NIBIO final report from project

Risk assessment, management and control of dollar spot caused by *Clarireedia* species on Scandinavian golf courses (2017-2020)

Results from field experiments on Scandinavian golf courses and laboratory studies at NIBIO Landvik

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This work was funded by the Scandinavian Turfgrass and Environment Research Foundation (STERF)

Photo: Karin Normann

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This report is a summary of previously published material.

1 Introduction

Dollar spot is a fungal turfgrass disease that is caused by the *Clarireedia* species. Worldwide the disease is known to cause extensive economical and physical damage on golf course greens and fairways. Dollar spot was officially documented in Norway in 2013 [1] and in Sweden in 2014 [2], and the disease exists on many Nordic golf courses. On some Scandinavian golf courses and in some years the damage from dollar spot has been up to 70-80% dead turf [3]. Golf greens which are affected by dollar spot get an uneven playing surface and recover very slowly, which significantly reduce the playing quality (Figure 1). There is no available fungicides against dollar spot in the Nordic countries except for Sweden. According to EU-Directive 2009/128 EU on 'establishing a framework on sustainable use of pesticides', the management and control of any pests has to follow IPM (Integrated Pest Management) principles. Regarding dollar spot, little research has been conducted in the Nordic environments on any control measures. Effective non-chemical measures for control of this disease are needed.

Figure 1. Dollar spot. Photo: Karin Normann.

The *Clarireedia* fungi do not produce spores, but most likely spread via infected grass attached to shoes, playing equipment and machines such as lawn mowers. To achieve good playing quality, golf greens are usually maintained at low mowing height, limited irrigation and low input of nitrogen fertilizer. From the U.S. where dollar spot has been studied for at least 50 years, it is known that the disease is favoured by the combination of dry soil and a moist turf canopy [4]. Thus, daily rolling may significantly reduce dollar spot severity on golf greens because it disperses concentrated guttation water [5] and contributes to an increase in soil moisture [6]. Positive effect of rolling has also been observed by Danish greenkeepers [7]. From the previous studies in the U.S. it is also known that dollar spot is favoured by such cultural practices as low fertilization, especially nitrogen [8,9]. The objectives of WP1 was to find the optimal frequency for rolling of golf greens in Scandinavia and investigate effect of nitrogen on dollar spot.

At least five species in the fungal genus *Clarireedia* cause dollar spot disease [10,11]. The pathogen was formerly known as *Sclerotinia homoeocarpa* F. T. Benn. [12]. At least two species of *Clarireedia* have been documented in Scandinavia: *C. jacksonii* and an unnamed species of *Clarireedia* [1,3]. To facilitate effective management of the potential symptoms, it is important to clearly understand the parameters that enable the fungus to actively cause disease. In the U.S., disease development is encouraged by an air temperature of up to 30 °C and high relative humidity [13,14] but no information is currently available on the environmental conditions that favour dollar spot disease in Scandinavia. The results from previous research in Sweden on the *in vitro* growth requirements of dollar spot isolates collected across Scandinavia were inconclusive [15] but they proposed lower cardinal temperatures compared to those documented for *Clarireedia* spp. isolated from dollar spot infected turf elsewhere around the world. Thus, the objective of WP2 was to identify whether there are differences in the temperature requirements of *Clarireedia* isolates collected from turfgrasses in Scandinavia, the USA and the UK.

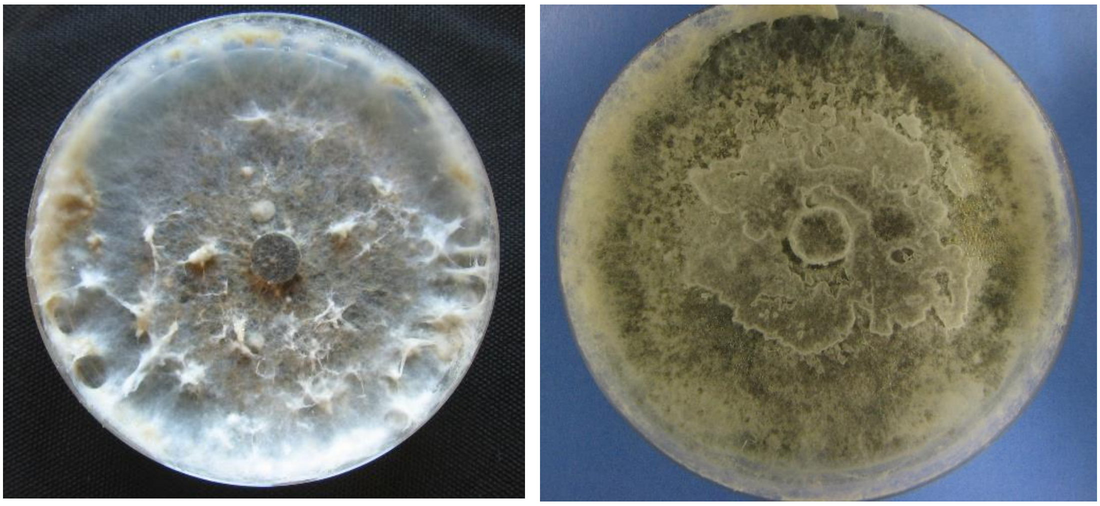

Figure 2. *Clarireedia* spp. Photo: T. Espevig.

