result in updated STERF IPM-fact sheets on chafer grubs and leather jackets in English and Scandinavian languages.

10.1 Materials and methods

In the first year of the WP4 a litterature study was compiled. A brief survey was done in Denmark and Sweden to get an overview on the current problems with leather jacktes and chafer grubs on golf courses in these two countries. The survey was done in the autumn 2020 by asking 7 golf course consultants in Sweden on the situation in Sweden and one golf course consultant in Denmark to give their estimates on the extent of the problems in 2020 and the recent 2-3 years back.

In Sweden the consultants estimated both the occurrence and the damages from chafer grubs and leather jackets on the golf courses. 'Damages' were defined as the number of golf courses that had recorded problems related to the pests. 'Occurrence' was defined as the number of golf courses that had observed the insects but did not experience any problems related to them. In the survey in Denmark the golf course consultant estimated the 'damages' as the number of golf courses that had recorded problems related to the pests. The estimates are shown both in total numbers and in % among the 662 golf courses in Sweden and 189 golf courses in Denmark.

10.2 Results and discussion

Table 17: Numbers and % of golf courses in Sweden and Denmark that had experienced damages and occurrence of leather jacktes and chafer grubs in 2018-20. 'Damages' are defined as courses who have recorded problems related to the pests, 'occurrence' are defined as the ones who have observed the insects but had not recorded any problems related to them.

	Leather jacktes				**Chafer grubs**			
	Damages		**Occurrence**		**Damages**		**Occurrence**	
	Number (golf courses)	% of golf courses	Number (golf courses)	% of golf courses	Number (golf courses)	% of golf courses	Number (golf courses)	% of golf courses
Denmark	37	20	-	-	7	3.7	-	-
Sweden	17	2.5	80	12	3	0.5	23	3.5

The results showed that the problems were larger in Denmark than in Sweden with 20% of the golf courses experiencing problems with leather jacktes compared to 2.5 % in Sweden. For chafer grubs 3.7 % of the Danish golf courses experienced problems compared to only 0.5% of the Swedish courses.

The problems with chafer grubs were located to sandy soils primarily in the south-eastern parts of Sweden, and in Denmark they were located to the northern parts of Jutland. Damages from leather jackets were estimated to cause increasing problems especially on the golf courses in Western Denmark on sandy soils. The problems were mostly on fairways and semi roughs but was also seen on greens and tees.

The problems with the pests in both Sweden and Denmark had been relatively alike in the years from 2018-2020. Compared to the situation in 2005-10 the problems with chafer grubs were minor in Denmark in 2018-20.

<u>Control measures (Denmark):</u>

In Denmark the insecticide Avaunt (indoxacarb) is legal to use against leather jacktes on a "minor use" approval in the autumn from 15th of Sep. to 1st of Dec. The *Bacillus thuringiensis* product (Gnatrol SC) is also "minor use"-approved to be used in the autumn 1-3 treatments on small insect larvae. In the spring it can also be used if the treatment in the autumn has not been sufficient. On a lot of golf courses, they put up starch boxes to attract these birds. The golf courses have focused on scaring off the crow birds as they are responsible of the most damages.

No pesticides are legal to use against chafer grubs in 2020. Merit turf (imidacloprid, formulated as a granular) was approved in 2006 and banned in 2019. From 1998-2003 damages from chafer grubs were increasing on golf courses, football pitches and on amenity lawns, so from 2003 experiments were carried out to find alternatives to control the pests.

Experiments from 2003 with entomopathogenic nematodes and fungi showed limited control of the pests (Larsen & Ravn, 2003). The use of topdressing with compost were tested in 2003 (Schmidt, 2003). They tested topdressing mixed with 25, 50 or 80 volume-% of compost and Cyperb used in the middle of June approx. one week before the beetles swarmed. The results showed that the amendment of 80% of compost to the topdressing and spraying with Cyperb had a reducing effect on the pests. Different cultural practices like the use of organic fertilizer, ryegrass with endophytes or irrigation showed some control of the pests. Aspecially on the publicly owned turfgrass areas (golf courses and football pitches on municipal land) a lot of experiments were done as the use of pesticides was banned here. Important experiences from the testing's with nematodes and fungi showed that the spraying technic is crucial to get a good result.

The efficacy of EPN (entomopathogenic nematodes) in controlling insect pests under outdoor conditions can be substantially improved. The main factors to improve the performance of EPN are:

Formulation, application technology and EPN species. Particularly the rearing of certain species of EPN that best would fit to the Nordic climate, is a challenge. The performance of currently available EPN species utilising formulations that enhance efficacy and survival has not been tested against chafer grubs and leather jackets in the field. This work should be carried out during the coming years.

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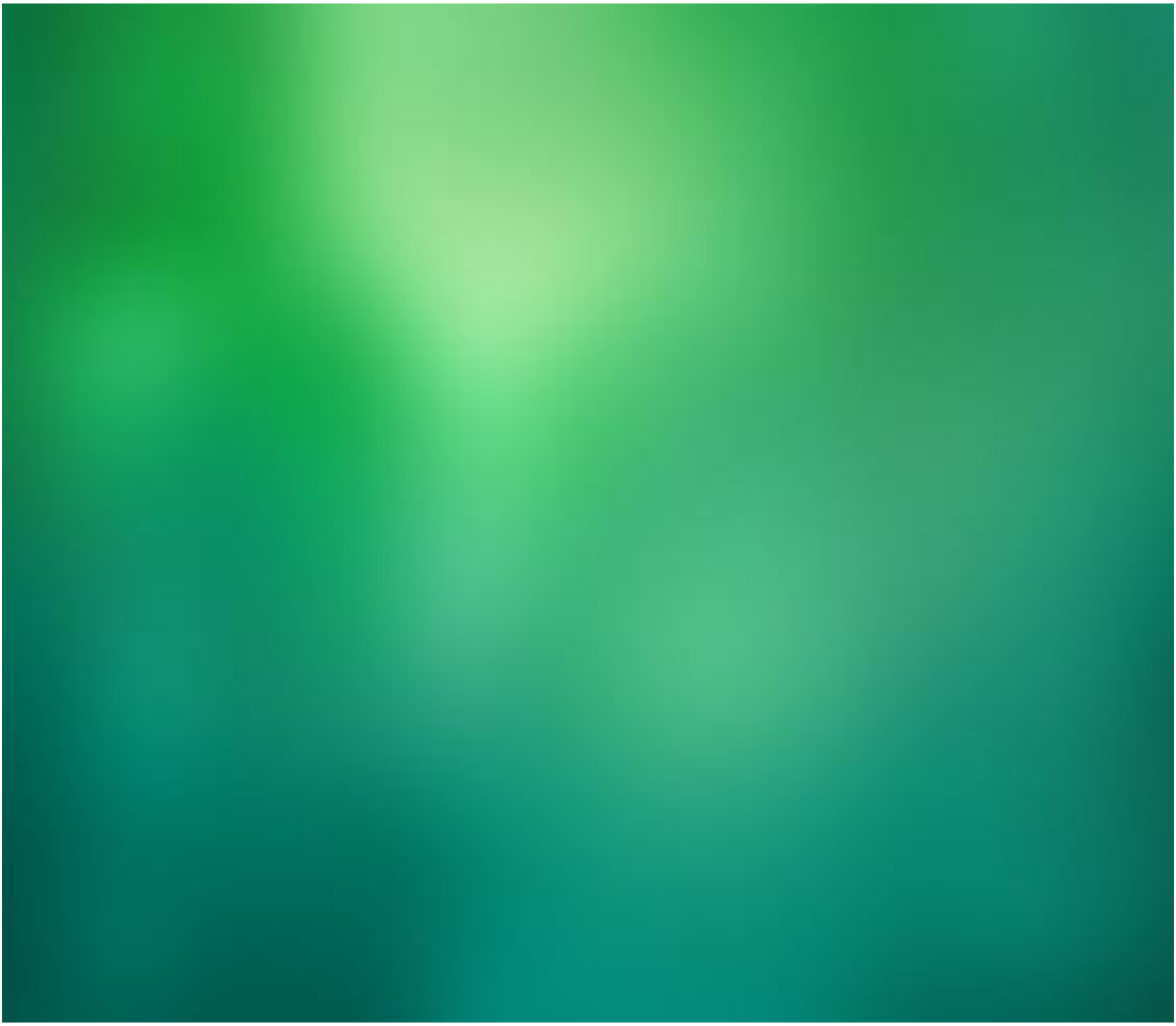

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