The resistance to dollar spot varies among turfgrass species and cultivars. The turfgrass species commonly seeded on Nordic golf courses include creeping bentgrass (*Agrostis stolonifera*), colonial bentgrass (*A. capillaris*), velvet bentgrass (*A. canina*), Chewings fescue (*Festuca rubra* ssp. *commutata*), slender creeping red fescue fescue (*F. rubra* ssp. *littoralis*), strong creeping red fescue (*F. rubra* ssp. *rubra*), Kentucky bluegrass (*Poa pratensis*) and perennial ryegrass (*Lolium perenne*). While creeping bentgrass and velvet bentgrass are seeded mainly on golf course putting greens, and strong creeping red fescue, Kentucky bluegrass and perennial ryegrass mainly on fairways, tees and roughs, colonial bentgrass, Chewings fescue and slender creeping red fescue are commonly included in seed mixtures for various turfgrass areas [16]. Despite the regular seeding and overseeding of these species, annual bluegrass (*Poa annua*) is probably the species most commonly found on greens, tees and fairways on Nordic golf courses. While dollar spot occurrence has been evaluated in some of the trials in the National Turfgrass Evaluation Program in USA 2005-2020 (https://www.ntep.org/contents2.shtml), virtually no information is available on the resistance of the same species to dollar spot under Nordic conditions. When it comes to cultivars, NTEP results are usually of little relevance except for creeping bentgrass where mostly the same cultivars are used in North America and the Nordic countries. Therefore, the objectives of WP3 were to (1) to screen the most commonly used turfgrass species and cultivars in the Nordic countries for their resistance to dollar spot; (2) to compare aggressiveness of *Clarireedia* isolates from Scandinavia, the U.S. and the U.K.; and (3) to evaluate an *in vitro* method for screening turfgrass cultivars for dollar spot resistance.

2 Field experiments on rolling and nitrogen fertilization

See original scientific publications 17 and 18.

2.1 Materials and methods

Field experiments on rolling were conducted at Vallda Golf & Country Club in Sweden (Figure 3) and Roskilde Golf Club in Denmark in summer 2017. The golf green at Vallda GC consisted of pure red fescue (40% Chewings fescue and 60% slender creeping red fescue) and the foregreen at Roskilde GC consisted 33% red fescue (16% Chewings fescue and 17% slender creeping red fescue), 34% colonial bentgrass, 27% perennial ryegrass and 6% annual bluegrass. The green at Vallda GC were mowed 3-4 times per week to 5-5.5 mm and foregreen at Roskilde GC - 2 times per week to 11-14 mm. Annual nitrogen rate was 40 kg ha^{-1} and 80 kg ha^{-1} at Vallda GC and Roskilde GC, respectively. Through monthly topdressing the greens received annually 5 mm sand at Vallda GC and approx. 1 mm sand at Roskilde GC. The rolling treatments started on 5 June and 12 June at Vallda GC and Roskilde GC, respectively. The following rolling treatments were compared: (i) no rolling (control); (ii) rolling 2 times per week; and (iii) rolling 4 times per week. Rolling was conducted using a Smithco roller, model 7530 Tournament LE Greens Roller (90-cm wide and 378-kg roll swath) at Vallda CG and a TRU-Turf RB4811A roller (122-cm wide and 290-kg roll swath) at Roskilde GC. The experiments were laid out as randomized complete block designs with 3 reps on each golf green, and the area for a single treatment (one plot) was 18 m^2 at Vallda GC and 7.2 m^2 at Roskilde GC. Corners of each plot were marked with spray at the start of the experiment, and the marks were maintained throughout the experiment. The dollar spot incidence was registered either by counting the number of individual infection centres per plot (Vallda GC, totally 3 times from June to September) or by determination of percentage of plot area covered with the disease (Roskilde GC, totally 5 times from June to October). Area under disease progress curve (AUDPC) was calculated by multiplying the difference in dollar spot incidence between the registration in September and in August by the time (days) between these registrations.

The registrations were done prior to the start of the experimental rolling treatments and then in August and September at Vallda CG and monthly from June to October at Roskilde GC. No fungicides were applied on the greens in 2017. Ball roll was measured using the United States Golf Association (USGA) Stimpmeter at Vallda GC in August.

Figure 3. Assessments of dollar spot in response to rolling at Vallda Golf & Country Club. Photo: Botaniska Analysgruppen.

A field trial on effects of N-fertilization on dollar spot and microdochium patch was conducted on a golf green with creeping bentgrass (predominant species) and annual bluegrass at Kävlinge Golf Club in Sweden in 2017 and 2018. The green was mown regularly to 4 mm. The annual P and K inputs amounted to 80 kg ha^{-1} and 140 kg ha^{-1}, respectively. Two annual N rates were compared: 150 kg ha^{-1} and 240 kg ha^{-1}. No fungicides were applied in 2017 and 2018. The experiments were laid out as randomized complete block design with 3 reps. The incidence of dollar spot was determined by counting the number of individual infection centres and incidence of microdochium patch (in the spring 2019 only) was determined as percentage of plot area covered with the disease.

The data from each of three experiments were analysed by the SAS procedure proc ANOVA using the statements for 1-factorial randomized complete block design (SAS Institute, version 9.4). Fisher LSD at 5% probability level identified significant differences among the treatments.

2.2 Results and discussion

On average for August-September 2017, rolling 2 and 4 times per week starting in June, reduced dollar spot by 61% and 95%, respectively, on the red fescue green at Vallda GC as compared with no rolling (79 individual infection centres per 1 m^2 on the plots with no rolling) (Table 1 and Figure 4). As expressed by AUDPC values, dollar spot at Vallda GC was reduced 49% and 96% by rolling 2 and 4 times per week, respectively. On the foregreen with red fescue and colonial bentgrass as the predominant species at Roskilde GC, 27% and 62% reductions in AUDPC values were observed after rolling 2 and 4 times per week, respectively (Table 1 and Figure 5). However, neither these reductions, nor the corresponding 37% and 54% reductions in dollar spot incidence on average for September and October were statistically significant. Our results are in agreement with Giordano et al. [6] who found that rolling 5 and 10 times per week resulted in 22-72% and 88-91% reduction in dollar spot, respectively, on a putting green with a mixture of creeping bentgrass and annual bluegrass. In that 3-yr experiment, the reduction in AUDPC was always significant with rolling 10 times per week, but the reduction in dollar spot with rolling 5 times per week was significant only in years with high disease pressure [6]. It appears that low disease pressure was the reason for a less pronounced effect of rolling 3 times per week on dollar spot infection also in an earlier study on a creeping bentgrass putting green [5].

Furthermore, as it was previously shown [5,6], rolling 4 times per week improved ball roll by 25% as compared with no-rolling at Vallda GC (Table 1). We agree with Nikolai et al. [5] that the benefit of light-weight green rolling is still underestimated, and in particular with respect to dollar spot. It appears that rolling 3-4 times per week can be recommended on Scandinavian golf greens that are under dollar spot pressure.

Table 1. Effect of rolling on dollar spot (DS) incidence on golf greens on Vallda GC (Sweden) and Roskilde GC (Denmark) in 2017.

	------------------ Vallda GC ------------------					---------------------- Roskilde GC ----------------------					
	DS infection centres				Ball roll	Percentage of plot covered with DS, %					
Rolling	5 June	18 Aug.	12 Sept.	AUDPC †	18 Aug.	12 June	5 July	7 Aug.	14 Sept.	26 Oct.	AUDPC ††
No rolling	0	33 a	126 a	2329 a	247 a	0.2	1.1	4.2	27.7	10.5	893
2x/ wk	0	10 b	58 b	1187 a	298 a	1.4	2.5	2.4	19.5	5.8	649
4x/ wk	0	2 c	6 c	102 c	308 b	1.4	6.5	6.2	15.0	4.0	336
P		*0.001*	*0.001*	*0.005*	*0.000*	*0.237*	*0.446*	*0.364*	*0.155*	*0.285*	*0.142*

† Area under disease progress curve (AUDPC) from 18 Aug. to 12 Sept. 2017
‡ AUDPC from 7 Aug. to 14 Sept. 2017

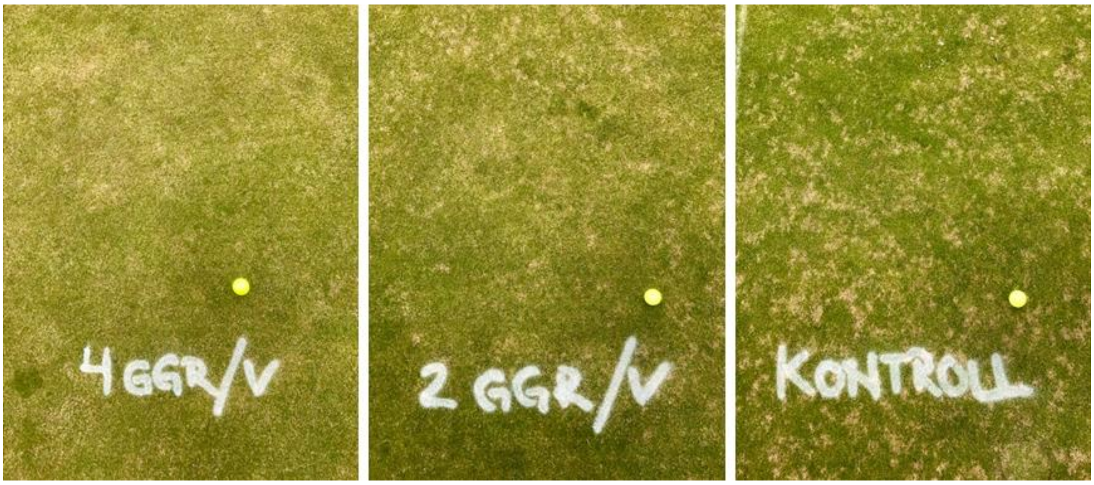

Figure 4. Rolling 4 and 2 times per week starting in June reduced dollar spot by 95% and 61% as compared with no rolling at Vallda GC in 2017. Photo: Stefan Nilsson.

Figure 5. Rolling 4 and 2 times per week reduced dollar spot 54% and 37%, respectively, compared with no rolling at Roskilde GC in 2017. Photo: Karin Normann.

At Kävlinge Golf Club, the increase in annual N amount from 150 kg ha^{-1} to 240 kg ha^{-1} led to 16% dollar spot reduction (from 71 to 60 infection centres per m^2) in 2017 ($p=0.478$) and to 24% dollar spot reduction (from 100 to 76 infection centres per m^2) in 2018 ($p=0.01$). However, in March 2019, on the plots which had received 240 kg N ha^{-1} in 2018, the microdochium patch incidence was 2 times higher than on the plots which received 150 kg N ha^{-1} (30% vs. 14% microdochium patch, respectively) (Figure 6). An earlier study by Espevig et al. [19] showed that an increase in N-amount in the fall led to an increase in microdochium patch on an annual bluegrass green but not on a creeping bentgrass green. As a result of the present study, it is impossible to draw unambiguous conclusions about the advisability of using increased doses of N to fight dollar spot on golf greens which are exposed to microdochium patch during winter time.

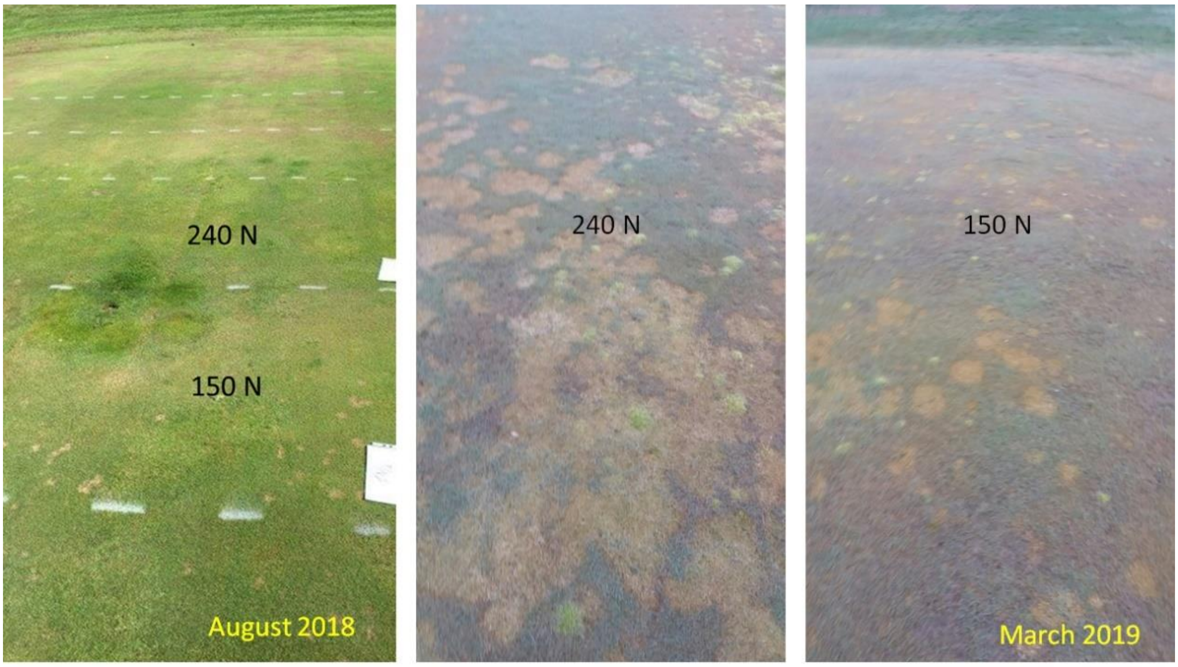

Figure 6. An increase in the annual N amount from 150 kg ha^{-1} to 240 kg ha^{-1} led to a 24% dollar spot reduction in 2018, but twice as much microdochium patch (30% vs. 14%) in spring 2019. Photos: Marina Usoltseva and Anders Olofsson.

3 Effect of temperature on the growth rate of *Clarireedia* spp. of different origin (lab experiments)

See original scientific publication 20.

3.1 Materials and methods

In these experiments, 10 *Clarireedia* isolates of different origin were used: two from the U.S., one from Canada, one from Denmark, one from Norway, three from Sweden and two from the U.K. (Table 2). *Clarireedia* isolates from Scandinavia and the U.K. were recovered from turfgrass samples collected in 2014 and 2017, respectively. Isolates MB-01, SH44 and RB-19 were collected in 2001, 2000 and 2008, respectively, and sent to NIBIO Landvik in 2015. All isolates were stored at NIBIO Landvik at -80°C until they were used in this study in 2017. The experiments were conducted in the laboratory at NIBIO Landvik. The isolates were grown on 50% potato dextrose agar (PDA, 19.5 g of PDA and 7.5 g agar per 1 L water) in Petri plates at 0, 4, 8, 16, 24, 32 and 40 °C in the dark for 17, 17, 8, 3, 2, 4 and 17 days, respectively. The increase in colony diameter was recorded daily (mm) (Figure 7). The Petri plates that were incubated at 0 °C and 40 °C, were maintained at their respective temperatures for 3 more days after which they were transferred to 16 °C for three further days incubation, to enable assessment of fungal regrowth. The *in vitro* daily growth rates were determined by dividing colony diameter (minus 5 mm of original plugs) by the corresponding number of days of growth. The reduction in the growth rate at 16 °C after being at 0 °C and 40 °C for 3 weeks was calculated as percentage of daily growth rate at 16 °C (data not shown). The data were analyzed by the SAS procedure proc ANOVA using the statements for 1-factorial completely randomized design either among the isolates within each temperature or among the temperatures within each isolate (SAS Institute, version 9.4). Fisher LSD at 5% probability level identified significant differences among the treatments.

Table 2. *Clarireedia* isolates used in this study

Isolate no.	Country of origin	Host grasses	Species of fungi	GenBank ITS accession
14.10	Denmark	*Poa annua*	*C. jacksonii*	MT623517
14.12	Norway	*Agrostis stolonifera*	*Clarireedia* sp.†	KJ775860
14.15	Sweden	*Festuca rubra spp.*	*C. jacksonii*	MT623519
14.16	Sweden	*Festuca rubra spp.*	*C. jacksonii*	MT623518
14.112	Sweden	*Poa annua*	*Clarireedia* sp.†	MT623516
MB-01	USA	*Agrostis stolonifera*	*C. jacksonii*	KF545290
SH44	Canada	*Agrostis stolonifera*	*C. jacksonii*	KF545299
RB-19	USA	*Hybrid bermudagrass*	*C. monteithiana*	KF545306
17.11	United Kingdom	*Festuca rubra spp.*	*Clarireedia* sp.	-
17.12	United Kingdom	*Poa pratensis*	*Clarireedia* sp.	-

† *Clarireedia* sp. 14.12.NO and 14.112.SE have identical sequence in the ribosomal internal transcribed spacer (ITS) region, and are different from those of *C. jacksonii* (97.6 % sequence similarity in the ITS region).

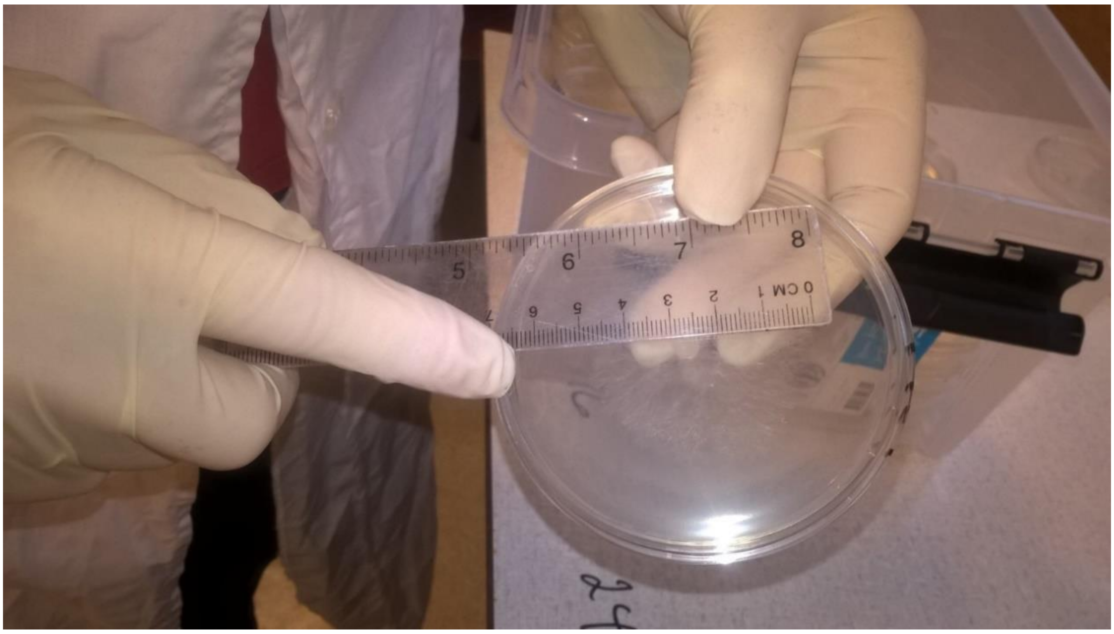

Figure 7. Measurements of radial growth of dollar spot isolates. Photo: T. Espevig.

3.2 Results and discussion

The maximum growth rate of the seven Scandinavian and British isolates, was recorded at 24 °C. There were significant differences in growth rates among the isolates (Figure 8) but curiously, the three isolates from Sweden all produced significantly different growth rates when incubated at 24 °C. The isolates MB-01 and SH44 from cool-season grasses had significantly lower growth rates at 24 °C than did all Scandinavian and British isolates. Moreover, the growth rate of MB01 and SH44 at 24 °C did not differ significantly from that at 16 °C (results from ANOVA of temperatures within each isolate not shown).

All ten isolates resumed growth when incubated at 16 °C after having been maintained at 0 °C for 3 weeks (data not shown). However, the growth rates of isolates from Denmark, Sweden and the U.K. were reduced by an average of 28% when compared to their growth at 16 °C prior to chilling. No reduction in growth rate was recorded for MB01 from the U.S., SH44 from Canada or 14.12 from Norway, all collected from cool-season grasses (data not shown). Thus, it appears that the minimum temperature for mycelial growth of *Clarireedia* spp. in this study was in accordance with Bennett [12] who reported 0-2 °C. Moreover, this apparent lack of inhibition in growth for MB01, SH44 and 14.12 could indicate a potential for enhanced survival during cold winter conditions but further work would be necessary to confirm this.

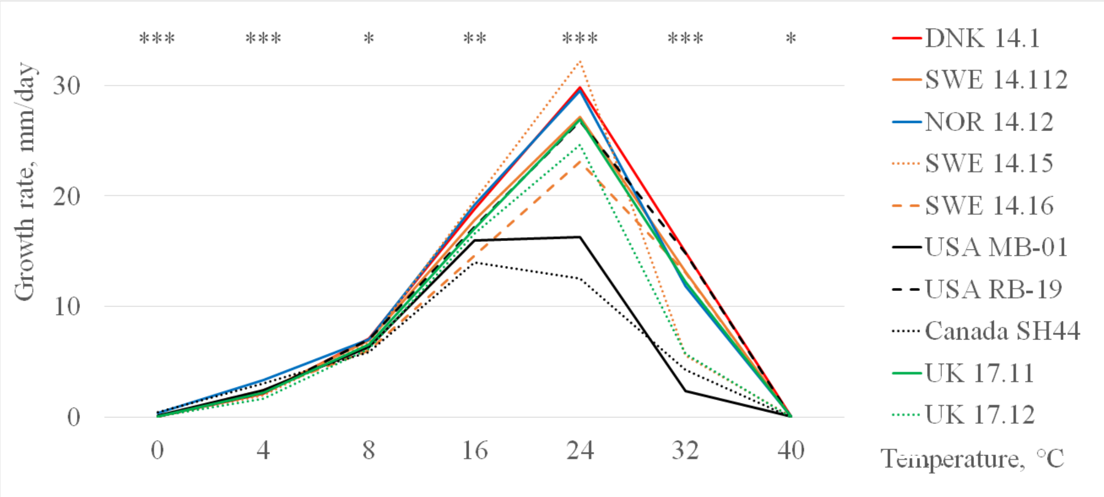

Figure 8. The effect of increasing temperature from 0 °C to 40 °C on growth rates of 10 isolates of *Clarireedia* spp. of different origin.

For all isolates except 14.15 from Sweden, incubation at 16 °C after incubation at 40 °C for three weeks, resulted in a reduction in growth rate of >98% (vs. 83% for 14.15) when compared to the isolate growth rates at 16 °C without the high temperature exposure (data not shown). Thus, the maximum growth temperature for most isolates in this study was between 32 and 40C, higher than previously reported [12].

4 Screening of turfgrass species and cultivars for resistance to dollar spot (lab experiments)

See original scientific publication 21.

4.1 Materials and methods

The experiments were conducted in growth chamber at NIBIO Landvik in the winter-spring of 2018 and 2019. In total 20 of the most widely used turfgrass cultivars of 6 turfgrass species (Table 3) were seeded in glass vials filled with Green Mix (80% sand and 20% garden compost, volume fractions) which was moistened prior to seeding. When the turfgrass seedlings were approx. 1-week old they were inoculated with one of ten dollar spot isolates from Norway, Denmark, Sweden, Canada, the U.K. and the U.S., the same isolates which were used in WP2 (Table 2). Prior to inoculation, the isolates were grown on 50% potato dextrose agar at 24°C for 2 days. A total of 800 tubes in 2018 and 720 tubes in 2019 (SH44 was not used in 2019), were inoculated with one fungal plug of 5 mm diameter which was taken from the colony edge. Control tubes of each turfgrass cultivar were inoculated with 50% PDA plugs without fungus. After inoculation, the tubes were capped to ensure high humidity and maintained at 19-20°C (day) for 16 h of light (250 µmol m^{-1} s^{-1}) and 14°C (night) for 8 h in darkness representing temperature conditions for a normal Norwegian summer. All tubes received water 25 days after inoculation.

Dollar spot resistance was assessed in percentage 34 days post-inoculation using scale from 1 to 9, where 1 = 0-12.4% healthy plants, 2 = 12.5-24.9%, 3 = 25- 37.4%, 4 = 37.5- 49.9%, 5 = 50-62.4%, 6 = 62.5-74.9%, 7 = 75-87.4%, 8 = 87.5-99.9%, and 9 = 100% healthy plants with no disease. Non-inoculated control tubes with the cultivars were used as standards under assessments.

The experiment was conducted according to a two-factorial randomized complete block design (RCBD) with four blocks in two years (2018 and 2019). The data were analyzed using the SAS procedure PROC GLIMMIX with species, cultivar (within species), isolate and their interactions as fixed factors; and year, block and their interaction as random factors. Least Squares Means values for species, cultivar (within species), isolate and their interactions were estimated using the procedure's LSMEANS statement (Model 1). Model 2 was used to give a simplified analysis of the observed significant interaction between species and isolate from Model 1. Thus, separately for each species the data were analyzed using the SAS procedure PROC GLIMMIX with cultivar, isolate and their interaction as fixed factors; and year, block and their interaction as random factors (Model 2). Tukey's multiple comparison method with 5% significance level was used to identify significant differences among the treatments means.

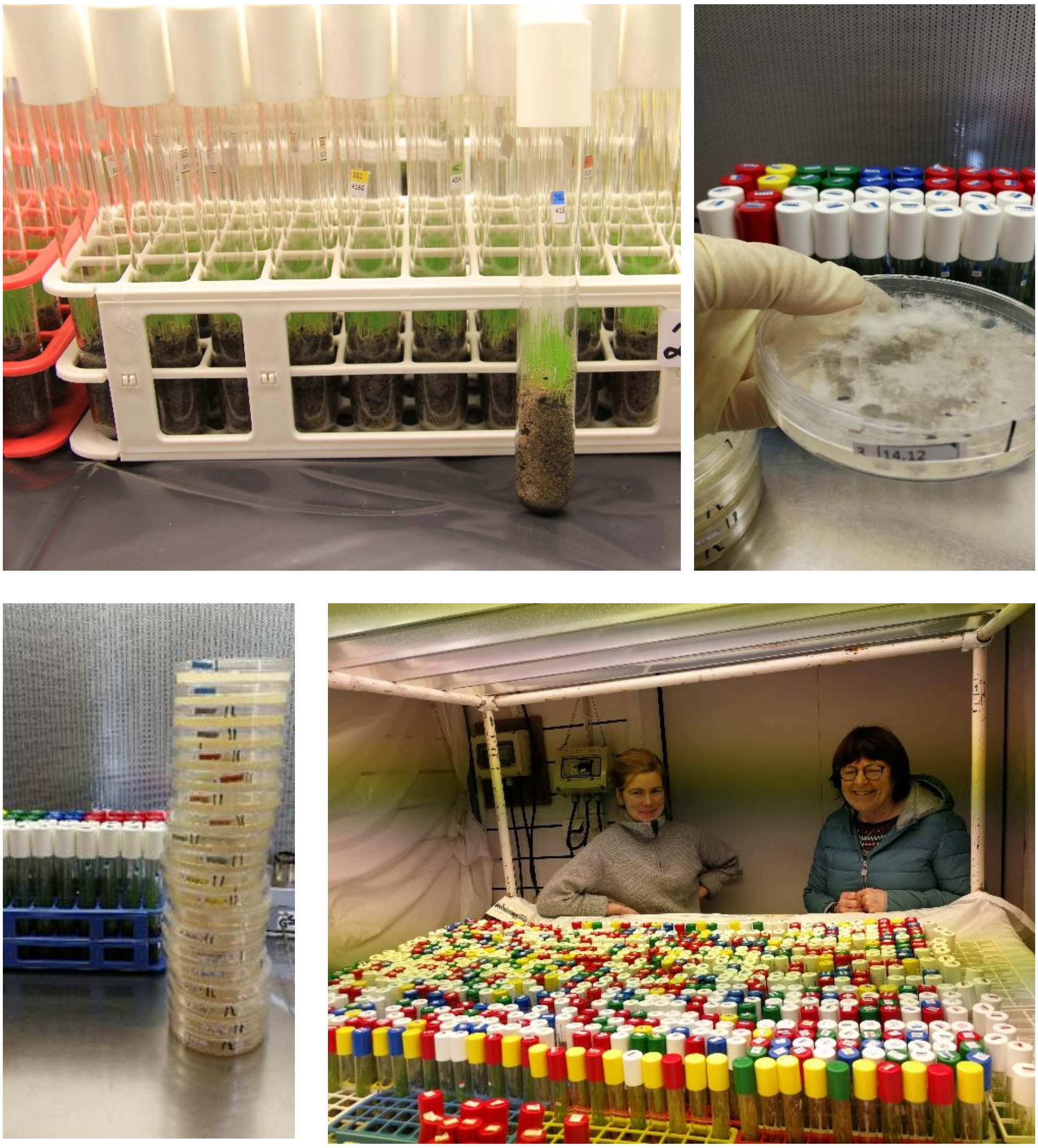

Figure 9. Totally 20 turfgrass cultivars were tested for their resistance to 10 dollar spot isolates of different origin. Photo: T. Espevig

4.2 Results and discussion

The results show that on average for all isolates, perennial ryegrass was most resistant to dollar spot. It was followed by slender creeping red fescue, strong creeping red fescue, Kentucky bluegrass, velvet bentgrass, colonial bentgrass, Chewings fescue and creeping bentgrass, whereas annual bluegrass was the least resistant (Table 3 and Table 4). As far as the cultivars are concerned, a lot of variation was found, especially in colonial bentgrass and Chewings fescue. Scandinavian golf courses with dollar spot, are therefore recommended to use the more resistant cultivars, especially of Chewings fescue.

Through these lab analyses it was found that different *Clarireedia* species which cause dollar spot disease vary in aggressiveness. The most aggressive isolates were 17.12.UK from the United Kingdom, MB-01 from the United States and SH44 from Canada, while the weakest were the Norwegian 14.12.NO and the other from the United Kingdom, 17.11.UK. Isolates from Denmark and Sweden were in the middle.

Significant differences in aggressiveness among *Clarireedia* isolates of different origin were found in all turfgrass species, except for annual bluegrass.

Country of origin had a bigger impact on the aggressiveness of *Clarireedia* isolates than the turfgrass species from which they were recovered. Thus, we still cannot conclude whether aggressiveness in *Clarireedia* species is species-specific or not.

Another important note is that the interaction between fungus and plants may not be the same in lab trials as it is in field trials. Ranking of cultivars should therefore be verified under field conditions, with minimized risk of the dollar spot disease spreading.

More research is needed on the impact of geography on aggressiveness of *Clarireedia* isolates and on mechanisms involved in the interaction between isolates and turfgrass species and cultivars.

Table 3. Dollar spot resistance (scale 1 to 9, where 9 = highest resistence, no disease) of 20 turfgrass cultivars used in the study.

Turfgrasses (common name)	Cultivar	Dollar spot resistance
Perennial ryegrass	Fabian	7.1 a[†]
Perennial ryegrass	Bargold	7.1 a
Slender creeping red fescue	Nigella	6.8 ba
Slender creeping red fescue	Cezanne	6.8 ba
Strong creeping red fescue	Frigg	6.1 bc
Chewings fescue	Bargreen II	5.8 bcd
Kentucky bluegrass	Limousine	5.5 ecd
Velvet bentgrass	Avalon (US: SR 7200)	5.1 efd
Colonial bentgrass	Greenspeed	5.1 efd
Chewings fescue	Lystig	4.8 efg
Kentucky bluegrass	Julius	4.7 efg
Velvet bentgrass	Villa	4.6 fg
Creeping bentgrass	Independence	4.2 hfg
Colonial bentgrass	Leirin	4.1 hg
Creeping bentgrass	Declaration	3.9 hg
Annual bluegrass	Two Putt	3.9 hg
Creeping bentgrass	Crystal Blue	3.8 hg
Colonial bentgrass	Jorvik	3.6 h
Creeping bentgrass	Luminary	3.5 h
Chewings fescue	Musica	2.2 i

[†] Least Squares Means with the same letter are not significantly different based on Tukey's multiple comparison method using significance level 0.05.

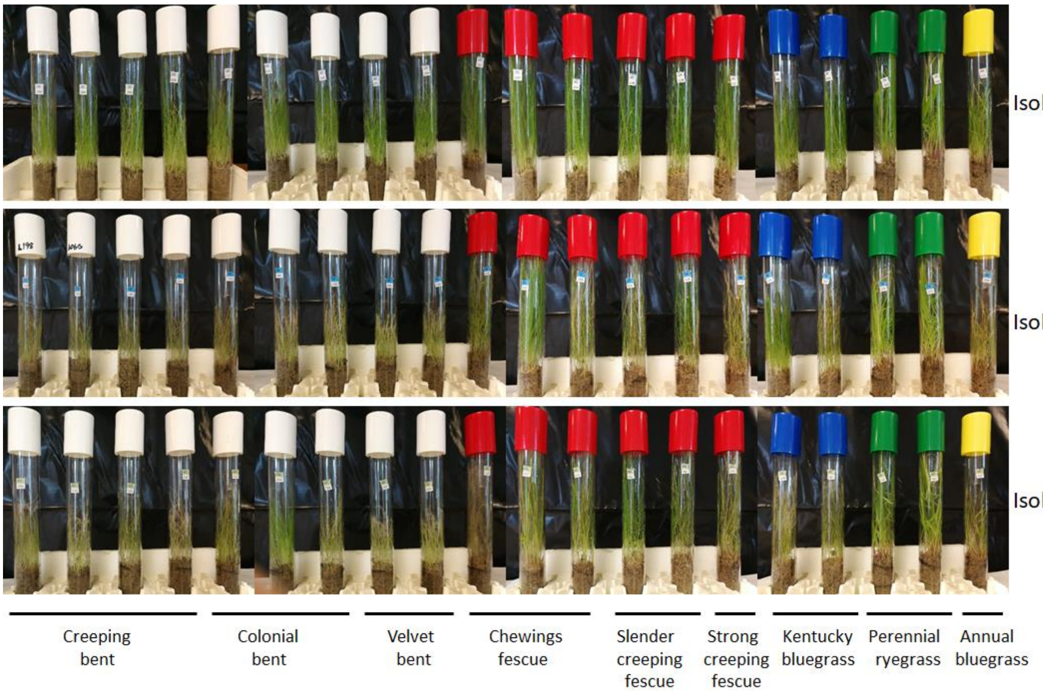

Figure 10. Among the most aggressive *Clarireedia* isolates were 17.12.UK from the United Kingdom and MB-01 from the United States, while the weakest was the Norwegian isolate 14.12.NO. Photo: T. Espevig.

Table 4. Resistance of nine turfgrass species to 10 dollar spot isolates (scale 1 to 9, where 9 = highest host resistance, no disease) (Model 2), number of selected cultivars is shown in brackets. The isolates are ranged from the most aggressive to the least aggressive (rightmost column); the bottom row shows an average estimated resistance of 10 turfgrass species/subspecies (Model 1).

			Turfgrass species									
Dollar spot isolates	Species of fungi†	Host turfgrass¶	Velvet bentgrass (2)	Colonial bentgrass (3)	Creeping bentgrass (4)	Chewings fescue (3)	Slender creeping red fescue (2)	Strong creeping red fescue (1)	Perennial ryegrass (2)	Kentucky bluegrass (2)	Annual Bluegrass (1)	Mean isolates
17.12.UK	*Clarireedia* spp.	KBG	2.1c‡	3.3dc	2.2c	2.4c	5.6d	4.3c	4.9d	3.5bc	3.1a	3.5e
MB-01	*C. jacksonii*	CBG	2.4c	3.3d	1.7c	3.3bc	6.1dc	4.4c	5.2cd	2.9c	2.4a	3.5e
SH44	*C. jacksonii*	CBG	1.8c	3.5bdc	2.5c	3.3bc	6.1bdc	6.7bac	5.7bcd	6.6ba	3.8a	4.5d
14.112.SE	***Clarireedia* sp.†**	**ABG**	**5.7b**	**4.5bdac**	**4.1b**	**2.9bc**	**6.5bdc**	**6.3bac**	**6.1bc**	**4.9bc**	**3.3a**	**4.9cd**
14.10.DK	*C. jacksonii*	ABG	5.6b	4.4bdac	4.4b	3.6bc	6.1dc	5.6bc	6.6ba	5.8ba	4.8a	5.2cbd
RB-19	*C. monteithiana*	HBG	5.7b	5.0ba	4.7b	4.0bac	7.1bac	6.0bac	6.5ba	5.5ba	3.3a	5.3cb
14.16.SE	C. *jacksonii*	FF	5.6b	4.7bac	4.2b	3.6bc	7.2bac	6.1bac	6.6ba	6.1ba	4.1a	5.4cb
14.15.SE	C. *jacksonii*	FF	6.0b	4.8ba	4.3b	4.7bac	7.6ba	6.9ba	6.8ba	5.8ba	4.0a	5.7b
17.11.UK	*Clarireedia* spp.	FF	5.9b	4.3bdac	4.3b	5.1ba	7.4ba	6.5bac	6.5ba	6.1ba	4.8a	5.7b
14.12.NO	***Clarireedia* sp.†**	**CBG**	**7.7a**	**5.6a**	**6.6a**	**6.2a**	**8.0a**	**8.3a**	**7.5a**	**7.6a**	**5.0a**	**7.0a**
Mean turfgrass species			4.9B§	4.3A	3.9A	4.3A	6.8D	6.1CD	6.3D	5.5CB	3.9A	4.9B§

† *Clarireedia* sp. 14.12.NO and 14.112.SE (bold font) have identical sequence in the ribosomal internal transcribed spacer (ITS) region, and are different from those of *C. jacksonii* (97.6 % sequence similarity in the ITS region).

‡ Least Squares Means with the same small letter in the same column are not significantly different based on Tukey's multiple comparison method using significance level 0.05.

§ Least Squares Means with the same capital letter in this row are not significantly different based on Tukey's multiple comparison method using significance level 0.05.

¶ ABG - annual bluegrass, CBG - creeping bentgrass, HBG - hybrid bermudagrass, FF – fine fescue.

5 Conclusions on benefits and advice for the golf turfgrass sector

- Rolling 3-4 times per week can be recommended for use on golf greens with dollar spot pressure. It also contributes to more even golf green surface and faster ball roll. However, more research is needed regarding the long-term effect of rolling on botanical composition of grass species and/or density of golf greens;

- Increased doses of nitrogen to fight dollar spot can be recommended on golf greens which are not exposed to microdochium patch during winter time;

- The fungi causing dollar spot may have a potential for better survival during cold winter conditions and further work is necessary to confirm this;

- Aggressiveness among *Clarireedia* isolates varied significantly, also among five *C. jacksonii* isolates. Country of origin had a bigger impact on the aggressiveness of *Clarireedia* isolates than the turfgrass species from which they were recovered, or their belonging to a certain *Clarireedia* species. Thus, it is still unclear whether aggressiveness in *Clarireedia* species is species-specific or not.

- On average for all isolates and respective cultivars, the dollar spot resistance of the turfgrass species in this study could be ranged as follows: perennial ryegrass = slender creeping red fescue > strong creeping red fescue > Kentucky bluegrass = velvet bentgrass > colonial bentgrass = Chewings fescue $\geq$ creeping bentgrass = annual bluegrass;

- Due to significant variation in susceptibility to dollar spot in colonial bentgrass and especially in Chewings fescue, the most resistant cultivars of these species ought to be preferred on Scandinavian golf courses that have this disease problem.

Photo: Stefan Nilsson

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